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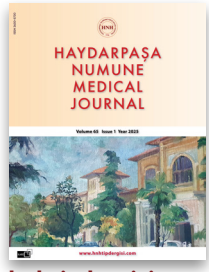

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ORIGINAL ARTICLE

Comparison of Clinical and Radiological Results of Surgery Versus Conservative Treatment in Pediatric Proximal Humeral Fractures

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Abstract

Introduction: Displaced proximal humerus fractures in pediatric patients are rare. Concepts such as remodeling potential, degree of deformity, and functional demands guide treatment decisions. The aim of this study is to compare the treatment outcomes between skeletally immature patients treated surgically and non-surgically for Neer-Horwitz type III–IV displaced proximal humerus fractures.

Methods: A total of 52 skeletally immature patients under the age of 15 who were treated for displaced proximal humerus fractures between 2015 and 2021 were included. The patients were divided into two groups: those treated non-surgically (n=22) and those treated surgically (n=30). Radiological outcomes were evaluated by measuring fracture angulation at initial presentation, as well as at the 3rd and 12th months post-fracture. Functional outcomes were assessed using QuickDASH scores at the 3rd and 12th months.

Results: Initial angulation was significantly higher in the surgical group compared to the non-surgical group (p=0.001). However, angulation at 3 months post-fracture was significantly lower in the surgical group (p=0.001). At 12 months, no significant difference was observed between the groups. Regarding functional outcomes, the mean QuickDASH scores at 3 months were significantly lower in the surgical group (p=0.001), indicating better early functional recovery. However, no significant difference was found between the groups at 12 months post-fracture.

Discussion and Conclusion: Although surgical treatment provided better radiological and functional outcomes in the early post-fracture period, long-term outcomes were similar between both groups. These findings suggest that treatment decisions for pediatric proximal humerus fractures should be individualized based on patient age, fracture displacement, and functional expectations. Both surgical and non-surgical treatments can yield satisfactory outcomes in the long term.

Keywords: Fracture; nonoperative treatment; operative treatment; pediatrics; proximal humerus; skeletally immature.

Proximal humerus fractures are rare fracture types seen in approximately 2–4% of the pediatric age group[1,2]. These fractures, which are more common between the ages of 10–14, occur due to high-energy traumas such as falls from heights and traffic accidents[3,4]. The most important feature of this region is that it is effective in approximately 70–80% of the longitudinal growth of the arm[1,5]. This feature provides the proximal humerus with a high remodeling ability[6].

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Serious angulation and displacement do not occur in the majority of pediatric proximal humerus fractures[1,2,5]. Due to the high remodeling of this region, non-surgical treatment is usually applied to fractures in this region[1,2,5,7,8]. However, there is ongoing debate in the literature regarding the treatment protocol to be used in fractures with excessive angulation and displacement (Neer–Horowitz type 3–4), especially in older pediatric patients with incomplete skeletal maturation[5,6]. Since the remodeling ability in this age group is reduced compared to younger ages, there is still no clear consensus on the need for surgical intervention, despite the increase[2,9,10]. While some researchers recommend non-surgical treatment, relying on the high remodeling ability of childhood, another group of researchers recommends surgical treatment, arguing that non-surgical treatment causes functional disability, pain, and dissatisfaction in older children and adolescents[9,11]. There are not enough studies on this subject, which is still a subject of debate in the literature, and the majority of studies are in the form of case series[2,8,12,13]. However, due to the scarcity of comparative, prospectively designed and long-term follow-up studies in the literature on this subject, especially in older children, a clear approach to treatment preferences has not been developed.

This study aims to provide evidence to guide treatment decisions by comparing the clinical and functional outcomes of surgical and non-surgical treatment methods in pediatric patients with Neer–Horowitz type 3–4 proximal humerus fractures.

Materials and Methods

This study was designed as a retrospective cohort study conducted in a tertiary care university hospital, in accordance with the Declaration of Helsinki, and was reported in compliance with the STROBE guidelines. Local ethics committee approval was obtained before starting the study (Date: 24.05.2022, No: 2022/5-9). Our hospital's digital data system was examined, and patients who applied to the emergency department and outpatient clinics with a diagnosis of proximal humerus fracture under the age of 15 between January 2015 and December 2021 were retrospectively evaluated. Among these patients, those aged 15 and under with type 3–4 fractures according to the Neer–Horowitz classification were identified[11]. As a result of the examination, 67 patients were identified.

