Influence of Ulnar Bow Sign on Surgical Treatment of Missed Bado Type I Monteggia Fracture in Children

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Research article

Keywords: children, missed Monteggia fracture, ulnar bow sign

Posted Date: November 23rd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-101496/v1

Abstract

Purpose

The present study aimed to explore the influence of ulnar bow on the surgical treatment of Bado type I missed Monteggia fracture in children.

Methods

This study is a retrospective review of 24 patients between November 2010 and March 2019. All patients were treated with open reduction of the radial head and ulnar opening wedge osteotomy without annular ligament reconstruction. The mean interval between injury onset and surgery was five months (range: 2–12 months). The average age of participants at the time of surgery was 6.4 years (range: 3–10 years). We evaluated the maximum ulnar bow (MUB) and MUB position (P-MUB) via radiography. The patients were divided into middle group (group A: 14 cases, MUB located at 40% to 60% of the distal ulna) and distal group (group B: 10 cases, MUB located at 20% to 40% from the distal end of the ulna) based on P-MUB. The mean period of follow-up was 37 months (range: 6–102 months).

Results

At the last follow-up, all the children showed stable reduction of the radial head, and the flexion function of elbow joint improved after operation ($P<0.05$). Group A presented a larger the ratio of maximum ulnar bow(R-MUB) and angle of ulnar osteotomy(OA) than group B ($P<0.05$). There was statistically significant difference between group A and Group B in the P-MUB ($P < 0.05$). The osteotomy angle was positively correlated with the R-MUB (R^2 =0.497,P=0.013), The osteotomy angle was positively correlated with the P-MUB (R^2=0.731,P=0.000), The R-MUB is proportional to the P-MUB (R^2 =0.597,P=0.002). The regression equation of P-MUB and osteotomy angle: Angle=7.064+33.227* P-MUB (R^2=0.459, P =0.000).

Conclusion

When the ulnar bow is positioned at the middle ulna, a stable reduction of radial head need to be achieved through a larger angle in the ulnar osteotomy. If the position of maximum ulnar bow (P-MUB) is closer to the middle of the ulna or the ratio of maximum ulnar bow (R-MUB) is larger, the osteotomy angle is larger.

Background

Missed Bado type I Monteggia fracture is characterised by an arcuate curvature of the metacarpal side of the ulna and anterior dislocation of the radial head. Bado type I is the most commonly missed Monteggia fracture, which easily causes elbow bulge or cubitus valgus deformity, limited elbow movement, joint instability, joint pain of different degrees and secondary nerve paralysis. Therefore, we advocate active surgical treatment. At present, the humeroradial joint open reduction and ulnar opening wedge osteotomy with or without annular ligament reconstruction have become the preferred clinical treatments of missed

Monteggia fracture in children[[1]]. However, radial head dislocation and forearm rotation limitation are still the most common complications in the surgical treatment of neglected Monteggia lesion. At present, an effective measure to prevent postoperative complications is by angulation in the opposite direction after ulnar osteotomy.

In 1994, Lincoln[[2]] proposed the concept of ulnar bow sign, which implied that the forearm has been severely injured. For missed Monteggia fracture, the ulna has basically healed, and the bow sign is an important factor to measure the injury condition at this point. Hoon Park et al.[[3]] pointed out that the ulnar bow sign can be used as an indicator for the formulation of surgical strategy. They reported that stable reduction could be achieved through simple incision when the maximum ulnar bow is less than 3 mm and located at 40% of the distal ulna. The abovementioned results show that the ulnar bow sign can not only be used as the diagnostic basis of missed Monteggia fracture in children but also as an objective index to guide surgical treatment.

A study[[3]] had reported the relationship of ulnar bow sign with indication for ulnar osteotomy, however, there are few papers to explore the influence of the relationship between ulnar bow sign and ulnar osteotomy angle on the surgical operation. This study aimed to provide a predictive index for the preoperative planning, surgical efficacy and complication prevention in missed Monteggia fracture.

