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Determination of risk factors for instability in pediatric distal radius fractures

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ABSTRACT

Aim: Distal radius fractures (DRF) are one of the most common injuries in childhood. DRF most commonly occurs as a result of low-energy falls onto an outstretched hand, resulting in axial loading of the metaphysodiaphyseal junction of skeletally immature long bones. One of the most common complications after the closed reduction and casting of displaced DRF is fracture relocation or loss of reduction. The aim of our study is to investigate the characteristics of these fractures by retrospectively scanning the patients who require surgical intervention in patients with distal radius fractures.

Methods: Between January 2018 and January 2021, patients aged 1-16 years with a diagnosis of distal radius fracture who were treated in our hospital were included in this study. The preoperative X-rays of the patients were evaluated and the fractures were classified according to their displacement ratio. The reduction quality was rated according to the study of Alemdaroglu criteria. The distance of the fracture line to the joint line, the presence of ipsilateral ulna fracture, the angle of the fracture, and whether it was fragmented were determined. Patients with and without surgery were compared.

Results: 206 patients who met the inclusion criteria were included in the study. A significant difference was found between the non-operated and operated groups in terms of age by Student's t-test (p=0.032). The distance from the fracture line of the surgical group to the joint line was measured to be 43.8 mm on average. A significant difference was found between the non-operated and operated groups in terms of the joint line distance of the fracture line by Student's t-test (p=0.010). There was a significant difference between the groups according to the Alemdaroğlu criteria and Mania criteria (p=0.001).

Conclusions: Our results show that complete displacement of distal radius fracture and non-anatomical reduction are important risk factors for re-displacement and therefore emerge as surgical indications in pediatric patients. Our study also emphasizes that surgical treatment may be required in older pediatric patients when the ulna fracture coexistence and the joint distance of the fracture line increases.

Key words: Pediatric distal radius fracture, pediatric Wrist fractures, Mani criteria, Alemdaroglu criteria.

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Introduction

Distal radius fractures (DRF) are one of the most common injuries in childhood [1]. DRF occurs as a result of low-energy falls that result in axial loading of the metaphysodiaphyseal junction [2]. Treatment of severely displaced and

shortened fractures usually requires sedation and closed reduction [1]. One of the most common complications after the closed reduction and casting of displaced DRF is fracture relocation or loss of reduction, occurring in 21% to 46% of patients and this may require reclosed reduction or surgical intervention [3]. There are two most important predictors of fracture re-displacement. These are the excessive displacement of the fracture during the presentation and insufficient correction after the reduction maneuver [4]. Poor molding and overfilling of the cast is a known cause of a loose-fitting cast which may lead to repositioning [5]. Most surgeons recommend osteosynthesis if the fracture is unstable after reduction [6]. Proctor et al. [7] suggested fixation in all cases where perfect reduction could not be achieved, while Prevot et al. [8] recommended wire fixation for unstable or irreducible fractures. Rodriguez Merchan et al. [9] and Ploegmakers et al. [10] recommended surgical treatment for children over the age of 10 with non-manually reducible forearm fractures.

In this study, we retrospectively screened pediatric patients with distal radius fractures. We determined the characteristics of pediatric distal radius fractures and compared the patients who underwent surgery and those who were treated conservatively. Thus, we aimed to inform orthopedic surgeons about which fractures of the pediatric distal radius may require surgery.

Materials and metods

Between January 2018 and January 2021, patients aged 1-16 years with a diagnosis of distal radius fracture who were treated in our hospital were included in this study. 206 patients who met the inclusion criteria were included in the study. The preoperative X-rays of the patients were evaluated and the fractures were classified according to their displacement ratio. The displacement rate was evaluated according to Mani criteria [11] which are categorized as follows: Grade I, without displacement; Grade II, displacement less than half the diameter of the bone; Grade III, displacement of more than half the diameter of the bone; and Grade IV, complete displacement with no contact. After reduction, translation was measured on wrist AP radiographs, translation and angulation were measured on lateral radiographs, and the reduction quality was classified. The reduction quality was rated according to the study of Alemdaroglu et al. [1]. The success of the first reduction after the maneuver was classified as follows : (1) anatomical (a complete anatomical reduction, no translation or angulation), (2) good (<10° of dorsal angulation or ≤2 mm of translation), or (3) fair (less than a good reduction, with the translation of between 2 and 5 mm, or angulation of between 10° and 20°, or any radial deviation of <5°, or a combination of 5° to 10° of dorsal angulation and ≤2 mm of translation).

