**Original Article**

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# The Value of Radiographic Parameters to Predict Loss of Reduction in the Conservative Treatment of Distal Radius Fractures

## Distal Radius Kırıklarının Konservatif Tedavisinde Redüksiyon Kaybını Tahmin Etmede Radyografik Parametrelerin Değeri

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## ABSTRACT

**Objective:** Distal radius fractures are the most common fractures of the upper extremity. The aims of this study were to determine the radiologic parameters that could predict maintenance of reduction during conservative treatment of distal radius fractures and to present the functional outcomes at 6$^{th}$ month of treatment in individuals with and without loss of reduction.

**Methods:** A total of 146 individuals that were treated conservatively (reduction and casting) were included. Radiographic parameters including radial inclination, radial height, articular step-off, three-point index (TPI), cast index, and padding index were examined. The clinical outcomes were assessed at the 6$^{th}$ month of reduction by visual analog scale (VAS), QuickDASH and Mayo wrist score. Logistic regression analysis was performed to determine the predictive value of radiographic parameters in loss of reduction.

**Results:** The mean age was 40.17±13.30. Loss of reduction was detected in 21.2%. Significant differences were found in the articular step-off, TPI and cast indices between individuals with and without loss of reduction ($p<0.05$). TPI and cast index were found to be highly predictive for loss of reduction in fractures with and without extension to the distal radius joint,

## ÖZ

**Amaç:** Distal radius kırıkları üst ekstremitenin en sık görülen kırıklarıdır. Bu çalışmanın amacı, distal radius kırıklarının konservatif tedavisi sırasında redüksiyonun sürdürülmesini öngörebilen radyolojik parametreleri belirlemek ve redüksiyon kaybı olan ve olmayan bireylerde tedavinin 6. ayındaki fonksiyonel sonuçları sunmaktır.

**Yöntemler:** Konservatif olarak tedavi edilen (redüksiyon ve alçı) toplam 146 birey dahil edildi. Radyal inklinasyon, radyal yükseklik, eklem içi basamaklanma, üç nokta indeksi (TPI), cast indeksi ve padding indeksi gibi radyografik parametreler incelendi. Klinik sonuçlar, redüksiyonun 6. ayında görsel analog skala (VAS), QuickDASH ve Mayo bilek skoru ile değerlendirildi. Radyografik parametrelerin redüksiyon kaybındaki öngörücü değerini belirlemek için lojistik regresyon analizi yapıldı.

**Bulgular:** Ortalama yaş 40,17±13,30 idi. Redüksiyon kaybı %21,2'sinde tespit edildi. Redüksiyon kaybı olan ve olmayan bireyler arasında eklem içi basamaklanma, TPI ve cast indekslerinde anlamlı farklılıklar bulundu ($p<0,05$). TPI ve cast indeksinin sırasıyla distal radius eklemine ekstansiyonu olan ve olmayan kırıklarda redüksiyon kaybı için yüksek öngörücü olduğu bulundu. Redüksiyon kaybı olan ve olmayan bireyler arasında VAS dışında fonksiyonel parametrelerde fark yoktu ($p>0,05$).

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## ABSTRACT

respectively. There was no difference in functional parameters other than VAS between individuals with and without loss of reduction (p>0.05).

**Conclusion:** Among the radiographic measures, TPI and cast indexes were the ones which had the higher predictive value for loss of reduction during conservative treatment in distal radius fractures.



**Keywords:** Conservative treatment, closed fracture reduction, distal radius fracture, plaster cast



## ÖZ

**Sonuç:** Radyografik ölçümler arasında TPI ve cast indeksleri, distal radius kırıklarında konservatif tedavi sırasında redüksiyon kaybı için en yüksek öngörücü değere sahip olanlardı.



**Anahtar Kelimeler:** Konservatif tedavi, kapalı kırık redüksiyonu, distal radius kırığı, alçı


## Introduction

Distal radius fractures are the most common fractures of the upper extremity, representing approximately 75% of fractures in the forearm (1). While fractures occur in young patients as a result of high energy trauma, in the elderly they usually occur as a result of low-energy trauma such as a fall from standing height (2). The type of fracture depends on the position of the hand at the time of trauma and the amount of energy exposed. The type of fracture also varies depending on the quality of the bone (3).