Methods

From November 2010 to March 2019, 24 children with Bado type I missed Monteggia fracture were treated by open radial head reduction and ulnar osteotomy without ligament reconstruction. A total of 18 males and 6 females, which included 9 left-sided and 15 right-sided fractures, were enrolled in the present study. The average time from injury to operation was five months (range: 2–12 months). The average age of children who underwent the operation was 6.4 years (range: 3–10 years), and the average follow-up time was 37 months (range: 6–102 months). Most children included the study consulted with a doctor because of elbow flexion and extension dysfunction or a hard mass in front of the elbow. Among these patients, two cases had 30° to 35° cubitus valgus deformity, and three cases featured a deep branch of radial nerve injury and limited wrist and thumb extension function without skin sensory disturbance. On the full-length lateral radiograph of the forearm, the radial head was dislocated forward, and the ulna was curved to the palmar side, indicating a positive Lincoln sign. In certain cases, calcification shadow around the radiocapitellar joint was observed. Computed Tomography (CT) and three-dimensional reconstruction showed that the radial head was discoid, and the radius was not extremely long. On the lateral radiograph of the forearm, we made a straight line between the olecranon and the distal ulnar metaphysis. The maximum vertical distance between the dorsal edge of the ulna and the straight line is defined as the maximum ulnar bow (MUB). To eliminate the influence of different X-ray proportion, we compared the size of MUB by the ratio of the maximum bow distance to the ulnar length (MUB ratio, R-MUB). Subsequently, the ratio of the distance from the largest arch to the distal ulna to the ulnar length (P-MUB) was used to express the position of MUB (Fig. 1).

Based on the P-MUB, the patients were divided into middle group (group A, 14 cases, 40–60% of P-MUB in distal ulna) and distal group (group B, 10 cases, 20–40% of P-MUB in distal ulna). We measured the MUB, ulnar angulation angle during operation, radial head stability after osteotomy and elbow joint function (Table 1).

Surgical Technique

All patients were treated via anterior and posterior approaches[[4]], and the radial head open reduction and fibrous scar resection were treated via anterior Henry's approach. The posterior approach was used for ulnar angulation and lengthening. In consideration of the anterior Henry's approach, we performed a skin incision parallel to the forearm, extending to 4–6 cm along the elbow. We cut along the gap between biceps brachii tendon and brachioradialis brachii muscle then recognised and protected the radial nerve in the deep muscle gap. Three children exhibited radial nerve paralysis symptoms. During the operation, the radial nerve was injured by compression. Neurolysis was performed immediately. After exposing the annular ligament, the radial head was dislocated and covered with fibrous scar tissue. The scar tissue was subsequently removed. Our study excluded the repair or reconstruction of the annular ligament. Proximal ulnar opening wedge osteotomy was performed using the posterior approach. The proximal part of the ulna was exposed by a 6 cm to 8 cm long incision on the ulnar side, and the transverse osteotomy was performed 4 cm to 5 cm below the ulnar olecranon. Afterward, we pressed the radial head backward under the direct vision of the anterior approach to obtain a fully reset. Afterward, we rotated the forearm and repositioned the radial head to guide the final position of the ulna. At this time, the radial head was reduced, and stability was evaluated. K-wire was used temporarily in the case of unstable radial head reduction. Osteotomy was fixed with a pre-curved steel plate. C-arm fluoroscopy was used to confirm the position of radial head and the correct fixation of steel plate and screw. If necessary, iliac bone transplantation should be performed.

Postoperative management

The elbow joint was fixed in flexion position and forearm neutral position or supination position by long arm plaster post bracket. About 3-6weeks after the operation, the anteroposterior and lateral X-ray of elbow joint were reviewed, the Kirschner pin was pulled out, and the plaster was removed. Afterward, periodic re-examination was conducted to observe whether any redislocation and functional recovery occurred. About 6–12 months after the operation, the steel plate can be removed when the X-ray showed the bony healing of the osteotomy end.

Temporary fixation with K-wire

In two cases, subluxation was observed within 2 weeks after operation, and the patients were sent to the operating room for temporary fixation with K wire of the radiocapitellar. All the patients fixed with K wire showed no complications, such as K-wire fracture and nail infection, and achieved good elbow joint function.

Statistical analysis

SPSS 19.0 was used for statistical. We compared the flexion and extension of elbow joint and the rotation range of the forearm before and after operation via paired t-test. The independent sample t-test and chi-square test were used to compare the two groups. Linear regression was used to analyze the factors affecting the osteotomy Angle. $P \leq 0.05$ was considered statistically significant.