The distance of the fracture line to the joint line, the presence of ipsilateral ulna fracture, the angle of the fracture, and whether it was fragmented were determined. It was checked for torus fracture and epiphysiolysis. Closed reduction and plaster cast under sedation were performed in all patients.

The patients were seen on weekly radiographs. The surgical procedure was performed in patients with displacement at the fracture line on follow-up radiographs. In the surgical procedure, the patients were placed in the supine position on the operating table. Closed reduction was tried on the patients first. K-wire fixation was performed in patients with successful closed reduction. Open reduction was performed in patients who could not be reduced by closed reduction. K-wire fixation was applied to the patients after open reduction.

Those patients who did not have appropriate radiographs had another fracture in the same extremity, those with insufficient follow-up, those with multi-trauma, and patients with previous fractures were excluded from this study. Anteroposterior and lateral wrist radiographs taken in the appropriate position before and after the treatment of all patients included in this study were evaluated by two orthopedic and traumatology specialists. Ethical approval was obtained from the local Non-Interventional Clinical Research Ethics Committee (approval date: 07.11.2022 / approval number: 13).

Statistical analysis

The mean values of the results are shown as ±SD and the frequencies as percentages. The student *t*-test and Chi-square test were used to compare groups. The significance level was determined as $p<0.05$.

Results

The files of a total of 206 patients were reviewed retrospectively. Nine patients in the surgically treated distal radius fracture group and 197 patients in the conservatively treated group were included in this study. Their mean age was calculated to be 12.8 (SD±4.04) years in the surgical group and 9.3 (SD±3.92) years in the conservative group. There was a significant difference between the groups ($p=0.032$). There were 1 female and 8 male cases in the surgical group and 49 female and 148 male cases in the conservatively treated group.

Fractures treated conservatively were classified according to the Mani criteria, with 140 cases as Grade 1, 35 cases as Grade 2, 12 cases as Grade 3, and 9 cases as Grade 4.

Epiphysiolysis was detected in 19 patients in the conservatively treated patient group. The mean age of the patient group presenting with epiphysiolysis was calculated to be 11.6 years (Table 1). According to the Mani classification, 1 case was classified as Grade 1, 12 cases as Grade 2, 5 cases as Grade 3, and 1 case as Grade 4 in the epiphysiolysis group. According to the Salter-Harris fracture classification, 1 patient in the epiphysiolysis group was classified as Type 1 and 18 patients were classified as Type 2 fractures. According to the reduction quality stated in the Alemdaroglu study, 8 patients were classified as Type 1 (anatomical), 9 patients as Type 2 (good), and 2 patients as Type 3 (fair). Sixteen patients of the epiphysiolysis group were treated with a short arm cast.

Torus fractures were detected in 121 cases out of the 197 patients treated conservatively. The mean age of the patients with torus fractures was calculated to be 8 years. A short arm cast was applied to 113 patients out of the 121 with torus fractures. Ulna fracture was detected in only 12 patients with torus fractures. The joint distance of the fractures of the torus group was measured as 15.7 mm, and only 5 patients had an oblique fracture line.

57 patients without epiphysiolysis or torus fractures in the conservative group were classified as follows: 19 cases as Grade 1, 22 cases as Grade 2 and 8 cases as Grade 3, and 8 cases as Grade 4 according to the Mani criteria, and the distance of the fracture line to the joint was measured to be 19.49 mm (Table 2). The reduction quality stated 35 patients were classified as Type 1, 20 patients as Type 2, and 2 patients as Type 3. A short arm cast was applied to 28 patients and a long arm cast was applied to 29 patients out of the 57 patients who were followed up conservatively.

