Research Article / Araştırma Makalesi

Pediatric Forearm Fractures with Unacceptable Angulation: Is Remodeling Effective?

Kabul Edilemez Angulasyonu Olan Çocuk Önkol Kırıkları: Remodelizasyon Etkili mi?

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Abstract: The aim of this study is to examine the remaining deformity after remodeling and its relationship with pronation/supination limitation in patients with unacceptable angulation according to the literature. 45 patients who had forearm fractures treated with closed reduction and plaster cast between 2014 and 2019 were included in the study. The maximum angulation amount was determined on anteroposterior or lateral radiographs by measuring the angulation of the radius and ulna on the radiographs taken during plaster removal (T1) and on the radiographs after remodeling (T2) at the last follow-up. The average follow-up period was 61.6 months (36-90 months). The patients were divided into 2 groups according to the angulation in the radiographs taken on the day the cast was removed (T1): Group 1 (acceptable angulation), and Group 2 (unacceptable angulation). While the average of maximum angulation values at T1 in Group 1 was 8.2° (±2.6) it was 15.4° (±4.1) in Group 2 (p = 0.002). While the mean residual angulation value at T2 was 3.5° (±1.8) in Group 1, it was 6.8° (±3.1) in Group 2 (p = 0.002). It was determined that 7 of 19 patients in Group 1 and 13 of 26 patients in Group 2 had a limitation of more than 10° (p = 0.382). Conservatively treated pediatric forearm fractures have the potential to heal to normal degrees at a high rate after remodeling, even if they have unacceptable angulation degrees, and the pronation/supination limitation in these patients is not directly related to the residual angulation degrees.
Keywords: Radius and ulna fracture, Closed fracture reduction, Malunion, Bone remodeling.

Özet: Bu çalışmanın amacı literatüre göre aslında kabul edilemez angulasyona sahip olan hastalarda, remodelizasyon sonrası kalan deformiteyi ve bunun pronasyon/supinasyon kısıtlılığı ile ilişkisini incelemektir. 2014-2019 yılları arasında kapalı redüksiyon ve alçı ile tedavi edilmiş 45 hasta çalışmaya dahil edildi. Alçı çıkarılması sırasında çekilen radyografiler (T1) ve son kontroldeki remodelizasyon sonraki grafiler (T2) üzerinden radius ve ulnanın angulasyonları ölçülerek ön-arka veya yan grafilerde maksimum angulasyon miktarı belirlendi. Ortalama takip süresi 61.6 aydı (36-90 ay). Hastalar alçının çıkarıldığı gün (T1) çekilen radyografilerdeki angulasyona göre 2 gruba ayrıldı (Grup 1: kabul edilebilir angulasyon; Grup 2: kabul edilemez angulasyon). Grup 1'de T1'de maksimum angulasyon değerlerinin ortalaması 8.2° (±2.6) iken, Grup 2'de 15.4° (±4.1) idi (p=0.002). T2'de ortalama rezidü angülasyon değeri Grup 1'de 3.5° (±1.8) iken, Grup 2'de 6.8° (±3.1) idi (p=0.002). Grup 1'de 19 hastanın 7'sinde, Grup 2'de ise 26 hastanın 13'ünde pronasyon veya supinasyonda 10°'den fazla kısıtlılık olduğu saptandı (p=0.382). Konservatif tedavi edilen çocuk önkol kırıkları kabul edilemez angulasyon derecelerinde olsa bile yüksek oranda normal derecelere iyileşme potansiyeline sahip olup, hastalarda oluşan pronasyon/supinasyon kısıtlılığı rezidü angulasyon dereceleri ile direkt ilişkili değildir.
Anahtar Kelimeler: Radius ve ulna kırığı, Kırığın kapalı redüksiyonu, Anormal kaynama, Kemik remodelizasyonu.

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1. Introduction

Forearm bone fractures are a common injury in the pediatric population, with double bone fractures of the radius and ulna accounting for an estimated 40% of all pediatric fractures [1]. These fractures typically result from indirect trauma from falling onto an outstretched hand and may involve the radius, ulna, or both [2]. The initial treatment of forearm fractures in the pediatric population is usually closed reduction and casting, which is successful as long as fracture reduction can be kept at acceptable levels until union occurs [3].

Child forearm double bone fractures may rarely lead to limitation of pronation and/or supination, which may affect daily activities [4]. The main factor responsible for this situation is the loss of reduction within the cast and the development of angular malunion [5]. Although it is estimated that angulation will improve with remodeling, it is a dilemma for clinicians to estimate whether the amount of angulation left behind at the endpoint will leave a clinically significant degree of pronation and/or supination restriction and whether to give the patient a new reduction decision.

The aim of this study is to evaluate the amount of remodeling after conservatively treated pediatric forearm double bone fractures and the relationship between the amount of angulation remaining after remodeling and pronation and/or supination limitation.

