

RESEARCH ARTICLE

## Cast Index Does Not Predict Loss of Reduction in Conservative Management of Adult Distal Radius Fractures

### Erişkin Distal Radius Kırıklarının Konservatif Tedavisinde Alçı İndeksi Redüksiyon Kaybını Öngörmüyor

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#### ABSTRACT

**Aim;** Cast index (CI) is widely used to assess risk of loss of reduction in pediatric patients for conservative treatment of forearm fractures, but its convenience in adults has not been investigated. We aimed to evaluate the success of CI in predicting risk of loss of reduction in conservative treatment of adult distal radius fractures.

**Method;** Ninety-six adult patients with distal radius fractures followed conservatively were evaluated retrospectively in terms of demographic data, AO/OTA classification and CI in two groups according to follow-up data: Non-displaced (n =58) and displaced (n =38). Also inter- and intra-observer reliability was assessed.

**Results;** No statistically significant difference was found in terms of CI between two groups. In logistic regression analysis, only AO/OTA classification was found to have an effect on displacement. There was strong inter- and intra-observer reliability for CI measurements.

**Conclusion;** CI was unsuccessful in assessing risk of displacement of distal radius fractures in adults despite having high inter- and intra-observer reliability.

**Keywords:** Adult Distal Radius Fracture, Cast Index, Displacement, Conservative Treatment.

#### ÖZET

**Giriş ve Amaç:** Alçı indeksi (CI), pediatrik hastalarda önkol kırıklarının konservatif tedavisinde redüksiyon kaybı riskini değerlendirmek için yaygın olarak kullanılmaktadır, ancak yetişkinlerde kullanımı araştırılmamıştır. Erişkin distal radius kırıklarının konservatif tedavisinde redüksiyon kaybı riskini öngörmeye CI'nin başarısını değerlendirmeyi amaçladık.

**Gereç ve Yöntemler:** Distal radius kırığı nedeniyle konservatif olarak takip edilen 96 erişkin hastanın, demografik verileri, AO/OTA sınıflandırması ve CI ölçümleri retrospektif olarak takip verilerine göre redüksiyon kaybı olmayan (n =58) ve redüksiyon kaybı olan (n =38) olmak üzere iki grupta değerlendirildi. Ayrıca gözlemciler arası ve gözlemciler içi güvenilirlik de değerlendirildi.

**Bulgular:** İki grup arasında CI açısından istatistiksel olarak anlamlı bir fark bulunamadı. Lojistik regresyon analizinde yalnızca AO/OTA sınıflandırmasının redüksiyon kaybı üzerinde etkili olduğu bulunmuştur. CI ölçümleri için gözlemciler arası ve gözlemciler içi güçlü bir güvenilirlik vardı.

**Sonuç:** CI, gözlemciler arası ve gözlemciler içi güvenilirliği yüksek olmasına rağmen yetişkinlerde distal radius kırıklarının redüksiyon kaybı riskini değerlendirmede başarısız oldu.

**Anahtar kelimeler:** Erişkin Distal Radius Kırığı, Alçı İndeksi, Deplasman, Konservatif Tedavi.

Distal radius fractures are among the most common fractures that lead to emergency departments (1). Achieving anatomical reduction in fracture healing is one of the most important steps in the patient's ability to use wrist joint without pain and limitation (2). Several conservative and surgical treatment methods have been defined. The choice of treatment mostly depends on the patient's age, comorbidities, lifestyle,

fracture type and patient preference (3). Even the experienced surgeons do not have a common opinion in deciding the best treatment option for distal radius fractures (4).

Conservatively treated distal radius fractures are followed for reduction quality and fracture alignment with weekly X-rays for 3 weeks and immobilized in a short-arm cast for 6 weeks. If reduction is lost or

deterioration in fracture alignment is seen, re-reduction or surgical treatment is recommended (3). Clinical parameters have been previously investigated to predict the success of conservative follow-up, but there seems to be a lack of radiologic parameters in the literature, especially in the follow-up of adult distal radius fractures treated conservatively (5). Parameters such as cast index, three-point index and gap index have been defined to predict the course of fracture reduction and alignment after cast application in childhood distal radius fractures (6-8). The three-point index has been found to be useful in adults (7), but it cannot be easily applied due to the complexity of the measurements. The cast index is an easy method that can be used to predict the course of fracture in pediatric distal forearm fractures (9). However, in our opinion, adult distal radius fractures need a special approach since adult and pediatric distal radius fractures have different characteristics in terms of both mechanism of occurrence and prognosis (10).