Fractures treated surgically were classified as Grade 2 in 1 case, Grade 3 in 1cases and Grade 4 in 7 cases according to the Mani criteria. There was a significant difference between the groups according to the Mania criteria ($p=0.001$). The distance from the fracture line of the surgical

Table 1. General characteristics of the patients.

Parameters	**Conservative** (n-197)	**Surgery** (n-9)	***P*- value**
Gender (Female / Male)	49/148	1/8	
Age (years)	9,3 (1-17)	12,8 (5-17)	0.032
Side (R/L)	95/102	2/7	
Torus No (Y) [F/M] ((R/L))	121 (8) [39/82] ((56/65))	0	
Epiphysiolysis No (Y) [F/M] ((R/L))	19 (11,6) [1/18] ((12/7))	0	
Conservative (Y) [F/M] ((R/L))	57 (11,3) [9/48] ((27/30))		
Distance of fracture line to joint (mm) [Torus]	16,9 (6,26 -39,82) [15.7 (6,26 – 34,57)]	43,8 (17,04-83,97)	0.010
Alemdaroglu criteria	Type 1 =164 Type 2 =29 Type 3 =4	Type 1 =0 Type 2 =2 Type 3 =7	0.001
Dorsal fragmentation (No)	14	2	
Surgery (K/ORIF)		5/4	

(R/L – Right/ Left; No – number; Y – years; F/M – Female/ male; mm- millimeter; K/ ORIF – K-wire/ Open reduction internal fixation)

Table 2. Mani criteria.

Mani criteria	**Number**	**Fracture - Joint (mm)**	**R/L**	**Ulna (+)**	**L/S**
Conservative	197 (57)	16,9 (19,4)	95/102 (27/30)	36 (22)	39/158
Grade I	140 (19)	16,2 (19,4)	66/74 (11/8)	16 (5)	12/128 (5/14)
Grade II	35 (22)	19,1 (19,3)	18/17 (9/13)	9 (7)	14/21 (12/10)
Grade III	13 (8)	19,4 (19,4)	7/6 (4/4)	4 (4)	7/6 (6/2)
Grade IV	9 (8)	20,2 (20,2)	4/5 (3/5)	7 (6)	6/3 (6/2)
Surgery	9	43,8	2/7	7	
Grade I	0				
Grade II	1	17,04	0/1	1	
Grade III	1	18,6	0/1	0	
Grade IV	7	51,3	2/5	6	

(R/L – Right/ Left; Ulna (+) – ulna fracture; L/S – Long / Short; (No)- conservative treatment without torus and epiphysiolysis group; Categorized as follows: grade I, no translation; grade II, translation < half the diameter of the bone; grade III, translation > half the diameter of the bone; and grade IV, complete translation with no end-to-end contact.)

group to the joint line was measured to be 43.8 mm on average. A significant difference was found between the non-operated and operated groups in terms of the joint line distance of the fracture line by Student's t-test (p=0.010). The reduction quality was classified as Type 2 for 2 patients and Type 3 for 7 patients according to the Alemdaroglu criteria. There was a significant difference between the groups according to the Alemdaroğlu criteria (*p*=0.001). Re-manipulation was applied to 3 patients approximately 2 weeks later. The bayonet was measured as 11.7 mm on average in 6 patients. Ulna fracture was detected in 7 cases. Closed reduction and fixation with K-wire were applied to 5 patients in the surgical group (Table 1).