Results

The mean follow-up time was 37 months (range: 6–102 months) in 24 children. The mean posterior angle of ulna during the operation was 20°. The postoperative incisions were all healed in one stage. No delayed union nor nonunion at the osteotomy site, no plate loosening nor broken and no K wire fracture nor nail channel infection was observed. X-ray in the last follow-up showed that the radial head was in place without dislocation or subluxation. The elbow joint functions of all children improved, especially the flexion and extension functions. The elbow flexion increased from 114° before operation to 137° after operation ($P < 0.001$). Forearm rotation function was decreased. However, no statistical significance was noted ($P > 0.05$) (Table 2). In the present study, three children with radial nerve injury before operation were noted, and these patients underwent exploration and release during operation. The finger extension function improved after operation and recovered completely 3–4 months after operation.

MUB and the osteotomy angle

The average R-MUB of 24 children was 0.037 (range: 0.011 to 0.086), with the average values reaching 0.044 for group A (range: 0.014 to 0.086) and 0.028 for group B (range: 0.011 to 0.051). The P-MUB of group A was smaller than that of group B ($P < 0.05$). The average ulnar osteotomy angle observed among the 24 children was 20.98° (range: 10° to 32°), while 24.64° (range: 17.0° to 32.0°) in group A and 15.60° (range: 12° to 22°) in group B ($P < 0.001$) (Table 3). A moderately high correlation was found between the P-MUB and the osteotomy angle (OA). ($r = 0.731$, $p = 0.000$). A moderately correlation was found between the R-MUB and OA. ($r = 0.497$, $p = 0.013$). Because the R-MUB had a good correlation with the OA, next, the R-MUB were used to calculate the linear regression equation of the OA. $OA = 32.98^{*}$ P-MUB + 7.173, $R^2 = 0.459$, $P = 0.000$. (Fig. 4).

Postoperative function

The flexion function of elbow joint in each group after operation improved significantly compared with that in pre-operation ($P < 0.05$) (Table 2). Group B exhibited slightly better flexion, extension and rotation functions than group A. However, no significant difference was noted (Table 3). The flexion and extension functions of the two groups significantly improved. The rotation function slightly decreased, and no statistically significant difference was observed (Table 4).

Discussion

In recent years, numerous reports have focused on the surgical treatment of Bado I type missed Monteggia fracture in children[[1],[5],[6],[7],[8]], and several articles have discussed the effect of surgery on

such condition. However, no researches are found to explore the influence of the relationship between ulnar bow sign and ulnar osteotomy angle on the surgical operation. The current paper aims to study above relationship on the surgical treatment of Bado I type missed Monteggia fracture in children.

Our data indicate that Angle formation of ulna in proximal ulnar osteotomy is related to the P-MUB and R-MUB. When the position of the ulnar bow sign is close to the middle of the ulna, then a larger angle is needed to achieve a stable reduction in the radial head, as shown in Figs. 4.

At present, the period from injury onset to surgery and the age of the child are widely accepted factors that influence surgical outcome. In addition to the above factors, accepted relevant articles are rarely reported. Oka et al. [[9]] noted that dislocation time reached more than three years, the ulnar and radial notch became shallow, and the shape of radial head changed from normal disc shape to flat to dome shape. Nakamura et al.[[10]] thought that the changes in osteoarthritis in young children were lighter than that in missed children, and such parameter is related to the time of dislocation. Wilkins[[11]] suggested that surgery should be performed within 12 years of age. In recent years, a growing number of researchers believe that surgery is better when the patient is younger than 10 years old, and when the dislocation is less than 12 months old [[12],[13]]. In the current study, the dislocation time of our selected cases were all within one year to eliminate the interference of dislocation time and age on the study. At the time of operation, the children were not over 10 years old, and no serious radial head deformity in imaging was present.

In 1994, Linclon[[2]] examined five children with radial head dislocation but without ulnar fracture and observed a straight line made between the olecranon and metaphysis of the distal end of the ulna on the lateral radiograph of the entire ulnar length. The maximum average distance from the dorsal edge of the ulna to the line was substantially greater than 1 mm (range: 3.9 ± 0.4 mm). Meanwhile, the values observed for the control group were all within 1 mm. Hence, the concept of ulnar arch sign was proposed. Given the rapid healing of children's fracture, the fracture line disappeared after 3 weeks, which left only the ulnar plastic deformation in the same direction as the radial head dislocation. The most common characteristic sign is the arch sign of ulna to the palmar side, that is, the Lincoln sign. Hoon Park[[3]] noted that when Lincoln's largest arch distance is small and located at the distal end of the ulna, a stable reduction can be achieved without ulnar osteotomy. They obtained satisfactory results by simple open reduction in five cases of children whose ulnar bow was inconspicuous and located at the distal ulna. Ulnar osteotomy is often needed when the MUB is greater than 3 mm and located at the proximal region. In the present study, we observed that the missed Bado type I Monteggia fractures in children were all accompanied with an ulnar bow sign located in the area 20–60% from the distal ulna. For areas within 40% of the distal ulna, we divided the cases into the middle and distal groups. When the bow sign is located in the middle part of the ulna, the maximum bow distance of the ulna is larger than that in the distal part. We speculate that this condition is related to the mechanism of injury. When a child is injured, with greater impact and closer fracture site to the end of ulna, an evident bowed sign forms at that point or appears eventually. The specific mechanism needs to be proven by biomechanical studies. In cases