The aim of the current study was to evaluate the success of cast index (CI) in predicting continuity of reduction in adult distal radius fractures that were followed conservatively. Our hypothesis was that the CI, which has been reported to successfully predict loss of reduction in children (9, 11-13) and which we think is an easily measurable method, could be used to predict loss of reduction in adult distal radius fractures.

## MATERIAL AND METHOD

### Design and Setting

In our single-center, retrospective clinical observational study, the data of the patients in the hospital system were examined after the ethics committee approval dated 09.12.2019 and numbered 77/09 was obtained from the ethics committee of Dışkapı Yıldırım Beyazıt Training and Research Hospital. Written informed consent was obtained from all patients and this study was conducted in accordance with the Declaration of Helsinki.

### Selection of Patients

Between March 1, 2019 and September 1, 2019, a total of 208 patients over the age of 18 were admitted to the emergency department of our hospital (level 1 trauma center) with the diagnosis of distal radius fracture. Patients in whom surgery was decided at the time of initial presentation, open fractures, patients with impaired general condition, patients in whom plaster could not be applied due to soft tissue compromise, patients who refused suggested treatment, previous fractures, pathologic fractures, patients with swelling in the distal extremity, circulatory disturbance or suspicion of median nerve compression after cast application, bilateral fractures, upper extremity injuries (i.e. ulna diaphysis fractures), patients who did not want to participate in

the study, patients without adequate follow-up and 2-way radiographs were excluded. After exclusion, total of 96 patients were included in the study.

### Interventions and follow-up

The first closed reduction and cast application was performed by a single senior resident under supervision of an orthopedic surgeon under conscious sedation and analgesia. One of the two assistants applied traction to the forearm while the other assistant applied counter traction by pulling the patient's fingers. The aim was to distract the fracture ends, with the help of ligament taxis. Force was applied to the fracture line from the volar or dorsal side in the direction of deformity and then towards the opposite side of the orientation of the fracture line in the initial state. After the reduction maneuvers, cast cotton was wrapped around the forearm, plaster of Paris was molded on the cast cotton at the distal metacarpophalangeal level and a short arm circular cast was applied. The cast was molded to achieve flexion at the level of the fracture line with the wrist in slight flexion and ulnar deviation. Control antero-posterior and lateral radiographs of the patients were evaluated after cast application (14).

All patients were called for follow-up visits at 24 hours and 3 days after cast application for neurovascular examination, especially for median nerve compression. All patients were re-evaluated at weekly outpatient clinic visits. In patients in whom the quality of reduction and fracture alignment were accepted to be appropriate (shortness <3 mm, radial inclination <10 degrees, intra-articular stepping <2 mm) (15) in the first three weeks of follow-up radiographs, the short arm casts were removed in the sixth week if radiologic union was observed in the follow-up radiographs. In the follow-up radiographs, the patients who were followed up by the same surgeon were found from the hospital information system and noted if there was a loss of reduction and re-reduction or surgery in the first three weeks was decided.

AO/OTA classification was performed according to AP and lateral radiographs of all patients. The 2-way radiographs taken after reduction and cast application and the cast index defined by Chess as the ratio of the width of the cast on the fracture line on the lateral radiograph to the width of the cast on the fracture line on the antero-posterior radiograph were recorded in patients (6). CI measurements of these patients after initial reduction were performed by two different surgeons on PACS viewer (Innbiotec DICOM Viewer, Innbiotec Software, Dubai, UAE).

### Cast index and outcomes

The method described by Chess et al. (6) in pediatric distal radius fractures was used to determine CI. For this purpose, the anteroposterior distance between the casts (excluding casts) at the level of the fracture line was calculated on the lateral radiograph, and then the medial-lateral distance between the casts

(excluding casts) at the level of the fracture line on the AP radiograph was calculated and the ratio was calculated. While Chess et al. initially said that a ratio of 0.7 was ideal, recent studies have found that a ratio between 0.80 and 0.84 is more important and ratios above this value increase the risk of reduction loss (8, 16).