Discussion

Distal radius fractures and re-displacement after manipulation have been reported in children with rates ranging from 7% to 39% [11,12]. Displaced DRF can be treated conservatively. However, displacement after reduction is reported to be 7-34% in the first 2 weeks, and therefore a stable fixation is recommended [13]. Roberts et al. [14] stated that a loss of rotation occurring in distal 1/3 radius fractures is associated with residual deviation. There are two most important predictors of fracture re-displacement. These are the excessive displacement of the fracture during the presentation and insufficient correction after the reduction maneuver. Several authors have identified risk factors for distal radius fractures, which can be categorized into two categories: primary and secondary causes [15]. The primary causes include being over 9 years of age, a complete displacement at the baseline, fractures of greater than 50% displacement, greater than 20° angles, oblique fracture lines, comminuted fractures, dorsal bayonet fractures, and ipsilateral distal ulna fractures [15]. Secondary causes include failure to achieve a primary perfect reduction, a suboptimal plaster immobilization technique with a cast index greater than 0.8, additional reduction maneuvers, and decreased sedation instead of general anesthesia, or the use of a hematoma block [15]. There are three risk factors for the need for surgery in children with a displaced distal radius fracture. These are the presence of ulna fractures, the complete initial displacement of the radius fracture, and unsuccessful anatomical reduction [16]. It is important to think of the advantages and disadvantages of non-surgical and operative treatments concerning the risk of relocation and its impact on the final outcome. An evaluation of eight predictors (age, sex, fracture of both bones, isolated radius, complete displacement, quality of reduction, Cast Index, Three-Point Index, and surgeon's experience) for re-displacement in children after reduction of a displaced distal bone in previous studies was made [16]. In our literature review, the distance of the fracture to the joint line was not evaluated. The feature of our study was to show that both an increase in the distance from the joint line of the fracture and completely displaced fractures make reduction difficult and adversely affect the preservation of reduction.

Distal radius fractures often occur in a torus fracture pattern in childhood. Torus fractures angle less than 10 degrees and are often located 1 cm proximal to the distal physis. It may not be clearly visible on AP radiographs. It is better detected on lateral radiographs. [17]. In our study, the most common type of fracture was found to be torus fractures. Torus fractures were detected in 121 patients out of the 197 patients treated conservatively. The distance to the joint line was determined to be 15.7 mm on average. In most of the patients, the angulation was found to be dorsal. Volar angulation was detected in

only 12 patients. In torus fractures, ulna fracture was detected in only 12 patients.

Age <10 vs. >10 years and female gender were reported not to be significant risk factors for fracture relocation [18,19]. In our study, it was found that the mean age of those patients who had difficult reduction and who underwent surgical treatment was higher than the mean age of those patients who were followed up conservatively. The mean age of those patients who underwent surgical treatment was calculated to be 12.8 (SD±4.04) years. The mean age of the patients who were followed up conservatively was calculated to be 9.3 (SD±3.92) years. A statistically significant difference was found between the two groups in terms of their mean ages (p=0.032). In the gender evaluation, surgery was performed on only 1 female patient in our study, and the F/M ratio of the conservative group was calculated as 49/148, but it was evaluated that gender had no effect on the surgical treatment due to the low number of cases in the surgical group.

Complete displacement (often defined as the width of a shaft) compared with partial displacement and fracture of both bones compared with an isolated radius fracture have been shown to be important risk factors for re-displacement [20, 21]. Severely displaced and partially reduced fractures are at high risk for loss of cast reduction. If reduction loss is acceptable, the potential for bone remodeling makes a second procedure unnecessary; if reduction loss is not acceptable, a second procedure and possible fixation with Kirschner wires are required. Persiani et al. stated that osteosynthesis with Kirschner wires following reduction should be considered as the main treatment option in fractures with a high risk of secondary displacement, with severe displacement or insufficient reduction [22]. In another study, the best predictor of re-displacement was immediate post-manipulation radiography. Therefore, it has been suggested that distal forearm fractures in children should not be manipulated by unsupervised young trainees and that the result of the first manipulation should be a perfect anatomical reduction. If this cannot be achieved, there should be a low threshold for operational stabilization, such as the use of Kirschner wires during the initial procedure [4].