with evident bow sign in the middle part of ulna, the angle formed during operation is larger than that in the cases with no remarkable bow sign located in the distal part of ulna. This finding is possibly related to the interosseous membrane injury. Reverse angulation of the ulnar osteotomy is performed mainly through the interosseous membrane traction to obtain a satisfactory location of the radial head. The angle of correction required during the operation depends on the tension of the antebrachial interosseous membrane[[14–19]]. The bow sign of ulna can well reflect the severity of injury. A prominent ulnar bow sign indicates considerable severity of the interosseous membrane injury. Hence, substantial reverse angulation of ulna is needed to turn the radial head.

All patients in the present study received ulnar osteotomy for the treatment of children's missed Bado type I Monteggia fracture. Several researchers[[14, 20, 21]] believe that the location of ulnar osteotomy should be at the proximal end of the ulna. The advantage of osteotomy in this setup is that this process can induce sufficient tension in the interosseous membrane to align the radial head in the correct anatomical position. All interosseous membranes should also be preserved to avoid limited forearm rotation. This finding is consistent with the osteotomy site in the present study. In this study, the rotation function of children after operation was slightly lost compared with that before operation. Group B presented a better rotation function than group A. However, no statistical difference was noted (Tables 2 and 3). Hsuan Yu[[13]] believed that the radial head deformity, which is gradually aggravated in the chronic course of the disease, is an important factor that limits forearm rotation. In the current study, the disease course of all the children was within one year. CT scan showed no notable radial head deformity. Thus, no significant loss of rotation function was noted in all the children after the operation. Complications of the ulnar opening wedge osteotomy included nonunion and fixation failure. Despite these complications, we believe that the stable reduction of the ulna ensures radial head reduction.Our research presents several limitations. This research is a retrospective study given the extremely low incidence of missed Monteggia fracture and our relatively small sample size (24 cases). Selection bias may be present, indicating the need for further verification by a larger sample size, multicentre study or prospective research. P-MUBAt present, limited reports have discussed these topics. The indication for osteotomy is difficult to establish, hence indicating the need for further research.

Conclusion

Despite these limitations, our data show that open reduction and ulnar osteotomy are reliable and effective methods for the treatment of missed Bado type I Monteggia fracture in children. The position of the maximum ulnar bow sign is an important parameter in surgical planning. When the ulnar bow is positioned at the middle ulna, a stable reduction of radial head need to be achieved through a larger angle in the ulnar osteotomy.

Abbreviations

MUB :maximum ulnar bow; P-MUB: MUB position; R-MUB:the ratio of maximum ulnar bow; CT: Computed Tomography; OA: angle of ulnar osteotomy.

Declarations

Ethics approval and consent to participate: The experimental protocol was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of the First Affiliated Hospital of Guangxi Medical University. Written informed consent was obtained from guardian participants.

Consent to publish: We obtained written consent from the patient of the participant before publishing this information.

Availability of data and materials: All the data needed to achieve the conclusion are presented in the paper.

Competing interests: The authors declare that they have no competing interests.

Funding: The authors were recipients of a workshop grant conceived, coordinated and submitted by DXF and LSJ from the Natural Science Foundation of Guangxi Province(2017GXNSFAA198305, 2018GXNSFBA281090).

Authors' contributions: LSJ and WTT prepared and revised the manuscript. HQ, LY, LRB and ZJM performed the data collection and analysis with WTT. XYF and WTT provides pathology assistance and picture editing work. DXF and XYF designed and supervised the overall study and revised the manuscript. All the authors have read and approved the manuscript.

Acknowledgements: Not applicable.