2. Materials and Methods

After ethics committee approval (Hacettepe University Ethics Committee 2023/05-21), pediatric patients diagnosed with double bone forearm fractures between 2014 and 2019 were retrospectively investigated using the hospital database. Of the 406 patients reached as a result of the assessment, 164 patients between the ages of 2 and 15 who were treated with closed reduction and long-arm casting and who came for regular check-ups until the cast was removed were evaluated. The parents of these 164 patients were contacted by phone and invited to the study. Isolated radius or ulna fractures, operated patients, patients with refracture, patients with a history of fracture in the opposite forearm, greenstick fractures, patients with Monteggia or Galeazzi fractures, patients diagnosed with pathological or open fractures, polytrauma patients and patients with insufficient radiographic follow-up in plaster cast were excluded. Of the 45 patients who agreed to participate in the study, 35 were male and 10 were female (Table 1). 25 patients had left forearm and 20 had right forearm fractured extremities in the study, and the average follow-up period was 61.6 months (36-90 months). For all patients, the degrees of supination and pronation in both forearms were measured using a goniometer with 2 movable arms of 20 cm, with the arm adducted touching the body and the elbow flexed at 90 degrees (Figure 1). Angulations of the radius and ulna were measured on the radiographs taken on the day the plaster cast for the treatment of the fracture was removed (T1) and on the radiographs after remodeling at the last follow-up (T2). For angulation measurement, the central longitudinal axis was determined in the proximal and distal parts of the fracture line in the radius and ulna in the anteroposterior and lateral radiographs, and the angle between them was recorded, and whichever was the maximum angulation amount was included in the analysis [6]. While commonly accepted reference ranges in the literature were used to evaluate angulation at T1, angulation of more than 10° was defined as malunion to evaluate the post-remodeling situation at T2 [3]. For interobserver variability, the difference between 10 consecutive measurements made by two experienced orthopedic surgeons. When there was a difference as low as 3° (0-5°), the measurement of a single orthopedic surgeon was included in the study.

Table 1. Demographic, radiographical and clinical parameters of the study population.

	Mean ± standart deviation/ frequency (n)	Median (min.-max.) / percent (%)
Age at fracture	7.6±2.9	7 (2-13)
Sex		
Boy	35	77.8
Girl	10	22.2
Side (R/L)		
L	25	55.6
R	20	44.4
Follow-up	61.6±16.1	59 (36-90)
Radial angulation at T1, anteroposterior	4.6±4.3	3.4 (0.4-21.9)
Ulnar angulation at T1, anteroposterior	4.2±3.6	2.7 (0.0-16.7)
Radial angulation at T1, lateral	9.9±6.4	10.0 (0.8-24.8)
Ulnar angulation at T1, lateral	4.9±4.0	3.6 (0.0-20.0)
Radial angulation at T2, anteroposterior	2.2±1.5	1.7 (0.6-6.3)
Ulnar angulation at T2, anteroposterior	2.6±1.9	1.8 (0.5-9.2)
Radial angulation at T2, lateral	4.4±3.1	3.6 (0.8-13.1)
Ulnar angulation at T2, lateral	2.9±2.6	2.1 (0.5-13.4)
Pronation in the fractured forearm	64.5±7.9	65.0 (45.0-80.0)
Pronation in the healthy forearm	73.7±7.8	74.0 (55.0-87.0)
Pronation limitation	9.1±6.7	7.0 (1.0-25.0)
Supination in the fractured forearm	84.4±6.4	85.0 (71.0-96.0)
Supination in the healthy forearm	90.0±6.5	90.0 (74.0-103.0)
Supination limitation	5.6±3.1	6.0 (1.0-12.0)

Abbreviations: T1, cast removal; T2, last follow-up.

***Figure 1**. Patient with pronation limitation in the right forearm.*

3. Results

The patients were divided into 2 groups according to the angulation in the radiographs taken on the day the cast was removed (T1): Group 1 was determined as acceptable angulation, and Group 2 was determined as unacceptable angulation. There were 19 patients (15 boys, 4 girls) in Group 1, and 26 patients (20 boys, 6 girls) in Group 2. The mean age was 6.9 (±2.8) in Group 1 and 8.1 (±2.9) in Group 2. Mean follow-up periods were 62.2 and 61.2 months, respectively. There was no significant difference between the groups in terms of gender, age and follow-up periods ($p>0.05$).

While the mean maximum angulation values at T1 on anteroposterior or lateral radiographs in Group 1 was 8.2° (±2.6) it was 15.4° (±4.1) in Group 2, and there was a significant difference between the two groups ($p = 0.002$). While the mean residual angulation value at T2 was 3.5° (±1.8) in Group 1, it was 6.8° (±3.1) in Group 2, and there was a significant difference between both groups ($p = 0.002$).