CI after initial reduction of all patients were measured twice at two weeks intervals by two investigators using the method described by Chess et al. (6) (Figure 1) and intra- and inter-observer correlations were evaluated.



**Figure 1.** Cast index (CI=a/b) is defined as sagittal cast width measurement divided by coronal width measurement of the interior site of the cast at the fracture site (6).

Patients were divided into two groups according to the presence or absence of reduction loss. The differences between the two groups according to fracture subtypes in the AO/OTA classification (17), cast index and demographic data (age, sex, body mass index) were analyzed.

### Statistical analysis

Statistical evaluation of the data was performed using Statistical Package for the Social Sciences (SPSS) for Windows version 20.0 software. Descriptive statistics for categorical variables were presented as numbers and percentages, and for numerical variables as mean  $\pm$  standard deviation and minimum-maximum values. Chi-square test was used to analyze relationship between categorical data

(i.e. sex, AO/OTA types, CI being less than 0.8 and loss of reduction). In the analysis of numerical data, conformity to normal distribution was examined with one sample Kolmogorov-Smirnov test. Since normal distribution of continuous data was confirmed, independent samples t test was used to assess statistical significance of difference between two groups in terms of age, BMI and CI. Also, logistic regression analysis was done to assess parameters that may have an impact on loss of reduction. p values less than 0.05 is considered statistically significant. Inter- and intra-observer reliabilities of CI were measured with inter and intraclass correlation coefficients (ICC) and 95% confidence intervals. A cut-off value of 0.8 was set for CI (8,16) and sensitivity and specificity for CI was assessed accordingly.

### RESULTS

Of the 96 patients included in our study, 50 were female (52.1%), 46 were male (47.9%), mean age was  $50.3 \pm 16.3$  years and mean BMI was  $23.3 \pm 3.4$  (Table 1).

According to AO/OTA classification, 43 patients (44.8%) were classified as AO/OTA type A (33 patients were AO/OTA type A2, 10 patients were AO/OTA type A3), 40 patients (41.7%) were classified as AO/OTA type B (25 patients were AO/OTA type B1, 3 patients were AO/OTA type B2, 12 patients were AO/OTA type B3), 13 (13.5%) belonged to AO/OTA type C (5 patients were AO/OTA type C1, 6 patients were AO/OTA type C2, 1 patient was AO/OTA type C3) (Table 1).

The mean CI was  $0.79 (\pm 0.07)$  (range: 0.64 - 0.96). During the follow-up of our patients, 38 patients (39.6%) required re-reduction in the first three weeks. Surgical treatment was performed in 13 of these patients (13.5%). Of the patients who underwent surgical treatment, 5 were in the AO/OTA type A, 5 in the AO/OTA type B, and 3 in the AO/OTA type C group (Table 1). No decision for surgery was made for any of the patients who did not lose reduction until the 3rd week after cast application. Descriptive data is shown in table 1.

**Table 1.** Descriptive data.

	Mean ( $\pm$ SD) (min - max)	n (%)
<b>Age</b>	50,3 ( $\pm$ 16,3) (18 - 86)	
<b>Sex</b>		
<b>Female</b>		50 (52.1%)
<b>Male</b>		46 (47.9%)
<b>Fracture type (AO/OTA)</b>		
<b>A2</b>		33 (34,4%)
<b>A3</b>		10 (10,4%)
<b>B1</b>		25 (26,0%)
<b>B2</b>		3 (3,1%)
<b>B3</b>		12 (12,5%)
<b>C1</b>		6 (6,3%)
<b>C2</b>		6 (6,3%)
<b>C3</b>		1 (1,0%)
<b>Cast Index (CI)</b>	0.79 ( $\pm$ 0.07) (0.64 - 0.96)	
<b>Loss of reduction</b>		38 (39.6%)
<b>Need for surgery</b>		13 (13.5%)

A strong inter-observer (0.955 - 95% confidence interval, 0.933 - 0.979) and intra-observer (0.969 - 95% confidence interval, 0.954 - 0.979) was found out for CI measurements.

