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Radial Bowing and Obesity: Do They Increase The Need For Surgical Intervention in Pediatric Radial Epiphyseal Fractures?

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ABSTRACT

Objective: Radial physeal fractures are the most common growth plate injuries in children. While most are treated nonoperatively, some cases require surgical intervention due to initial displacement or loss of reduction. Individual biomechanical factors such as radial bowing and obesity-related soft-tissue mass may influence fracture stability but remain underexplored. This study aimed to assess whether increased radial bowing and body mass index (BMI) are associated with a higher risk of requiring surgical treatment in pediatric radial epiphyseal fractures.

Materials and Methods: In this retrospective observational study, 106 children aged 2–16 years with isolated proximal or distal radial epiphyseal fractures were analyzed. Radiographic parameters, including radial bowing (percentage and location) and soft-tissue-to-bone ratio (SKYO), were measured on the contralateral intact forearm. BMI percentiles were calculated, and fracture characteristics were recorded. The primary outcome was the need for surgical treatment; secondary outcomes included re-reduction rates and associations between anatomical variables and treatment approach. Statistical analyses included Student's t-tests and Spearman correlation.

Results: Of 106 patients (63.2% male; mean age: 10.2 years), only 2 (1.9%) underwent surgery. The mean radial bowing was 6.24% (range: 4.4–8.71), with an average bowing location at 61.2% of radial length. Mean SKYO was 33.1%, and average BMI percentile was 68.67. No significant relationship was found between radial bowing, SKYO, or BMI and the need for surgery. A positive correlation was observed between radial bowing and SKYO (p=0.032), and an inverse correlation between BMI percentile and SKYO (p=0.041).

Conclusion: Radial bowing and soft-tissue thickness (SKYO), although anatomically variable, were not predictive of surgical need in pediatric radial epiphyseal fractures. Nearly all cases were effectively managed conservatively, with excellent functional outcomes. These findings suggest that individual anatomical variation, including radial bowing and BMI, should not influence initial surgical decision-making in physeal fractures of the radius.

Keywords: Pediatric orthopedics, Physeal injuries, Radial fractures

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INTRODUCTION

Radial growth plate fractures represent the most common type of physeal injury in the pediatric population, primarily due to the vulnerability of the distal radial physis during growth periods.[1] These injuries can involve both the distal and proximal ends of the radius. In addition, metaphyseal fractures and diaphyseal fractures that do not affect the physis are also frequently encountered in children.[2] Because the physis is the primary center for longitudinal bone growth, injuries involving this region carry the potential risk of physeal arrest. Subsequent complications such as angular deformities or limb length discrepancies may arise as a result of premature physeal closure.[1] As such, early identification and accurate management of these fractures are paramount to ensuring proper skeletal development and minimizing long-term disability.

The clinical decision-making process for the management of radial growth plate fractures often involves determining the necessity of surgical intervention. While many of these fractures can be treated nonoperatively through closed reduction and casting, failure to achieve or maintain adequate reduction can necessitate surgical treatment. In some instances, insufficient reduction during the initial emergency department visit may be the cause, while in other cases, displacement may occur during follow-up despite appropriate initial treatment.[1] Although current classification systems and treatment guidelines provide general criteria for acceptable alignment, they do not fully account for individual anatomic or biomechanical factors that may predispose a fracture to instability.

One such potential factor is the natural radial bowing of the forearm, which is known to vary among individuals. An increased radial bow may theoretically alter the biomechanics of the radius in a way that contributes to either initial displacement or subsequent loss of reduction. However, the relationship between radial bowing and the risk of surgical intervention in physeal fractures has not been well established in the pediatric population.

Moreover, body habitus–particularly the impact of obesity–has been increasingly recognized as a potential risk factor in pediatric orthopedic trauma. Excess body weight may increase the mechanical load on the skeleton, potentially influencing fracture patterns and stability. However, the role of body weight and height as independent risk factors for surgical treatment in radial physeal injuries remains underexplored in the literature.

In this study, we aimed to investigate whether increased radial bowing and elevated body mass index (BMI) are associated with a higher risk of requiring surgical intervention in pediatric radial epiphyseal fractures. We hypothesized that both increased radial bowing and higher BMI act as biomechanical stressors, potentially contributing to initial fracture displacement and increasing the likelihood of fracture instability, thereby necessitating surgical management.