In distal radius fractures, posteroanterior and lateral radiographs are often sufficient for diagnosis and the treatment. In the AP radiographs, the inclination of the radial joint surface, the condition of the radial process and ulnar styloid process, displacement and comminution of the distal fragment, cast indices, and the position of the wrist are evaluated. In lateral radiography, the angulation of the distal fragment relative to the dorsal or palmar surfaces and the angle of the distal articular surface of the radius and cast indices are evaluated. Oblique views are ordered when deemed necessary to evaluate the relationship of the fracture to the joint, to detect carpal bone fractures and carpal bone instability (4). Radiological parameters that guide the treatment and frequently used in radiological follow-up are radial inclination, radial height, articular step-off, second metacarpal-radius angle, stewart index, three-point index (TPI), cast index and padding (PAD) index (5-11).

When choosing the type of treatment, factors such as fracture type, patient's age, lifestyle, comorbidities, treatment compliance, and physical and mental capacity should be evaluated together (12,13). Closed reduction and casting are the preferred treatment methods in 84% of the cases which are considered as conservative treatments (14).

The aims of this study were to determine which radiological parameter/parameters had the higher predictive value to determine loss of reduction during conservative treatment and to present the functional status of individuals with and without loss of reduction at 6$^{th}$ month of the treatment. Thus, we hypothesized that the radiological parameters such as radial inclination, radial height, articular step-off, TPI, cast index, and PAD index had predictive value in the maintenance of reduction during conservative treatment of distal radius fractures.

## Methods

### Study Design and Ethical Issues

In this retrospective study, clinical and radiological data of the patients who were diagnosed as having distal radius fractures and received conservative treatment in our clinic between February 2019 and July 2020 were evaluated. Ethical approval for this study was obtained from University of Health Sciences Türkiye, Ankara City Hospital, Clinical Research Ethics Committee (decision no: E1/1133/2020, date: 30.09.2020). Written and verbal consents were obtained from the patients.

### Participants and Follow-up

To evaluate whether the sample size used in this study was sufficient, a post-hoc power analysis was performed using G*Power 3.1. With an effect size of 0.30, an alpha level of 0.05, and a total sample size of 146, the achieved statistical power (1-β) was calculated as 0.81, indicating that the study had adequate power to detect the expected effect. The inclusion criteria for the study were; a) being between the ages of 18 to 65 years old, b) having a distal radius fracture treated conservatively, c) willing to participate in the study, d) having regular check-ups during the treatment, and e) having a clinical evaluation at the 6$^{th}$ month. The exclusion criteria from the study were; a) being incompatible with treatment and follow-up, b) having planned surgical treatment after admission, c) having an open distal radius fracture, and d) having a history of previous wrist fracture.

### Assessment

A total of 146 patients who met the inclusion criteria were evaluated. Fractures were reduced with an appropriate reduction maneuver and all patients were applied a short or long arm cast, depending on the decision of the team working that day.

As stated in the literature, the following criteria were used to determine the adequacy of the reduction: 1. Shortening less than 5 mm in distal radioulnar joint compared to the healthy side, 2. On AP radiographs 21-28° radial inclination, 3. On lateral radiographs volar tilt between 0-20°, 4.

Articular step-off less than 2 mm (15). Patients were called the next day to check their swelling and their cast was bivalved if indicated. When the swelling subsided, the splint was replaced with a cast, and the post-reduction radiographs taken at that time were included in the study.

A new reduction maneuver was performed, and a new circular cast was applied to patients whose reduction loss was detected in early control radiographs. In these patients, the day their second cast was applied was considered the day the treatment started. All patients were called for follow-ups at 1st, 3rd and 5th weeks. In patients who had a long-arm circular cast, the cast was changed to a short-arm cast in the third week. The casts were removed at 5th week and patients in whom healing was suspected to be inadequate were applied a static wrist brace for one week.

### a) Radiological Assessment

The radiographs were evaluated and the fractures were classified according to Frykman and Arbeitsgemeinschaft für Osteosynthesefragen (AO)/Orthopaedic Trauma Association (OTA) classification (16). In the Frykman classification, fractures are classified into 8 different types, ranging from Type 1 to Type 8, based on their relationship to the ulna styloid, radiocarpal joint and radio ulnar joint. In Type 3, Type 4, Type 7 or Type 8, the fracture extends to the radiocarpal joint (17). The AO/OTA classification is the most frequently used classification system today and is considered prognostically guiding. According to this classification, fractures are classified as B1, B2, B3, C1, C2 or C3 according to the extend to the distal radius joint. Radiological calculations were made by the researchers whose expertise field was orthopaedics.