Inclusion criteria:

1. Those with Neer–Horowitz type 3–4 proximal humerus fractures,
2. Those under the age of 15 with incomplete skeletal maturation,
3. Those with shoulder joint anteroposterior (AP) radiographs at the time of initial presentation, and at the 3rd and 12th months after the fracture,
4. Those with at least one year of follow-up.

Exclusion criteria:

1. Those with less than 1-year follow-up (n=6),
2. Pathological fracture (n=3),
3. Open fracture (n=2),
4. Those without AP radiographs of the shoulder joint at the time of initial application and at the 3rd and 12th months after the fracture (n=4).

After excluding 15 patients with the exclusion criteria, the remaining 52 patients were included in the study (Fig. 1). These patients were divided into two groups: those treated non-surgically and those treated surgically. Group 1 consisted of 22 patients treated non-surgically, and Group 2 consisted of 30 patients treated surgically.

In the non-surgically treated patients, the patient's refusal to accept surgical treatment or the surgeon's decision to treat non-surgically was effective in determining the treatment option (Fig. 2). This non-randomized grouping carries a potential risk of selection bias. To minimize this,

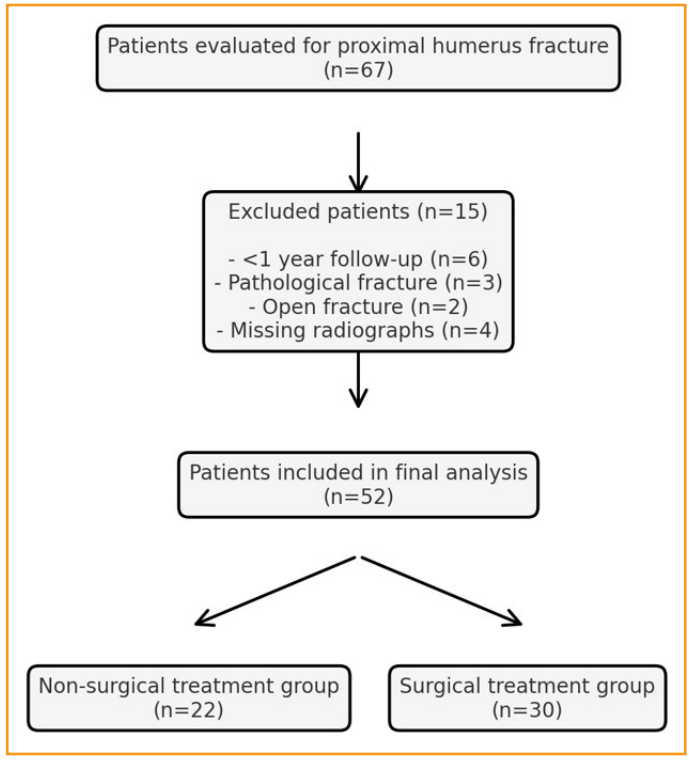

Figure 1. Flow diagram of patients' selection.