MATERIALS AND METHODS

Study Design and Participants

This retrospective observational study included pediatric patients who presented to the emergency department of our hospital with proximal or distal radial epiphyseal fractures between June 2021 and January 2023. A total of 126 patients were initially identified. Standard anteroposterior and lateral forearm radiographs obtained during emergency department visits and follow-up outpatient clinic visits were evaluated. Twenty patients who failed to attend follow-up visits or whose radiographic data were incomplete were excluded from the analysis. The final study population consisted of 106 patients. Of these, 67 were male and 39 were female, with ages ranging from 2 to 16 years. Inclusion criteria were as follows: Age between 2 and 16 years, presence of an isolated epiphyseal fracture of the radius (proximal or distal), and availability of comparative radiographs of both forearms. Exclusion criteria were as follows: Open fractures, concurrent fractures of other bones in the same limb, history of previous fracture in the same arm, and congenital anomalies affecting the upper limbs.

Data Collection and Measurements

Demographic data including age, sex, height, and weight were recorded. Fracture characteristics such as location (proximal or distal), affected side (right/left), and classification according to the Salter-Harris system were documented. Radial bowing measurements were performed on the intact contralateral forearm using standard anterior-posterior radiographs. The maximum perpendicular distance (r) from the radius's diaphyseal arc to a straight line (x) connecting the radial head and distal radial metaphysis was used to calculate radial bowing. Bowing location (y/x) was calculated by identifying the distance (y) from the radial head to the point of maximum bowing along the line x (Fig. 1). Soft-tissue thickness measurements were performed on the same radiographs. The total transverse skin-to-skin forearm width (c) at the level of radial midshaft was measured. At the same level, the sum of radial and ulnar bone widths (a+b) was measured. The soft-tissue-to-bone ratio (SKYO) was then calculated using the formula: $(a+b)/c \times 100$ (Fig. 2). These values were used to assess whether increased soft-tissue thickness (as a surrogate for obesity) was associated with a need for surgical intervention or re-reduction.

Outcome Assessment

The primary outcome was the need for surgical intervention (initial or during follow-up). Secondary outcomes included the need for re-reduction and the correlation of this with anatomical and anthropometric variables.

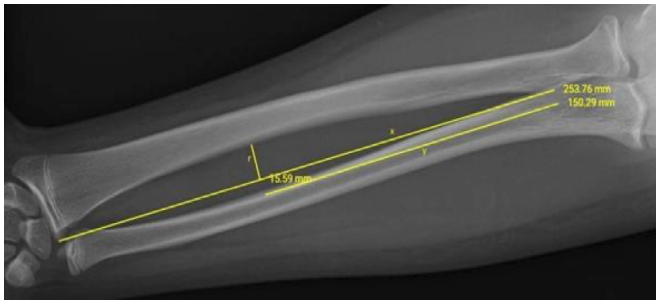

Figure 1. Measurement method for radial bowing and the location of maximum bowing as per the method described by Firl and Wünsch (2004).[3] The radial bowing (r/x) was calculated by measuring the maximum perpendicular distance (r) from the shaft of the radius to a straight line (x) drawn from the radial head to the radial styloid process on an anteroposterior radiograph. The bowing location (y/x) was defined as the distance (y) from the proximal radial end to the point of maximal bowing, divided by the total radial length (x).

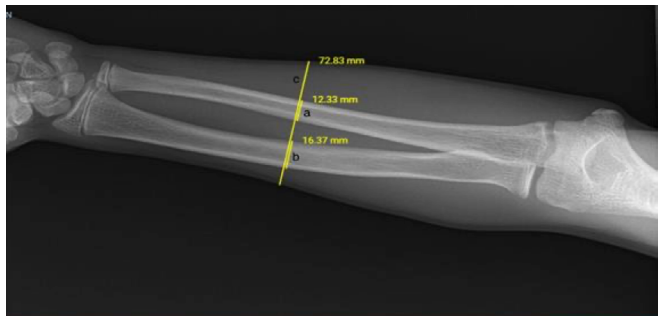

Figure 2. Measurement of the soft-tissue-bone ratio on a lateral forearm radiograph: The ratio of soft-tissue thickness to radial bone diameter at the point of maximal bowing. Anteroposterior radiographs were used to measure the sum of radial and ulnar widths (a+b) at the mid-diaphyseal level, and the total forearm width from skin to skin (c) at the same level. The soft-tissue-to-bone ratio was calculated using the formula: [(a+b)/c]×100. This ratio was used as a radiographic surrogate for soft-tissue thickness and potential obesity.

Ethics

This study was approved by the Institutional Ethics Committee on June 22, 2021, under approval number 2012-KAEK-15/2332. Our study was conducted in accordance with the Declaration of Helsinki.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY). Descriptive statistics were presented as means±standard deviation for continuous variables and frequencies (n) and percentages (%) for categorical variables. The Kolmogorov–Smirnov test was used to assess the normality of data distribution, as the sample size was >50. Comparisons of continuous variables between two independent groups (e.g., surgical vs. non-surgical treatment groups) were performed using the Student's t-test for normally distributed variables. The relationship between radial bowing, bowing location, BMI (derived from height and weight), and SKYO with the need for surgery was assessed using the Spearman rank correlation test, as some variables were ordinal or non-normally distributed. $P<0.05$ was considered statistically significant in all analyses.