CI had a sensitivity of 42.1%, specificity of 46.6%, positive predictive value of 34% and negative predictive value of 55.1% in terms of predicting loss of reduction and sensitivity of 61.5%, specificity of 53%, positive predictive value of 17% and negative

predictive value of 89.8% in predicting need for surgery.

No statistically significant relationship is seen between CI and loss of reduction ( $p=0.948$ ) and also when analyzed categorically (cut-off was set to 0.8) there was no relationship between CI being more than or equal to 0.8 and loss of reduction ( $p=0.277$ ). The only variable that has an impact on loss of reduction is AO/OTA classification. Results of the analysis can be seen in table 2.

**Table 2.** The impact of parameters on loss of reduction. (a) Independent samples t test, (b)chi-square test.

	No loss of reduction (n =58)	Loss of reduction (n =38)	p value
<b>Age</b>	49.7 $\pm$ 16.8	51.1 $\pm$ 15.7	0.662 (a)
<b>Sex</b>			0.741 (b)
<b>Male</b>	27 (46.6%)	19 (50%)	
<b>Female</b>	31 (50.4%)	19 (50%)	
<b>BMI</b>	23.1 $\pm$ 3.7	23.7 $\pm$ 2.7	0.406 (a)
<b>AO/OTA classification</b>			0.016 (b)
<b>23.A2 (n =33)</b>	23 (39.7%)	10 (26.3%)	
<b>23.A3 (n =10)</b>	3 (5.2%)	7 (18.4%)	
<b>23.B1 (n =25)</b>	20 (34.5%)	5 (13.2%)	
<b>23.B2 (n =3)</b>	2 (3.4%)	1 (2.6%)	
<b>23.B3 (n =12)</b>	5 (8.6%)	7 (18.4%)	
<b>23.C1 (n =6)</b>	4 (6.9%)	2 (5.3%)	
<b>23.C2 (n =6)</b>	1 (1.7%)	5 (13.2%)	
<b>23.C3 (n =1)</b>	0 (0,0%)	1 (2.6%)	
<b>Cast Index (CI)</b>	0.79 $\pm$ 0.04	0.79 $\pm$ 0.08	0.948 (a)
<b>Cast Index (CI) <math>\geq</math> 0.8</b>	31 (50.4%)	16 (42.1%)	0.277 (b)

Logistic regression analysis did not reveal CI, age, BMI and sex as predictive factors for loss of reduction. AO/OTA types A3 and C2 had higher loss of reduction risk (Odds ratio: 5.348 and 11.909,

$p=0.04$  and  $0.034$  respectively) based on the analysis. Results of logistic regression analysis are shown in table 3.

**Table 3.** Results of logistic regression analysis.

Predictor	Estimate	Standard error	Odds ratio (95% confidence interval)	p value
Cast Index (CI)	-0.269	3.677	0.764 (0-1031.22)	0.942
Age	-0.001	0.016	0.999 (0.967-1.03)	0.938
BMI	0.067	0.073	1.069 (0.925-1.24)	0.364
Gender (Male)	-0.037	0.526	0.963 (0.343-2.7)	0.963
<b>Fracture type</b>				
<b>23.A3 (n =10)</b>	<b>1.676</b>	<b>0.818</b>	<b>5.348 (1.076-26.58)</b>	<b>0.04</b>
23.B1 (n =25)	-0.639	0.656	0.528 (0.145-1.91)	0.331
23.B2 (n =3)	0.17	1.286	1.186 (0.095-14.76)	0.895
23.B3 (n=12)	1.087	0.722	2.968 (0.72-12.22)	0.132
23.C1 (n =6)	0.265	0.984	1.304 (0.189-8.99)	0.787
23.C2 (n =6)	<b>2.477</b>	<b>1.169</b>	<b>11.909 (1.202-117.95)</b>	<b>0.034</b>
23.C3 (n =1)	16.391	1.455.397	1.31e+7 (0-∞)	0.991

## DISCUSSION

There have been many studies on the treatment of adult distal radius fractures and there are various opinions on treatment choices (4). In current literature, although there are many studies comparing the results of conservative and surgical treatment, there are very few studies that provide information about the effectiveness of cast treatment in adult patients. For this reason, adult patients are called for frequent controls after cast application and close follow-up is necessary. Some studies in the literature suggest that the use of radiology extensively for follow-up causes unnecessary radiation exposure (18). Currently, it is difficult to estimate prognosis of fractures in conservatively followed adult patients from initial radiographs.