In our study, of the 9 patients who underwent surgical treatment, 7 patients had complete displacement and no cortex contact (Mani Grade 4), and 2 patients were found to be displaced (Mani Grade 3). In the conservative group, complete displacement (Mani Grade 4) was observed in only 9 (4.5%) of the 197 patients. In addition, 12 (6.1%) patients were found to be displaced (Mani Grade 3). In the conservatively followed patient group, displaced fractures were detected in 10.6% of the patients. If we compare this rate, a statistically significant difference was found between the two groups (p=0.001). Fractures of both bones were observed in 36 (18%) patients in the conservatively treated patient group. In the group of patients treated surgically, fractures were found in both bones in 7 patients (77%). A significant difference was found between these two groups (p=0.001).

There are studies indicating that anatomical reduction significantly reduces the risk of repositioning compared to non-anatomical reduction. Proctor et al. [7] advocated fixation in all cases where perfect reduction could not be achieved, while Prevot et al. [8] recommended fixation with K-wires for those patients with instability or inability to reduce. Perfect anatomic reduction is one of the most widely accepted factors preventing repositioning [16,20]. For this reason, Haddad and Williams [4] suggested K-wire fixation if complete anatomical reduction could not be achieved. In another study, it was emphasized that the failure of anatomical

reduction of the fracture increased the risk of re-displacement 5 times compared to anatomically reduced fractures [1]. They stated that in children with distal forearm fractures, a first angulation of less than 10° and translation at the bone ends provides relative stability and thus a good prognosis [4]. Van Delft et al. [23] stated in their study that although the anatomical reduction is an important condition in distal forearm fractures, it is not sufficient alone for conservative treatment. In our study, in the surgical group, the reduction quality was evaluated as poor in 8 out of 10 (80%) patients according to the reduction criteria of the Alemdaroglu study [1]. In the conservative group, the reduction quality was observed in only 3 patients out of the 196 patients, and the reduction quality was found to be moderate (Type 2 according to Alemdaroglu criteria) in 29 patients. Re-manipulation was applied to only 2 patients from the conservative patient group, which were evaluated as poor and moderate reduction quality. Of the 32 patients with poor or moderate reduction, 11 patients were admitted with a diagnosis of epiphysiolysis. The angulation was found to be volar in 6 patients out of these 32 patients (average 22°), radial displacement in 2 patients, and dorsal in 1 patient. The displacement rate and reduction quality we found in our study were shown to increase the need for surgery, and these findings support the literature.

There is a consensus that there is no difference in secondary displacement between long arm cast and short arm cast in distal forearm fractures [24]. In our study, a long arm cast was applied to 8 patients in the surgical group. In the conservative group, a long arm cast was applied to 39 patients out of the 196. Fracture angulation was detected in 8 of these patients. Ulna fracture was detected in 21 patients who were treated with a long arm cast. Long arm cast was applied to 21 patients out of the total of 36 patients with ulna fractures, and it was determined that long arm cast was mostly applied in cases presenting with ulna fractures. However, in our study, a long-arm cast was found to be ineffective in maintaining reduction because, in total follow-up, 8 out of 11 patients with displaced fractures had received long-arm casts.

In our evaluation of our patients, we decided to measure the distance of the fracture line to the joint line. In the literature, this parameter has not been investigated in distal radius fractures with a high surgical risk. In the surgical group, the distance from the fracture line to the joint was measured to be 43 mm on average. In the conservatively treated patient group, this distance was measured to be 16.9 mm. In addition, in the measurements we made not including torus fractures, the average distance from the fracture line to the joint line of 57 patients was measured to be 19.4 mm. A statistically significant difference was found between the two groups in terms of the distances from the fracture line to the joint line.

Conclusions

Our results support that surgical indications for distal radius fractures include complete initial displacement of the fracture and unsuccessful anatomic reduction. Our study also emphasizes that surgical treatment may be required in older pediatric patients when the ulna fracture coexistence and the joint distance of the fracture line increases.

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