**Radial Inclination:** On AP radiographs, the angle between the line drawn from the tip of the radial styloid to the radioulnar corner and the horizontal lines perpendicular to the long axis of the radius (5,6).

**Radial Height:** It is defined as the distance between the horizontal line perpendicular to the long axis of the radius from the radial styloid on the AP radiographs and the parallel lines tangent to the distal joint surface of the ulna (5,6).

**Articular Step-off:** It is a measurement that expresses the space between joint fragments. On direct x-rays, a gap of 2 mm or less is recommended (6).

**Three-point Index (TPI):** In conservatively treated distal radius fractures, the TPI, developed by Alemdaroğlu et al. (9), has been demonstrated to be the most statistically significant predictor of re-displacement of surgical variables. It embodies the fundamentals of fracture treatment, such as three-point fixation and appropriate anatomical reduction (18). A TPI of 0.8 or higher resulted with a relative risk of 46 for fracture re-displacement, according to data from Alemdaroğlu et al. (9) The radial TPI was computed as (a+b+c)/d using the measurements of the plaster cast and soft tissue on the radial side at the level of the radius's distal epiphyseal line (a), the ulnar side space in the fracture line (b), the radial side space at the level of the radial tubercle's beginning (c), and the total external diameter of the proximal radius at the level of the fracture line (d) on the anteroposterior (AP) radiograph (19). Three values were added together and written into the numerator. Following this measurement, the contact fracture surface at the distal radius was calculated and written in the denominator. Then, in the lateral radiograph, in accordance with the rules observed in the AP radiograph, the dorsal cast spaces and the volar cast space at the level of the fracture line were measured and written in the numerator. Thus, the mathematical value of the TPI defined for radius distal end fractures was obtained by adding the ratios obtained from AP and lateral radiographs. Examples of radiographs are presented in Figure 1 and Figure 2.

**Cast Index:** It is defined as the ratio of AP and lateral diameter at the fracture level after reduction and casting in distal radius fractures. The normal value is accepted as <0.8 (10). Examples of radiographs are presented in Figure 3.

**PAD Index:** It is the ratio between the interosseous space closest to the fracture on the AP radiograph and the widest space closest to the fracture line on the lateral radiograph, and its normal value is stated as <0.3 (11).

### b) Functional Assessments

At the 6th month of the treatment, QuickDASH was performed to assess upper extremity functions and symptoms, the Mayo wrist score to rate the functional status of the wrist, and the visual analog scale (VAS) to assess the pain (20-22).

### Statistical Analysis

Statistical analyzes were performed using SPSS version 18 software. The suitability of the variables to normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Simirnov tests). Descriptive statistics were given as mean ± standard deviation for normally distributed variables, and using median and interquartile range for non-normally distributed variables (using frequency tables for ordinal variables). Chi-square test was used to compare the results of radiological evaluation after reduction between individuals with and without reduction loss. Independent sample t-test was used to compare VAS, QuickDASH and Mayo means in patients with and without reduction loss. Regression analysis was performed to evaluate the effect of plaster indices on loss of reduction in fractures extending and not extending to the distal radial joint surface. The significance level was accepted as <0.05.