RESULTS

A total of 106 patients were included in the study, with 67 males (63.2%) and 39 females (36.8%). The mean age was 10.2 years (range: 2–16 years). Patients were followed for a minimum of 2 years. Radiographs taken during emergency admission, outpatient follow-up, and at the 6th and 12th months post-union were included in the evaluation.

The mean radial bowing in the intact arms was 6.24%, ranging from 4.4% to 8.71%. The location of bowing along the radial shaft was on average 61.2%, with a minimum of 49.45% and a maximum of 71.62% (Fig. 3). The average BMI percentile of the patients was 68.67. Distribution was as follows: 20 patients (19%) were above the 95th percentile, 25 (23%) between the 85th and 95th, 58 (55%) between the 5th and 85th, and 3 (2.8%) below the 5th percentile. The intact forearm SKYO had a mean of 33.1%, ranging from 23% to 48%.

According to the Salter-Harris classification, 93 patients (94%) had type II fractures, while the remaining had other types. Two patients (1.9%) underwent surgical treatment (one distal, one

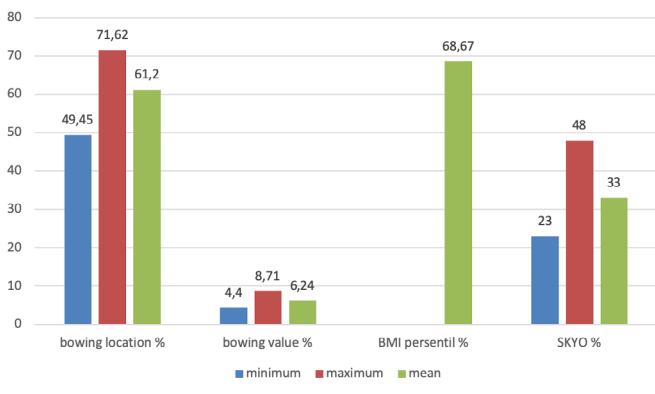

Figure 3. Distribution histogram of radial bowing percentage and bowing location among patients. Most values fall within the expected normal anatomical range.

proximal radial epiphyseal fracture), while the remaining 104 (98.1%) were treated with cast immobilization post-closed reduction. No significant relationship was found between the degree of radial bowing and the need for surgery. No statistically significant differences were found between gender and radial bowing, bowing location, or SKYO (p=0.779, p=0.415, and p=0.951, respectively) (Fig. 4).

Spearman correlation analysis (Table 1) revealed: A significant inverse relationship between age and BMI percentile (p=0.000), a positive correlation between radial bowing and SKYO (p=0.032), and a negative correlation between BMI percentile and SKYO (p=0.041). No association was found between fracture location (proximal or distal) and radial bowing or SKYO.

Among the non-operated group, all post-reduction angulation and displacement values were within acceptable limits and normalized during follow-up. Seventeen patients developed cast-related soft-tissue complications; five required splint conversion. All cases resolved without sequelae. At the 1-year follow-up, range of motion was symmetric with the contralateral limb. VAS pain scores ranged from 0 to 1; 85 patients scored 0, and 21 scored 1. All patients eventually reported pain-free active motion. 4.

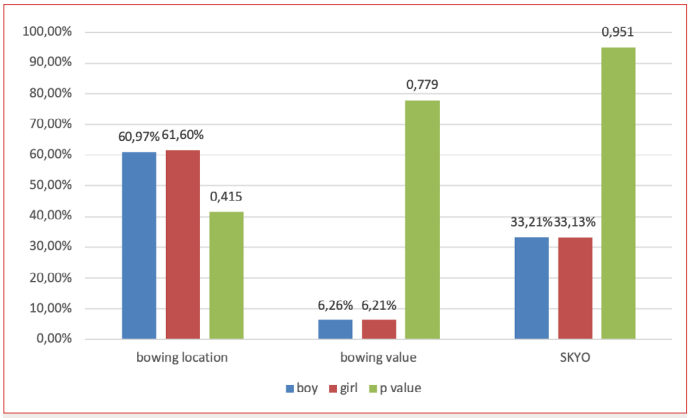

Figure 4. Comparison of radial bowing, SKYO, and bowing location between genders. No statistically significant differences were observed.

DISCUSSION

This study aimed to evaluate the potential risk factors – including radial bowing, SKYO, and obesity–for surgical intervention in radial growth plate fractures in children. The most significant findings were the lack of association between radial bowing and the need for surgery, and the novel observation that increased radial bowing correlates with increased SKYO. Moreover, a higher BMI percentile was associated with a lower SKYO value.