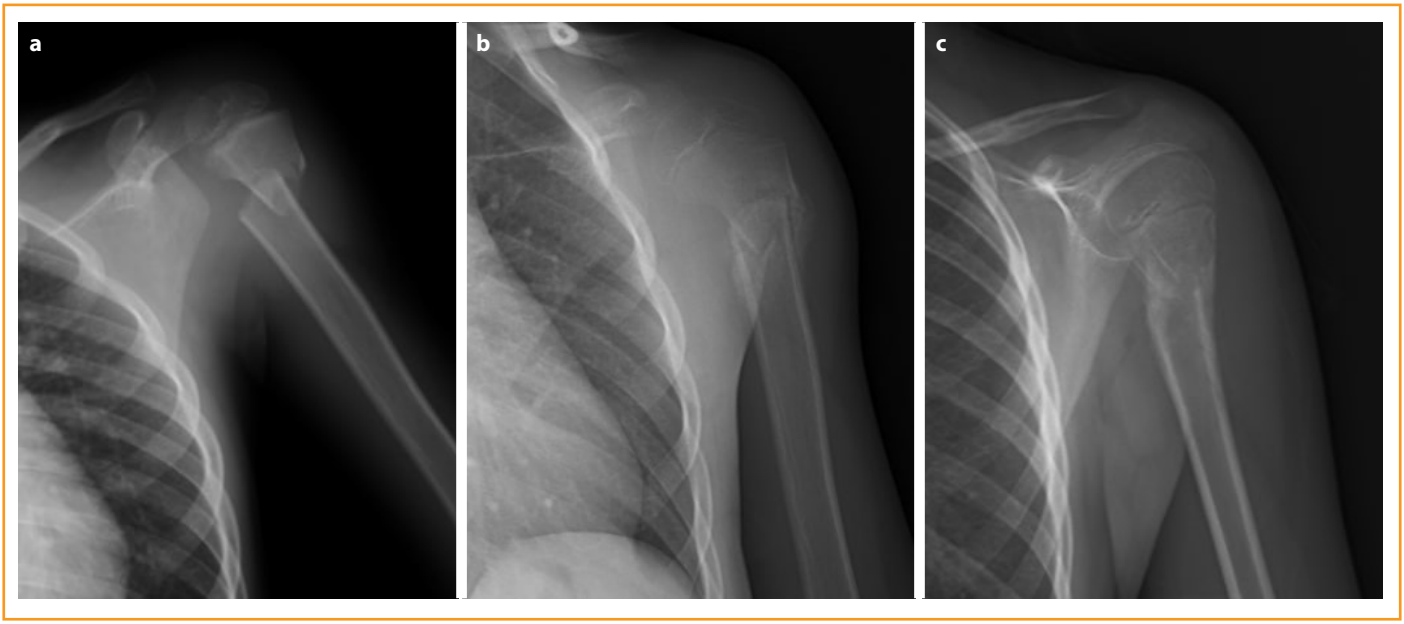

Figure 2. The radiographs show a 7-year-old male child who underwent non-surgical treatment for a proximal humerus fracture sustained during a fall from a swing. **(a)** Radiographs taken at the time of the initial injury. **(b)** Radiographs taken six weeks after the injury. **(c)** Radiographs taken six months after the injury. At the final follow-up, the patient reported full and painless range of motion

key demographic and clinical variables such as age and initial angulation were compared between groups. In the non-surgically treated group, patients were managed with shoulder arm slings for 4 weeks without attempting closed reduction. No closed reduction maneuver was performed, as the treatment plan was based on the expectation of remodeling potential in skeletally immature patients. No additional casting or splinting methods such as hanging casts or plaster immobilization were applied.

All patients in Group 2 who were treated surgically were operated on under general anesthesia, and 75 mg/kg cefazolin sodium prophylaxis was administered before the operation. After the reduction was achieved with open or closed intervention, fixation was performed using 2 or 3 1.6–2.0 mm Kirschner (K) wires (Fig. 3). The K wires were removed in the outpatient clinic in the 4th week postoperatively. In both groups, immobilization was performed with a shoulder arm sling for the first 4 weeks after the fracture. After the 4th week, the shoulder arm sling was removed, and passive and active motion was started.

The hospital's digital data system was examined, and data regarding the patient's age, gender, affected side, and follow-up period were collected. In the radiological evaluation, AP radiographs of the shoulder joint taken at the first application and at the 3rd and 12th months after the fracture were used. In these radiographs, the amount of angulation in the fracture area at the time of the first application and at the 3rd and 12th months after the fracture was evaluated[14]. All shoulder joint AP radiographs were digitized with Picture Archiving Communication System (PACS) software (PiViewStar®; Infinit Technology, Seoul, Korea), and a digital protractor with 1/1000 precision provided by the software and other measuring instruments was used for all measurements. QuickDASH scores calculated at the 3rd and 12th month post-fracture examinations were used to evaluate the functional outcomes of the patients. The validated Turkish version of the QuickDASH questionnaire was used. Questionnaires were administered face-to-face by a trained physiotherapist during routine follow-up visits. Incomplete items were managed in accordance with QuickDASH guidelines. QuickDASH score, a functional outcome measure, is a scoring system used to measure physical function and symptoms in patients with upper extremity musculoskeletal disorders[15]. The scale consists of 11 questions, and each question is scored between 1 and 5. Scoring ranges from 0 (no disability) to 100 (maximum disability). Lower QuickDASH scores indicate that patients are functionally better off.