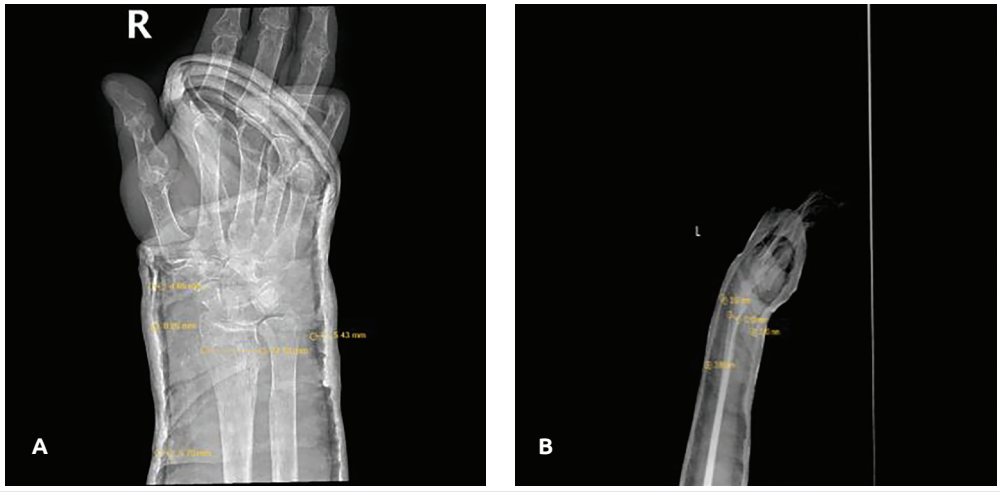


**Figure 1.** Patient with AO type B2, Frykman Type 3 fracture, whose treatment was completed without loss of reduction (A: Antero-posterior view, B: Lateral view) (TPI >0.8)

AO: Arbeitsgemeinschaft für Osteosynthesefragen, TPI: Three-point index


**Figure 2.** Patient with AO type B3, Frykman Type 3 fracture; TPI >0.8 before reduction (A,B); TPI <0.8 after reduction (C,D) (A: Antero-posterior view, B: Lateral view, C: Antero-posterior view, D: Lateral view)

AO: Arbeitsgemeinschaft für Osteosynthesefragen, TPI: Three-point index


**Figure 3.** Patient with AO type A2, Frykman type 5 fracture; cast index >0.8 after first reduction (A,B); cast index <0.8 after rereduction (C,D) (A: Antero-posterior view, B: Lateral view, C: Antero-posterior view, D: Lateral view)

AO: Arbeitsgemeinschaft für Osteosynthesefragen

## Results

Table 1 shows the patients' sociodemographic characteristics and characteristics related to the Frykman and AO classification. The mean age of the individuals included in the study (n=146) was 40.17±13.30 (min-max: 19-65) and 115 (78.8%) were male and 31 (21.2%) were female. According to the Frykman classification, 15 fractures (10.3%) were Type 1, 11 (7.5%) were Type 2, 25 (17.1%) were Type 3, 43 (29.5%) were Type 4, 11 (7.5%) were Type 5, 16 (11%) were Type 6, 15 (10.3%) were Type 7, 10 (6.8%) were Type 8; while according to AO classification, 31 (21.2%) were A2, 23 (15.8%) were A3, 8 (5.5%) were B1, 18 (12.3%) were B2, 18 (12.3%) were B3, 20 (13.7%) were C1, 20 (13.7%) were C2, 8 (5.5%) were C3.

A loss of reduction was observed in 31 (21.2%) of the individuals included in the study the comparison of post reduction radiological evaluation results between individuals with and without loss of reduction was shown in Table 2. A statistically significant difference was found between individuals with and without loss of reduction in terms of articular step-off, TPI, and cast indices ($p<0.05$). Considering the result of Bonferroni correction in the post-hoc analysis ($p<0.017$), the articular step-off difference between individuals with and without loss of reduction originated from the group with gap <2 mm.

The results of the logistic regression analysis performed to examine the effect of cast indices on loss of reduction in fractures with or without extension to the distal radius joint were given in Table 3 and Table 4. For the loss of reduction, the predictive value of TPI [95% confidence intervals (CI) (13.33, 1638.60)] was found the highest amongst the others in fractures extended to the distal radial articular surface (Table 3), according to both the AO and Frykman classifications while the predictive value of cast index [95% CIs (7.55, 1540.44)] was higher than the others in fractures that did not extend to the distal radial articular surface ($p<0.05$) (Table 4).

The findings regarding the functional scores showed that 76% (n=111) of the individuals had a QuickDASH score of "very good", 80.1% (n=117) had a Mayo score of "very good", and 80.8% (n=118) had a VAS score of 2 and below. The differences between the functional scores of the individuals with and without loss of reduction were given in Table 5. Accordingly, the VAS score at 6$^{th}$ month was significantly higher in individuals with loss of reduction ($p<0.05$).

## Discussion

In this study, 21.20% of the patients experienced loss of reduction after the first intervention contrary to the literature which demonstrated higher patient ratio with loss of reduction as 78% in the study of Makhni et al. (23) and 69% in the study of Chang et al. (24). The low rate of patients with loss of reduction may be due to cases aged over 65 not being included in the study. Thus, it can be concluded that conservative treatment for fractures in middle adulthood, when bone quality and healing are better, has a higher success rate.