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Tables

Table 1. Data of Group A and B

	Group A	Group B	no. of patients	P value
Sex				
male	10	8	18	0.506
female	4	2	6	
Side				
Left	7	2	9	0.21
Right	7	8	15	
Age at Surgery(yr)	5.92±2.79	6.90±1.85	6.33±2.44	0.348
Delay to surgery(mo)	5.86±3.13	4.90±2.85	5.46±2.99	0.452
Follow-up time（mo）	41.42±22.87	31.40±16.15	37.25±20.58	0.248
P-MUB	0.50±0.07	0.29±0.06	0.42±0.12	**0.00**

P-MUB, the position of maximum ulnar bow

Table 2　Comparison of ROM (preoperative vs follow-up) in patients

	Preoperative□°□	Follow-up□°□	P value
Flexion	114.17±7.78	136.75±5.74	**□0.001**
Extension	1.21±5.31	1.75±4.15	0.278
Pronation	83.75±2.57	80.58±3.48	0.086
Supination	82.88±2.79	82.21±2.83	0.098
ROM, range of motion.			

Table 3. comparison between two group in Maximum distance of bow sign and Intraoperative ulnar osteotomy angle and Post-operation ROM

	Group A	Group B	P value
R-MUB	0.044±0.019	0.028±0.011	**0.03**
Intraoperative osteotomy angle	24.64±4.46	15.60±3.57	**□0.001**
Post-operation Flexion	134.60±4.06	138.29±6.38	0.132
Post-operation Extension	1.70±5.36	1.78±3.26	0.962
Post-operation Pronation	79.32±2.98	82.35±2.94	0.075
Post-operation Supination	82.56±4.97	83.89±5.31	0.458

Table 4. Comparison of two group in ROM (preoperative vs follow-up) in patients			
	Change in ROM□°□		P value
	A	B	
Flexion	+1.50±7.29	-0.80±7.16	0.52
Extension	+23.57±9.70	+21.20±6.59	0.45
Pronation	-3.43±5.11	-2.80±5.25	0.77
Supination	-1.21±3.04	+0.10±3.25	0.32

Figures

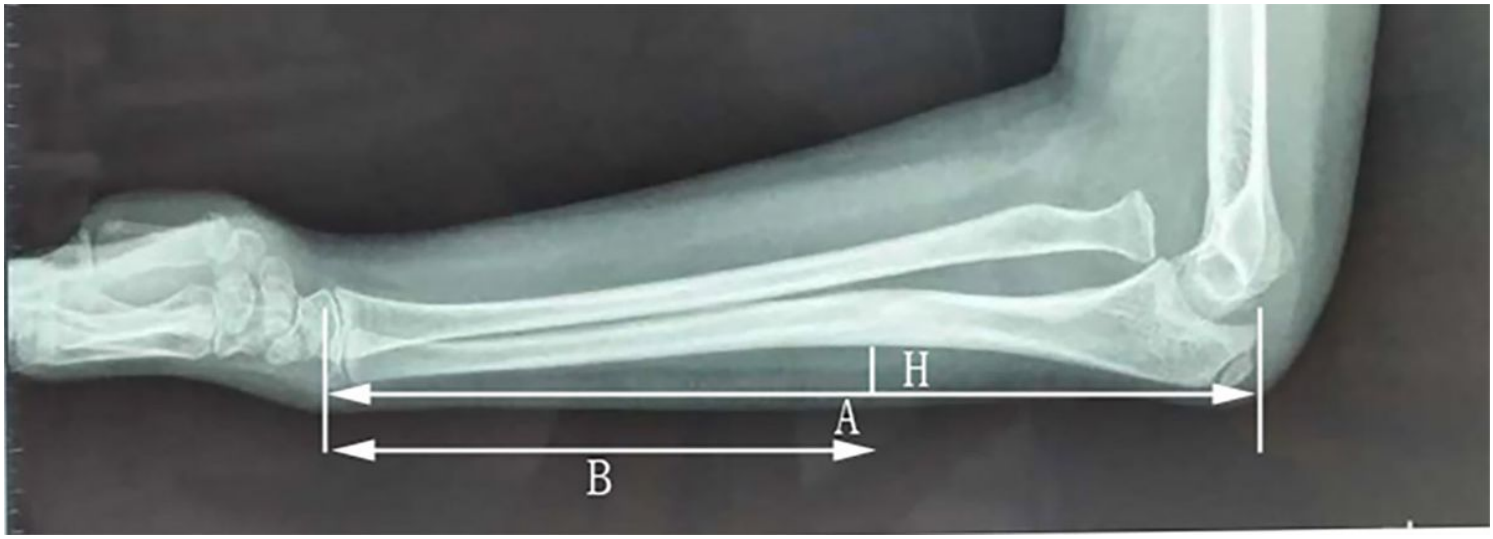

Figure 1

We make a straight line from the olecranon to the metaphysis of the distal ulna. The maximum vertical distance from the straight line to the dorsal edge of the ulna is the maximum arcuate distance of the ulna recorded as MUB (H), a is the distance from the olecranon to the epiphysis of the distal ulna, and B is the distance from the position of the maximum arcuate sign to the epiphysis of the distal ulna. The maximum bow ratio is recorded as R-MUB (H / A), and the position of the maximum bow distance is recorded as P-MUB (B / A).