Statistical Analysis

IBM SPSS 25.0 (IBM Corp., Armonk, NY, USA) software was used for statistical analysis. Descriptive statistical methods (mean, standard deviation, frequency, minimum, maximum) were used to evaluate the data, and the data were summarized. Shapiro–Wilk test was used for normality

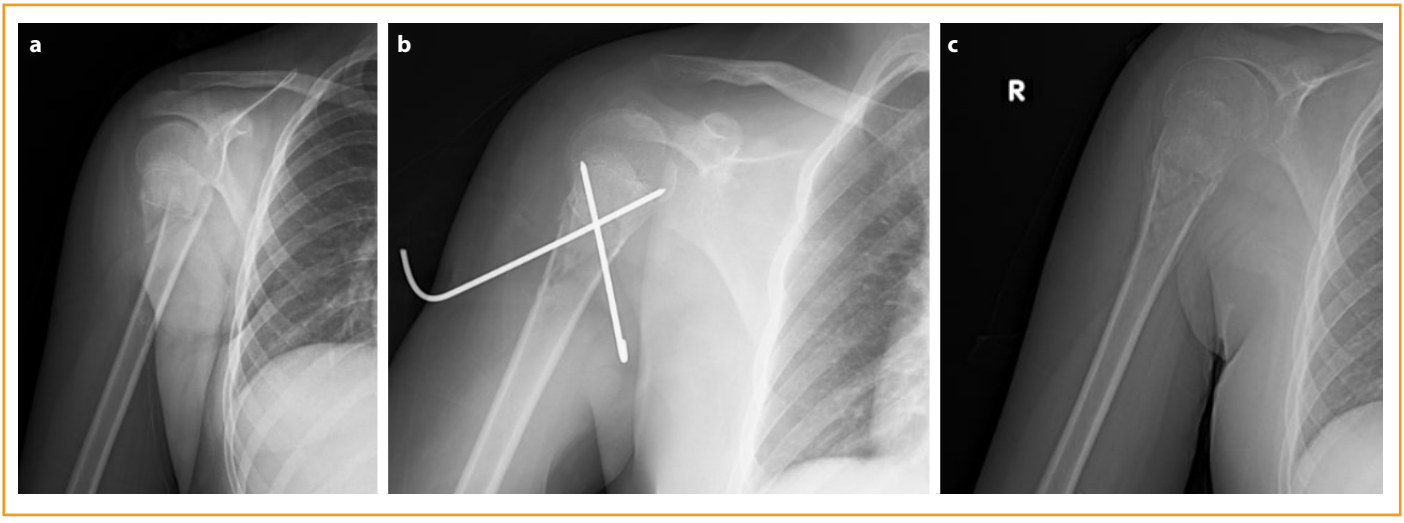

Figure 3. The radiographs show a 8-year-old female child who underwent surgery for a proximal humerus fracture caused by a simple fall. **(a)** Radiographs taken at the time of the initial injury. **(b)** Radiographs taken ten days after the injury. **(c)** Radiographs taken three months after the injury, following the removal of Kirschner wires. At the final follow-up, the patient reported full and painless range of motion.

tests of continuous variables, and Pearson Chi-square independence test was used to test the independence between two categorical variables. Mann–Whitney U test was used to compare data that did not show normal distribution, and Independent Samples t test was used for those that showed normal distribution. $p<0.05$ values were considered statistically significant.

Results

Fifty-two patients were included in the study. Thirty-two (61.5%) patients were male, and 20 (38.5%) patients were female. The mean age was 10.35±3.3 years. The data obtained as a result of the comparison of the demographic parameters of the patients between the groups are shown in Table 1. Accordingly, no significant difference was found in the analyses made between the groups in terms of age, gender, affected side, fracture classification, and follow-up period. Although the difference was not statistically significant, there appears to be a trend toward higher mean age in patients who underwent surgical treatment compared to those who received non-surgical treatment.

Table 1. Characteristics of patients

	Non-surgical Group n=22	Surgical group n=30	p
Age	9.41±2.91	11.03±3.44	0.052
Gender			
Female (n, %)	10 (45.5)	11 (36.7)	0.375
Male (n, %)	12 (54.5)	19 (63.3)	
Side			
Left (n, %)	12 (54.5)	15 (50)	0.746
Right (n, %)	10 (45.5)	15 (50)	
Neer-Horowitz classification			
Type 3 (n, %)	8 (36.4)	12 (40)	0.790
Type 4 (n, %)	14 (63.6)	18 (60)	
Follow up time (month)	30.50±16.97	44.53±26.91	0.061

The results of the comparison of the fracture displacement amount at the first application and the 3rd and 12th months after the fracture are shown in Table 2. In addition, the

Table 2. Comparison of the change in fracture angulation and QuickDash score averages between the two groups