**Table 1.** Sociodemographic characteristics of the patients and their characteristics related to the Frykman and AO classification (n=146)

| **Age (mean ± SD)** | **40.17±13.30** |
|---|---|
| | n (%) |
| **Gender** | |
| Male | 115 (78.8) |
| Female | 31 (21.2) |
| **Frykman classification** | |
| Type 1 | 15 (10.3) |
| Type 2 | 11 (7.5) |
| Type 3 | 25 (17.1) |
| Type 4 | 43 (29.5) |
| Type 5 | 11 (7.5) |
| Type 6 | 16 (11) |
| Type 7 | 15 (10.3) |
| Type 8 | 10 (6.8) |
| **AO classification** | |
| A2 | 31 (21.2) |
| A3 | 23 (15.8) |
| B1 | 8 (5.5) |
| B2 | 18 (12.3) |
| B3 | 18 (12.3) |
| C1 | 20 (13.7) |
| C2 | 20 (13.7) |
| C3 | 8 (5.5) |

AO: Arbeitsgemeinschaft für Osteosynthesefragen, SD: Standard deviation

An articular step-off of 2 mm or more is defined as the space between the joint fragments in the distal radius joint. This is an indication for surgical intervention and changes in the articular step-off are considered an important parameter that indicating loss of reduction and necessitating re-reduction (25). In current study, 70.5% of the individuals had a articular step-off ≤2 mm and most of the remaining individuals had >2-<3 mm articular step-off. Considering that articular step-off was one of the indicators for surgical intervention, our findings were consistent with those in the literature and confirmed that the patients were suitable for conservative treatment. However the results of studies examining the effect of articular step-off on loss of reduction and functional scores vary. One study reported articular step-off was reported as an important determinant of loss of reduction and one of the basic criteria for reduction follow-up (24). However others such as Jaremko et al. (25) and Synn et al. (26) have stated that articular step-off is effective in re-reduction but does not

**Table 2.** Comparison of post reduction radiological evaluation results between individuals with and without reduction loss

| | **Loss of reduction** | | $\chi^2$ | **p** |
|---|---|---|---|---|
| | **Present (n=31) n (%)** | **Absent (n=115) n (%)** | | |
| **Radial inclination** | | | | |
| ≤25 | 19 (61.3) | 71 (61.7) | 0.02 | 0.96 |
| >25 | 12 (38.7) | 44 (38.3) | | |
| **Articular step-off** | | | | |
| <2 mm | 17 (54.80) | 86 (74.80) | 7.69 | **0.02** |
| 2-3mm | 10 (32.30) | 26 (22.60) | | |
| >3 mm | 4 (12.90) | 3 (2.60) | | |
| **Radial height loss** | | | | |
| <2 mm | 15 (48.4) | 64 (55.7) | 2.24 | 0.68 |
| 2-4 mm | 15 (48.4) | 41 (35.7) | | |
| >4 mm | 1 (3.2) | 10 (8.7) | | |
| **Three-point index** | | | | |
| **≤0.8** | 13 (15.3) | 72 (84.7) | 4.29 | **0.03** |
| **>0.8** | 18 (29.5) | 43 (70.5) | | |
| **Cast index** | | | | |
| **≤0.8** | 15 (23.8) | 48 (76.2) | 4.44 | **0.05** |
| **>0.8** | 16 (19.3) | 67 (80.7) | | |
| **PAD index** | | | | |
| **≤0.3** | 19 (28.8) | 47 (71.2) | 4.11 | 0.06 |
| **>0.3** | 12 (15.0) | 68 (85.0) | | |

$\chi^2$: Chi-square test, PAD: Padding

**Table 3.** The effect of cast indexes on loss of reduction in fractures extending to the distal radial articular surface (n=146)

| | | Multivariable analysis | | |
|---|---|---|---|---|
| | **B** | **OR** | **95% CI** | **p** |
| **AO classification (B1, B2, B3, C1, C2, C3)** | | | | |
| TPI | 4.99 | 147.820 | 13.33-1638.60 | **0.000** |
| Cast index | -4.42 | 0.010 | 0.01-0.15 | **0.001** |
| PAD index | 0.21 | 1.230 | 0.12-11.91 | 0.853 |
| **Frykman classification (Type 3, Type 4, Type 7, Type 8)** | | | | |
| TPI | 5.25 | 191.730 | 17.23-2132.40 | **0.000** |
| Cast index | -4.68 | 0.090 | 0.00-0.13 | **0.001** |
| PAD index | 0.39 | 1.49 | 0.14-14.84 | 0.73 |