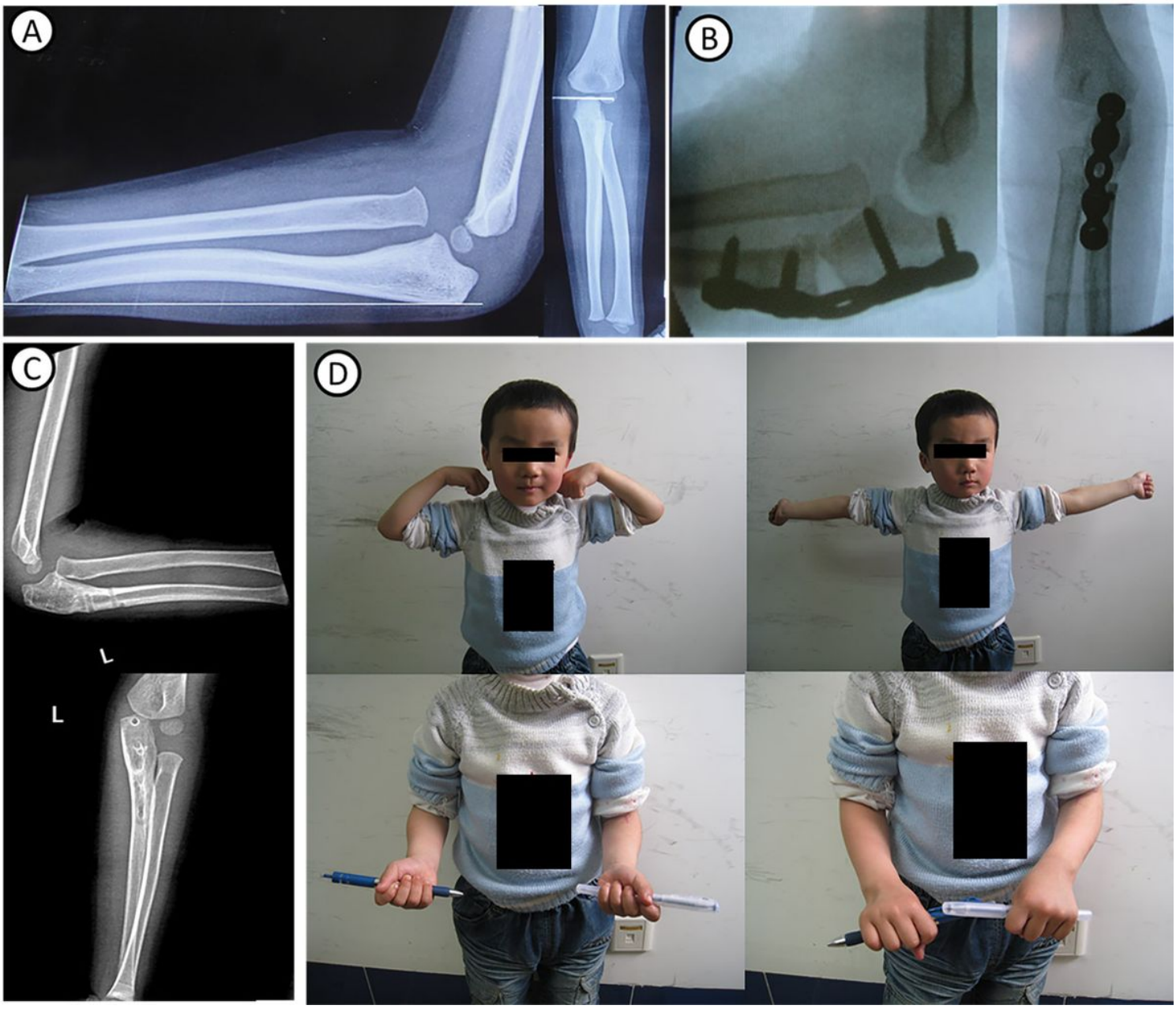

Figure 2

Typical case 1: A 3.5 years old boy, left missed Monteggia fracture. (A): Bado I type, ulna bow sign is located in the middle of ulna (group A). (B): in operation, reverse angulation is 24 °, radial head reduction. (C): There was no dislocation of the radial head after the osteotomy was healed and the internal fixation was removed. (D): elbow joint function is good after operation, no loss of rotation function.