With this in mind, we aimed to test the CI for adult patients, which is frequently used in children and is considered to be a successful indicator for success of cast treatment (9, 11-13). Our purpose of using the CI was that the measurement method could be applied quite easily compared to the three-point index, which was shown to be successful in adult patients (7). Indeed, inter- and intra-observer reliability was high in our study for CI. However, we concluded that the CI failed to predict fracture displacement both as a continuous value and when we set a cut-off value of 0.8. We also found that the CI failed to predict displacement when we included demographic data in the analysis.

Successful cast application is the most important step in conservative treatment. Loose casts prevent the fracture from being stable, while tight casts increase the risk of post-fracture, circulatory disorders and compartment syndrome. CI is routinely used in our clinical practice for pediatric fractures. We started with the idea that it can be used in adult patients, especially since there is no study examining the success of CI in reduction continuity.

Previously, Alemdaroğlu et al. (7) found that the three-point index was successful in predicting

fracture reduction and was superior in sensitivity and specificity to other cast parameters, including the CI. However, the related study examined many parameters that may be effective on the loss of reduction and performed this evaluation with univariate logistic regression analysis and as a result, it was seen that some other parameters (such as ulnar deviation and fracture obliquity) besides the three-point index also affected this result. In our study, the direct relationship between CI and reduction loss was analyzed and no relationship was found. In addition, our evaluation with multi-variate logistic regression analysis showed that the type of fracture according to the AO/OTA classification affected maintenance of reduction.

In 1989, Lafontaine et al. (19) suggested five parameters (dorsal angulation, intraarticular extension, dorsal comminution, ulna fracture and age>60 years) for predicting loss of reduction and these criteria are still being used extensively in terms of decision to surgery or re-reduction. However, this criterion were not defined to evaluate the success of cast treatment and we think that a well-made cast may prevent reduction loss even in patients that meet most of these criteria. Furthermore, the success of these criteria were questioned in literature previously (20). In our study, no relationship was found between age and loss of reduction in fracture, while volar or dorsal fragmentation and radial inclination was not investigated. A meta-analysis published by Walenkamp et al. (21) examined the factors that may be effective on the loss of fracture reduction and found that parameters such as fracture type (especially AO/OTA type 3 fractures), volar fragmentation, loss of radial inclination were effective when analyzed individually, while in pooled analysis, dorsal fragmentation and age were found to cause loss of reduction. Instead of using a single parameter such as CI for reduction loss, several parameters can be used together (11). The inclusion of other cast parameters in the analysis in future studies may help to produce better models for predicting cast success.

The AO/OTA classification is one of the most commonly used classification systems to indicate fracture types (17). Especially AO/OTA subtype 3 (A3/B3/C3) was shown to be a risk factor for early reduction loss in a previous study (22). In our study, the risk of reduction loss was found to be higher for AO/OTA type A3 and C2 fractures. Since we often prefer primary surgical treatment for C3 fractures, only one patient was followed conservatively and this did not allow us to analyze this subtype.

The main limitations of our study was its retrospective nature and not being able to define the exact time of displacement due to the follow-up protocol. However, it can also be considered as a strength preventing potential bias on follow-up and treatment decisions. Also it can be argued that fracture parameters such as Lafontaine's criteria or intra-articular displacement and volar tilt should be identified and analyzed separately as in other similar studies (7), however the authors think that AO/OTA classification is a reliable system to define the properties of the fracture and analyzing many

parameters that may influence displacement rates may have a weakening effect on the main aim of the study. Other cast-related indices may also be investigated, however that may also distract from the original purpose.

### Conclusion

Although having good inter- and intra-observer reliability of cast index, unlike pediatric population, it does not have a prognostic value in predicting loss of reduction in adult patients. There is a need for defining other easy-to-apply indices to predict.

### Statement of Ethics

Approval dated 09.12.2019 and numbered 77/09 was obtained from the ethics committee of Dışkapı Yıldırım Beyazıt Training and Research Hospital. Written informed consent was obtained from all patients and this study was conducted in accordance with the Declaration of Helsinki.

**Conflict of interest:** The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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