AO: Arbeitsgemeinschaft für Osteosynthesefragen, TPI: Three-point index, PAD: Padding, CI: Confidence interval

**Table 4.** The effect of cast indexes on loss of reduction in fractures that do not extend to the distal radial articular surface (n=146)

| | | Multivariable analysis | | |
|---|---|---|---|---|
| | **B** | **OR** | **95% Cl** | **p** |
| **AO classification (A2, A3)** | | | | |
| TPI | -5.25 | 0.005 | 0.00-0.05 | **0.000** |
| Cast index | 4.68 | 107.863 | 7.55-1540.44 | **0.001** |
| PAD index | -0.39 | 0.671 | 0.67-6.69 | 0.734 |
| **Frykman classification (Type 1, Type 2, Type 5, Type 6)** | | | | |
| TPI | -5.25 | 0.005 | 0.00-0.05 | **0.000** |
| Cast index | 4.68 | 107.863 | 7.55-1540.44 | **0.001** |
| PAD index | -0.39 | 0.671 | 0.67-6.69 | 0.734 |

AO: Arbeitsgemeinschaft für Osteosynthesefragen, TPI:Three-point index, PAD: Padding, CI: Confidence interval

**Table 5.** Comparison of functional scores in individuals with and without loss of reduction

| **Loss of reduction** | | | | |
|---|---|---|---|---|
| | **Present (n=31) $\bar{x}$ ± SD** | **Absent (n=115) $\bar{x}$ ± SD** | **Test*** | **p** |
| **VAS** | 2.41±1.02 | 1.79±1.07 | 0.015 | **0.04** |
| **QuickDASH** | 11.27±3.66 | 10.28±3.90 | 0.550 | 0.19 |
| **Mayo wrist score** | 90.16±5.55 | 92.21±6.42 | 2.310 | 0.08 |

VAS: Visual analog scale, *: Independent sample t-test

affect functional scores. In this study, loss of reduction was examined in different articular step-off classifications, and it was determined that there was a significant difference between the groups in terms of reduction continuation in favor of the group with articular step-off ≤2 mm which supported the literature concluding that articular step-off was important in loss of reduction and follow-up.

It has been known that one of the most important undesirable consequences of conservative treatment is loss of reduction, and there are some radiological parameters and cast indices used to estimate it (27). However, it is still unclear in the literature which of these parameters is more effective in predicting loss of reduction (7,18). It was shown that there was no significant relationship between radial inclination angle and loss of reduction and functional scores in the literature (28-30). Similarly, our results suggested that the radial inclination angle had no effect on predicting loss of reduction. In normal AP radiographs, the distance between the top of the radial styloid and the top of the distal radioulnar joint is defined as the radial height. According to some surgeons, changes in radial height value are indicators of surgery (31). For some surgeons, in conservative treatment, radial height is accepted as an important parameter for the loss of reduction and its follow-up (32). The results of studies examining the relationship between radial height, reduction loss and functional scores vary in the literature. In the study conducted by Maluta et al. (29), it was stated that radial height loss was not effective on loss of reduction andfollow-up, similar to the findings of Einsiedel et al. (33) and Földhazy et al. (34). On the other hand, it was found that radial height loss was effective on reduction follow-up and functional scores in a study (30). In another study, it was observed that radial height loss had an effect on functional scores (35). In current study, reduction loss was examined in different radial height losses, and it was determined that there was no difference in reduction loss between the groups. In this case, literature stating that radial height loss was not a criterion in reduction follow-up were also supported by our study.