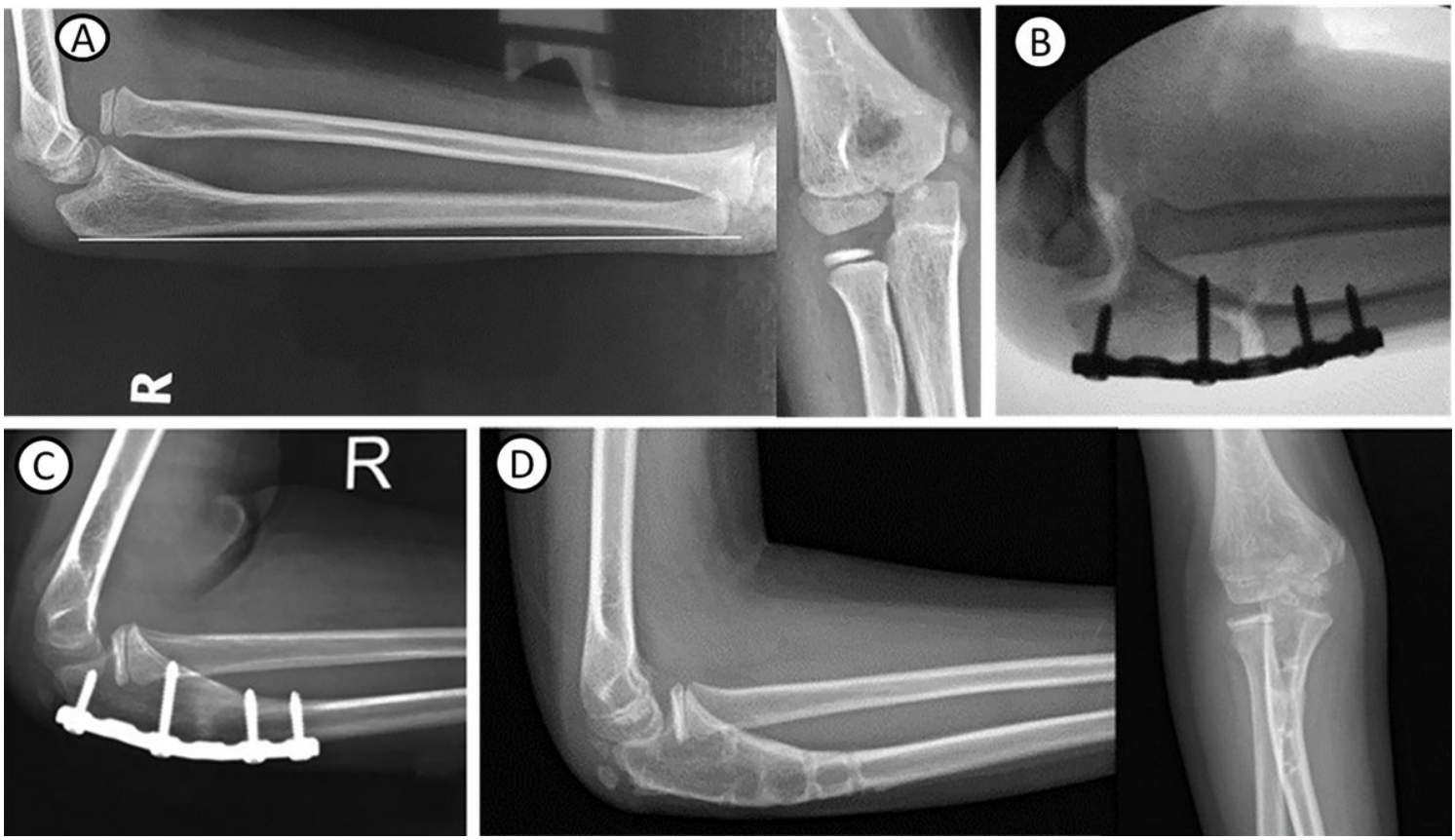

Figure 3

Typical case 2: A 8 years old boy, right missed Monteggia fracture. (A): Bado type I, ulna bow sign is located at the distal end of ulna (group B). (B): reverse angulation 12 ° during operation, radial head reduction. (C): 5 months after operation, radial head is in place, the osteotomy end has completely healed. (D): 1 year after operation, radial head is in place.