Our results support earlier observations that most growth plate fractures, especially Salter-Harris type II, can be effectively managed with conservative treatment. The findings align with the descriptive bowing studies of Firl[3] and Weber et al.,[4] who documented typical bowing values and locations in healthy pediatric populations. Our study confirmed that these normal anatomical variations do not predispose children to more severe injury outcomes requiring surgical correction.

The very low surgical intervention rate (1.9%) in our cohort supports previous work. For instance, Larsen et al.[5] showed that physis fractures are predominantly treated conservatively with favorable outcomes. Similarly, the high incidence of distal radial physis fractures in our study (94.3%) echoes epidemiological data by Randsborg et al.[6] and de Putter et al.,[7] who both found distal radius fractures to be the most common in children.

A novel aspect of this study is the measurement of SKYO and its positive correlation with radial bowing (p=0.032). While no prior research has investigated this relationship, our findings raise questions about whether increased SKYO is an adaptive or protective response to greater bowing stress, or a coinci-

Table 1. Spearman correlation coefficients among radial bowing, location of bowing, SKYO, age, and BMI percentile

	Age	Radial bowing location p-value	Radial bowing p-value	BMI persentil p-value	Intact forearm bone soft tissue ratio p-value
Age		0.06	0.74	0.00	0.741
Radial bowing location	0.06		0.39	0.108	0.528
Radial bowing	0.7	0.39		0.87	0.032
BMI persentil	0.00	0.1	0.87		0.041
SKYO	0.74	0.52	0.03	0.41	

Statistically significant correlations are marked in bold (p<0.05), BMI: Body mass index, SKYO: Soft-tissue-to-bone ratio.

dental anatomical variant. Since increased SKYO represents a higher bone mass relative to soft tissue at the radial midline, this might reflect developmental adaptation rather than a pathological marker.

Regarding obesity, prior research has shown it to be a risk factor for fractures. Studies by Liu,[8] Li,[9] and Seeley[10] demonstrated associations between high BMI and various pediatric upper extremity fractures. However, our study did not find any relationship between BMI percentile and the need for surgery or re-reduction in physis fractures. The only observed effect was a decrease in SKYO with increasing BMI (p=0.041), possibly indicating that obese children have more soft-tissue coverage around the forearm, potentially buffering mechanical forces.[11]

Almost all our patients were successfully managed with closed reduction and casting. This is consistent with the outcomes of McQuinn,[12] Jordan,[13] and Sengab et al.,[14] who identified initial displacement severity – not anatomical bowing – as the main predictor for surgical need in distal radius fractures. Our study builds on this by suggesting that radial bowing is not a determinant of treatment failure. Ramoutar et al.[15] demonstrated that early surgical intervention in displaced distal radius fractures shortened the treatment duration and improved radiographic outcomes. Furthermore, in a Cochrane meta-analysis conducted by Handoll et al.,[16] it was reported that distal radius fractures in children yielded similar functional outcomes whether treated conservatively or surgically, with surgical intervention being required at a low rate.

This study sets the groundwork for future investigation into SKYO as a measurable, reproducible radiographic parameter in children. It may also inspire additional research into whether higher SKYO values can be used to estimate fracture risk, guide immobilization strategies, or predict remodeling potential in pediatric upper limb fractures.

In the broader context of pediatric fracture management, this study contributes novel insight into anatomical and biomechanical factors that do not necessitate surgical intervention. The finding that high BMI does not equate to worse outcomes in physis fractures is particularly relevant, highlighting the resilience and remodeling potential of the growth plate region.

Limitations

Limitations include the lack of a healthy control group to establish normative values of SKYO across ages. In addition, we did not evaluate radial bowing or SKYO in the context of metaphyseal or diaphyseal fractures. Future studies could also consider lateral plane bowing and include ulnar bowing as a comparative variable. Furthermore, the predictive value of SKYO for fracture occurrence or displacement risk remains unexplored and warrants prospective investigation.

CONCLUSION

This study demonstrates that neither the degree nor the location of physiological radial bowing, nor the SKYO, significantly affect the need for surgical intervention in pediatric radial epiphyseal fractures. Although a positive correlation was found between radial bowing and SKYO, and an inverse correlation between BMI percentile and SKYO, these anatomical and anthropometric variations did not influence treatment outcomes. Nearly, all fractures were successfully managed with conservative treatment, and patients achieved excellent functional recovery without long-term complications. These findings suggest that normal anatomical variations such as radial bowing and SKYO should not be considered risk factors for surgical requirement in growth plate injuries of the radius.

DECLARATIONS

Ethics Committee Approval: The study was approved by Ankara Keçiören Training and Research Hospital Chief Medical Officer's Office Clinical Research Ethics Committee (No: 2012-KAEK-15/2332, Date: 22/06/2021).

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