	Non-surgical Group n=22	Surgical group n=30	p
Angulation of the fracture (degree)	21.32±8.82	36.43±18.13	0.001
Angulation 3 months after fracture (degree)	15.27±12.46	2.43±4.44	0.001
Angulation 12 months after fracture (degree)	1.86±1.44	1.6±1.3	0.436
QuickDash score 3 months after fracture	37.39±10.06	25.83±6.58	0.001
QuickDash score 12 months after fracture	1.55±4.98	1.06±3.08	0.914

results of the comparison of the QuickDASH score means at the 3rd and 12th months after the fracture are shown in Table 2. Accordingly, it was determined that the amount of angulation at the first application was higher in the patients in the surgical group than in the non-surgical group (p=0.001). The amount of angulation at 3 months after fracture was found to be statistically significantly lower in patients who underwent surgery (p=0.001). No significant difference was found between the groups at 12 months after fracture. Similar results were obtained in QuickDASH score results. The mean QuickDASH scores at 3 months after fracture were found to be significantly lower in the surgery group (p=0.001). However, there was no significant difference between the two groups at 12 months after fracture.

Discussion

This study aimed to compare the functional and clinical outcomes in patients treated non-surgically and surgically for Neer–Horowitz type 3–4 pediatric proximal humerus fractures. As a result of the analyses performed for this purpose, some important results were obtained. Although there was no statistically significant difference between the groups in terms of age, it was determined that the mean age of patients who underwent surgery was significantly higher. It was determined that the fracture angulation at first presentation was higher in the surgical group and that there was a statistically significant decrease in fracture angulation in this group compared to the non-surgical group at 3 months after the fracture. However, it was observed that the difference between the groups disappeared at 12 months after the fracture. Another important result was in the QuickDASH scores. While the QuickDASH score was lower in the surgical group at 3 months after the fracture, no significant difference was found between the groups at 12 months after the fracture. Although QuickDASH scores at 3 months were statistically significantly lower in the surgical group, it is not clear whether this difference exceeds the threshold of clinical significance (Minimal Clinically Important Difference–MCID). Therefore, the impact of statistical significance on clinical practice should be carefully evaluated.

Proximal humerus fractures are one of the fracture types that are rarely seen in the pediatric age group[8,16,17]. The most common mechanism of injury is falling backward with the arm extended[4]. Although it usually occurs as a result of sports injuries in adolescence, high-energy traumas in particular are the most important causes[3,8,18]. The very high remodeling ability of the proximal humerus region has caused discussions on the determination of the treatment method to be applied in these fractures[18-20]. Some studies have shown that excellent results are obtained when non-surgical treatment is applied to Neer–Horowitz type 1 and 2 fractures[5,8,21,22]. For this reason, non-surgical treatment is widely accepted especially in young pediatric patients with low displacement[9,18]. In addition, studies on this subject in recent years have focused on the evaluation of the results in older children with decreased remodeling and patients with high displacement[5,9,20,23,24]. In light of the literature data, the general opinion in deciding on surgical treatment is the increase in age and the amount of displacement[1,5,7].

Chaus et al.[2] reported a higher rate of poor results in patients aged 12 and over in their study. It is possible to come across other studies with similar results recently[5,22]. Bahr et al.[5] treated all Neer–Horowitz type 3–4 proximal humerus fractures surgically and did not encounter any complications. Song et al.[9] showed that age is one of the most important factors determining surgical treatment and that severe displacement in fractures leads to surgical treatment. The surgical treatment rate was determined as 60% in proximal humerus fractures with severe displacement (Neer–Horowitz type 3–4). The mean age in our study was determined as 10.35±3.3. No significant difference was found in the comparison of mean ages between the groups. However, it was observed that the mean age of patients in the surgical group (11.03±3.44) was significantly higher than those in the non-surgical treatment group (9.41±2.91). The higher mean age in the surgically treated group suggests that the age factor plays a determining role in the clinical decision process. This may lead to a preference for surgery due to decreased remodeling capacity and increased risk of malunion at older ages.

The increase in angulation is another important parameter in making a surgical decision in pediatric proximal humerus fractures[19]. There is an increase in the number of studies recommending surgery in patients with increased angulation and displacement before surgery and inadequate correction after reduction[9,18,19]. Beringer et al.[21] showed the importance of anatomic reduction in older children in their study. It was emphasized that non-surgical treatment in patients in this age group may cause undesirable results. Other studies have also documented in the literature that non-surgical treatment causes permanent deformities, especially in older patients[5,11,21]. It was found that there was a shortening of 0.5–0.7 cm in the humerus length after non-surgical treatment in

Neer–Horowitz type 3–4 patients[11]. Although there was correction with angular deformity, Baxter et al.[25] showed that there was no decrease in patient satisfaction in such patients. In one of the meta-analyses conducted in recent years, it was determined that better results were obtained after surgical treatment in proximal humerus fractures with high displacement[26].