In Group 1, the average pronation was 64° in the fractured forearm and 73° in the healthy forearm, while in Group 2 the same values were 65° and 74°, respectively. In Group 1, the average supination was 84 in the fractured forearm and 90° in the healthy forearm, while in Group 2 the same values were 84° and 90°, respectively. When the groups were evaluated in terms of whether there was a limitation of more than 10° in pronation or supination relative to the opposite forearm, it was determined that 7 of 19 patients in Group 1 and 13 of 26 patients in Group 2 had a limitation of more than 10°. In this respect, no significant difference was detected between the groups ($p = 0.382$).

Considering the entire population of 45 patients included in the study, the average supination limitation was 5.6° (±3.1) and pronation limitation was 9.1° (±6.7). While patients with more than 10° pronation and/or supination limitation had 5.7° residual angulation, patients with less than 10° movement limitation had 5.2° residual angulation. No significant difference was detected between residual angulations according to pronation/supination limitation ($p>0.05$).

Although it was determined that 4 out of 45 patients healed with malunion, the amount of movement limitation in these patients was found to be 4°,14°,21° and 25°, respectively.

4. Discussion and Conclusion

The main finding of this study is that even if conservatively treated pediatric forearm double bone fractures have unacceptable angulation levels, they have the potential to heal after remodeling to reduce high angulations to normal limits. Additionally, there is no direct relationship between pronation/supination limitation and the degree of residual angulation.

Malunion, which occurs after pediatric forearm double bone fractures, is a complication that may include not only residual angulation but also translation and rotation deformities and is generally seen after conservatively treated fractures [4, 5]. Considering cadaveric studies, it has been shown that malunion of less than 10° causes minimal pronation and supination limitation, while higher degrees cause significant loss in the same movements [4, 5, 7]. Surgical treatment is recommended to prevent functional and cosmetic problems [8-10].

However, in childhood, bones have a weapon called remodeling. The remodeling phase of fracture healing is a process in which callus tissue is gradually eliminated and new bone is formed along the stress lines, which can last months or even years in some bone structures [11]. Even though fractures distant from the physis, such as forearm double bone fractures, have relatively less remodeling capacity than fractures closer to the physis, such as metaphysis, this process often provides almost perfect cosmetic recovery, especially in young children [12, 13]. In the patient cohort in our study, of the 26 patients who had unacceptable angulation according to the literature upon removal of the cast and constituted Group 2, angulation persistence was less than 5° in 7 patients, 5-10° in 15 patients, and more than 10° in only 4 patients. That is, successful remodeling occurred in

22/26 (84%) patients, and although they remodeled with higher degrees of angulation than patients within acceptable limits, most forearms healed without developing malunion (Figure 2). This shows that remodeling in pediatric forearm fractures is better than expected, and therefore the acceptability limits should be reconsidered with new long-term studies.

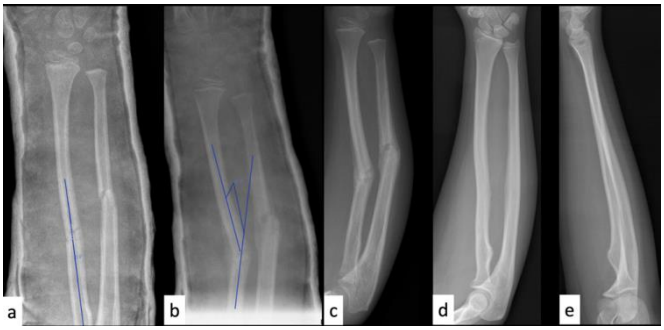

Figure 2. *Radiographs of a 6-year-old patient. a. Radiograph after closed reduction, b. Unacceptable angulation was observed 2-weeks after reduction, c. Radiography after cast removal, d,e. Successful remodeling 7 years after fracture.*

Malunion is not the only cause of movement limitation after a forearm fracture. After trauma, not only bone fractures occur, but soft tissue structures such as interosseous membrane and surrounding muscles can also be damaged [14]. Especially while the interosseous membrane damage is healing, fibrotic tissues may form, which may cause contracture and cause limitation of pronation and supination [15]. In our study, when comparing patients who developed and did not develop pronation and supination restriction, there was no significant difference in the amount of residual angulation, which can be explained by contractures secondary to the soft tissue injuries mentioned above.

The strengths of this study are that the follow-up period is long enough to complete remodeling and that it consists of patients treated similarly in a single center. The limitations of the study are that it was retrospective, the number of patients was small, the age range was wide, elbow and wrist ranges of motion were not compared, possible rotational deformities were not evaluated, analysis was not made according to forearm fracture levels, and soft tissue injuries that could explain the limitation of movement were not evaluated.

In conclusion, it should be known that even if there is a significant angulation in conservatively treated patients, this can be corrected by remodeling before malunion develops, and in patients who develop pronation/supination movement limitation, residual angulation may not be the only reason. Soft tissue injuries such as interosseous membrane damage should also be evaluated in order to predict which patients are likely to develop movement limitations.

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Ethics

Ethics Committee Approval: The study was approved by Hacettepe University Ethics Committee (Decision no: 2023/05-21, Date: 24.10.2023).
Informed Consent: All patients provided a written informed consent.
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