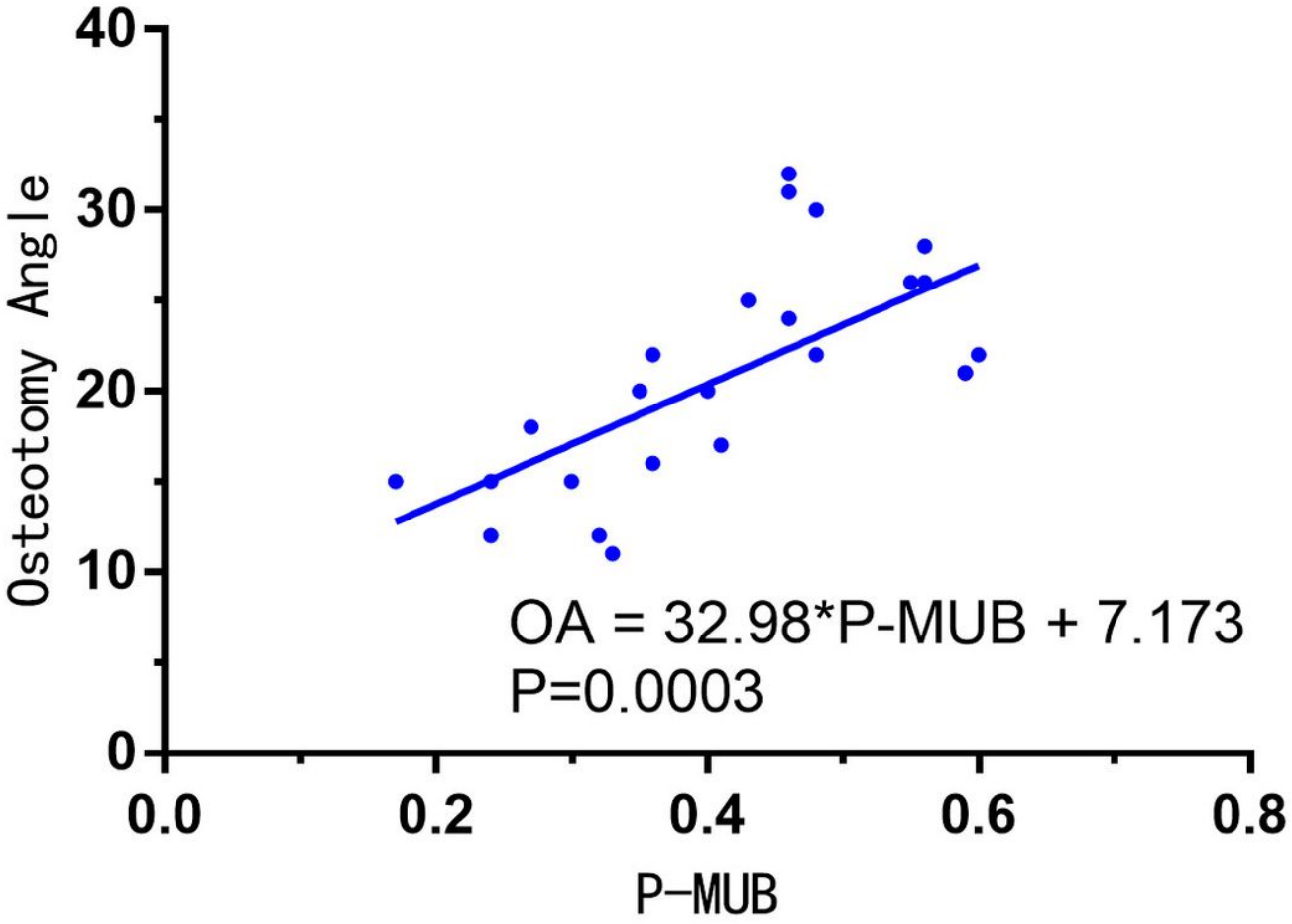

Figure 4

The linear regression equation. OA: the osteotomy angle. OA = 32.98* L-MUB + 7.173, R2 = 0.459, P=0.000.(Fig 2).