In our study, it was shown that the fracture angulation amount was higher in the surgical group patients at the time of first application. This result is consistent with the literature data. We think that the increase in fracture angulation affects surgical decision-making. Another important result we found in our study is related to the change in angulation amounts in the 3rd and 12th months after the fracture. Accordingly, although there was a significant decrease in the amount of angulation in the group that underwent surgery at 3 months after the fracture, no significant difference was found at 12 months after the fracture. In patients who underwent surgery, inadequate immobilization in patients who underwent non-surgical treatment may affect the radiological evaluation at 3 months after the fracture. In addition, we believe that the significant difference between the groups 12 months after the fracture disappeared as a result of the very high remodeling ability in the proximal humerus.

In recent years, there has been a tendency toward more surgical treatment for all types of fractures in the pediatric age group[2,8]. This situation has become more common, especially in the elderly pediatric patient group[2]. One of the most important reasons for this is the desire to increase functional results[4,18,27]. Proximal humerus fractures are also one of these fractures where the tendency for surgery has increased[2]. According to some publications, the preference for non-surgical treatment after fracture, especially in the elderly pediatric patient group, negatively affects the functional result[9,18,23]. However, it is also possible to come across studies claiming the opposite.[9,18] In the study conducted by Chaus et al.[2] comparing surgical and non-surgical treatment in Neer–Horowitz type 3–4 humerus proximal fractures, they did not find any difference in functional results between the two groups. Bahrs et al.[5] also showed that high Constant scores were obtained in patients who received non-surgical treatment.

In our study, the mean QuickDASH scores at 3 months after the fracture were significantly lower in the surgical group. However, no significant difference was found between the two groups at 12 months after the fracture. We think that the more angular union of the patients in the non-surgically treated group and the fact that the patients started moving later affected the functional results at 3 months after the fracture. Based on the findings of this study, while surgical treatment may be preferred in pediatric proximal humerus fractures with advanced age and high-degree displacement, non-surgical treatment remains an effective alternative considering long-term outcomes. Therefore, the treatment decision should be individualized by taking into account the patient's age, fracture type, and degree of angulation.

In our study, non-surgical treatment was performed without closed reduction, relying on the remodeling capacity of the proximal humerus. Shoulder arm slings were used for immobilization, and no additional casting or splinting methods were employed. The absence of reduction maneuvers might have influenced the angulation outcomes in the early follow-up period. However, long-term results showed comparable outcomes between both groups, suggesting that this minimal approach may still be sufficient in selected pediatric patients.

This study has some limitations. Firstly, the retrospective design of the study increases the risk of selection and information bias in patient selection and data collection. Secondly, although the mean follow-up period was over 2 years, this period may not be sufficient in terms of growth plate-related deformities or functional problems that may be seen in pediatric patients in the long term. Because of the high remodeling capacity of the proximal humerus, long-term follow-up is important for a better evaluation of the results. Another limitation is the relatively small sample size. Finally, all radiologic measurements were performed by a single observer. This may limit the objectivity and reliability of the measurements. Despite all these limitations, we believe that our study contributes to this field where there are few comparative studies in the literature. Especially focusing on Neer–Horowitz type 3–4 fractures with high angulation and displacement, homogenization of the patient group and evaluation of functional outcomes are important contributions. However, in order to make stronger conclusions on this subject in the future, prospectively designed, multicenter studies with larger samples and long-term follow-up are needed.

Conclusion

In conclusion, although surgical treatment may provide faster radiological and functional recovery in the early period for pediatric Neer–Horowitz type III–IV proximal humerus fractures, long-term outcomes appear comparable between surgical and non-surgical approaches. These findings

highlight that treatment decisions should be individualized, considering patient age, fracture displacement, and functional expectations. Both treatment modalities can achieve satisfactory outcomes, and clinicians should tailor the management strategy based on patient-specific factors. Our results contribute to guiding clinical decision-making in this still-debated area of pediatric orthopedics.

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Conflict of Interest: The authors declare that there is no conflict of interest.

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