Radiological indices used to monitor loss of reduction in conservative treatment of distal radius fractures with and without extension into the joint are TPI, cast and PAD indices. In literature, a few studies examined the relationship of TPI with loss of reduction as well as its effect according to the joint extension of the fracture. In a study conducted with adult patients, it was stated that TPI was not an important criterion in loss of reduction and follow-up (18), whereas in a study conducted on patients in the pediatric age group, TPI was found to be an important criterion in loss of reduction and follow-up (36). In another study conducted on patients in the pediatric age group, it was reported that TPI was not an important criterion in loss of reduction and follow-up (37). In current study, it was determined that TPI and cast indices were effective factors in predicting loss of reduction in fractures extending to the

distal radius joint according to the AO and Frykman fracture classification. It was determined that the most important factor predicting loss of reduction in fractures extending to the distal radius joint in the AO and Frykman fracture classifications was TPI. Accordingly, it can be said that TPI is the most effective index in monitoring loss of reduction in fractures extending into the joint.

Cast index is calculated as the ratio of the plaster gaps at the fracture level in AP and lateral radiographs and is expected to have a value of 0.8 or below (10). Although opinions regarding the effect of cast index on loss of reduction vary in the literature, few studies have been found regarding its effectiveness on fracture type in adult distal radius fractures. In the studies conducted on patients in the pediatric age group, it was stated that the cast index was important in monitoring loss of reduction and its follow-up (7,38). Similarly, it was reported that TPI was the most effective index in loss of reduction and follow-up in extra-articular fractures in adults (32). In this study, when the effects of TPI, cast and PAD indices were examined in fractures that did not extend to the distal radius joint according to the AO and Frykman Fracture classification; it was determined that TPI and cast indices had higher value in predicting loss of reduction. It was also determined that the most effective factor predicting loss of reduction in fractures that did not extend to the distal radius joint in the AO and Frykman fracture classifications was the cast index. Accordingly, it can be stated that cast index is the most effective index in the prediction of loss of reduction and its follow-up in fractures that do not extend into the joint.

Although the PAD index was reported as a protective factor against loss of reduction in a study conducted with pediatric patients by Ravier et al. (37). McQuinn and Jaarsma (39) stated the PAD index to be insignificant in reduction loss and follow-up. Similarly, Alemdaroğlu et al. (32) concluded that the PAD index had no effect on loss of reduction in their study with adult patients. In this study, it was determined that the PAD index was not an important factor in predicting loss of reduction in distal radius fractures; therefore, it was concluded that it was not necessary to use the PAD index in predicting and monitoring loss of reduction after distal radius fractures in adult patients.

Another parameter examined in our study was the change in functional scores of patients with and without loss of reduction. Regarding the effects of surgical and conservative treatment on long-term functional scores, it was stated that there was no difference between the two treatments, but the pain level was higher in patients who underwent surgical intervention (7). In the study, it was determined that there was no difference in functional scores between patients who underwent re-reduction and those who did not (24). Similarly in another study, it was shown that there was no difference in functional scores between patients who underwent reduction and those who did not (40). In this study, when functional scores were compared between patients with and without loss of reduction, it was observed that only the pain level of patients with loss of reduction was higher than those without loss of reduction. However, both groups recovered similarly in terms of functionality measured by QuickDASH and Mayo. Accordingly, considering the complications of surgical intervention, it may be recommended to re-reduce patients who develop loss of reduction and continue the treatment conservatively, assuming that it will not lead to functional loss.

### Study Limitations

The retrospective study design and the lack of randomization and control group can be considered as the limitations of current study.

## Conclusion

As a result of our study, it was seen that intra-articular stepping more than 2 mm was one of the most important parameters in loss of reduction. For reduction continuity, it was determined that the cast indices used had different effects depending on the fracture type. In our study, it was shown that TPI was the most effective parameter in predicting loss of reduction in fractures extending into the joint, and cast index was the most effective parameter in predicting loss of reduction in fractures that did not extend into the joint. In terms of functionality, it was determined that, after loss of reduction, re-reduction could lead to similar results to the recovery without loss of reduction.

**Ethics**

**Ethics Committee Approval:** Ethical approval for this study was obtained from University of Health Sciences Türkiye, Ankara City Hospital, Clinical Research Ethics Committee (decision no: E1/1133/2020, date: 30.09.2020).

**Informed Consent:** Written and verbal consents were obtained from the patients.

**Footnotes**

**Authorship Contributions**

Surgical and Medical Practices: H.C., A.U., B.Ö., Design: H.C., A.U., Data Collection or Processing: H.C., A.U., Analysis or Interpretation: H.C., Literature Search: H.C., Writing: H.C., A.U., B.Ö.

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