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Neural wedge osteotomy method of correction for cubitus varus deformity in children

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Abstract

In this study, we evaluated the clinical outcome of neutral wedge osteotomy assisted with the center of rotation of angulation (CORA) method of distal humerus anatomical axis for the treatment of cubitus varus deformity in children. From 2016 to 2019, 20 children with cubitus varus deformity after supracondylar fracture of the humerus were enrolled. Standard anteroposterior radiograph of the humerus was taken preoperatively. The CORA point and angulation angles were obtained by measuring the proximal and distal humerus anatomical axis. During the operation, neutral wedge osteotomy was performed to correct the varus deformity. The Baumann angle and the carrying angle were used to evaluate the correction effect of the distal humeral varus deformity. The average age of the patients was 7.8 years. Patients were followed up for an average of 29.3 months (range, 24–36 months). The average interval between surgery and injury was 12 months. The mean preoperative Baumann angle and carrying angle were 99° (90°–115°) and –14° (range, –10° to –30°), respectively. At the last follow-up, the mean Baumann angle and carrying angle was 76° (70°–80°) and 13.6° (10°–18°), respectively, with 16 cases showing excellent outcome and 4 cases showing good outcome. Our results indicated that the neutral wedge osteotomy assisted with CORA method of distal humerus anatomical axis showed good clinical outcomes in the treatment of cubitus varus deformity in children and is worthy of clinical application. The level of evidence is IV.

Abbreviations: CORA = center of rotation of angulation, DAA = distal anatomic axis, PAA = proximal anatomic axis, Post-op = postoperative.

Keywords: CORA, cubitus varus, neutral wedge osteotomy

1. Introduction

Cubitus varus deformity is a common late complication of supracondylar fractures of the humerus in children and is mostly correlated with the varus tilt caused by distal humeral fractures.[1] After cubitus varus, the alignment of the upper limb alignment is altered, which can lead to an increase in torsion and shear forces generated by the capitulum of humerus after trauma and easily cause secondary humeral lateral condyle fracture.[2] Moreover, cubitus varus often results in deformity in distal humerus rotation, but it can be compensated by the shoulder joint without causing serious consequences. In addition, some cases of cubitus varus deformity are accompanied by delayed ulnar nerve palsy.[3] The main reason that most patients with cubitus varus deformity seek surgical correction is to correct the appearance of the deformity.[4]

Most cubitus varus deformities in children are bony deformities, which cannot be reshaped with growth. Therefore, these deformities need to be corrected by osteotomy.[5] The currently used osteotomies include lateral closed wedge osteotomy,[6] medial open wedge osteotomy, step-cut osteotomy, and dome-shaped osteotomy.[7] At present, lateral closed wedge osteotomy is the simplest and most commonly used osteotomy method in clinical practice. However, this method leads to an inconsistent diameter of the proximal and distal ends of the osteotomy and results in obvious deformity of the distal humerus, which is manifested by the appearance of the steps of the distal humerus on imaging.[8] The center of rotation of angulation (CORA) method and the neutral wedge osteotomy are widely used in the correction of lower limb deformity[13]. With the assistance of CORA, the neutral wedge osteotomy corrects the varus deformity. In this osteotomy method, while correcting the alignment, the osteotomy end will not be offset and the limbs will not be shortened.

In this study, we aimed to evaluate the feasibility and clinical effect of the neutral wedge osteotomy assisted with CORA method of distal humerus anatomical axis for the treatment of cubitus varus deformity in children.

2. Materials and Methods

2.1. Patient enrollment

We enrolled 20 children with cubitus varus deformity after supracondylar fracture of the humerus that was treated by neutral wedge osteotomy assisted with CORA method between

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All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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March 2016 and 2019. The average age of the patients was 7.8 years (range 4–12 years). The average interval between surgery and injury was 12 months. This study was approved by the Institutional Research Ethics Committee of XXX (approval 2019LW017). Informed consent from the patients and their family was obtained. All demographic data related to patients were processed by XXX, and all surgical procedures were conducted by XXX.

2.2. Preoperative templating for the osteotomy

Before the operation, a standard anteroposterior radiograph of the bilateral humerus was taken. The line connecting the center points of the inner and outer cortical bones in any 2 planes of the proximal humerus is the proximal anatomic axis (PAA) of the humerus. A line was drawn along the epiphyseal plate of the lateral condyle of the humerus. The angle between the line and the PAA is the Baumann angle. Two lines were drawn parallel to the PAA along the inner and outer sides of the distal humerus, and the extension line of the lateral humerus epiphyseal plate intersects at points E and F. The EF center point was marked as O, and using OF as the baseline, the distal anatomic axis (DAA) was drawn with the Baumann angle of the contralateral side. The intersection of PAA and DAA is the CORA point, and the angle between PAA and DAA is the angle of distal humeral varus deformity, called Mag (Fig. 1). A distal osteotomy line was drawn through the CORA point parallel to the epiphyseal line of the lateral epicondyle of the humerus. A proximal osteotomy line was drawn with the CORA point as the vertex and the Mag angle as the included angle. The area between the proximal and distal osteotomy lines is the osteotomy area (Fig. 2). The CORA point is used as the center of rotation, and the distal end of the humerus can be turned outward to the osteotomy surface for anastomosis; 3 Kirschner wires are inserted through the lateral condyle of the humerus for fixation (Fig. 3).

2.3. Surgical technique

All patients were maintained in supine position and given intravenous and inhalation combined general anesthesia. A sterile tourniquet was used at the proximal end of the upper arm. A longitudinal incision was performed on the lateral of the elbow to expose the distal end of the humerus in the intermuscular space between the triceps and brachialis, and 2 Kirschner wires were inserted through the CORA point to mark the proximal and distal osteotomy lines with the help of C-arm fluoroscopy (Fig. 4). Next, the bone was cut along the proximal Kirschner wire to the CORA point using an oscillating/sagittal saw and the distal humeral osteotomy was then completed along the distal Kirschner wire. Then, the distal end of the humerus was turned outward to the osteotomy surface for anastomosis with the CORA point as the center of rotation, and 3 Kirschner wires were inserted through the lateral condyle of the humerus to fix the proximal and distal ends of the osteotomy. Finally, the Kirschner wire was placed externally, and the elbow was fixed with a plaster in the flexion position (Figs. 5 and 6). Figures 1 to 3 demonstrate a neutral wedge osteotomy with medial opening. However, we retained part of the medial cancellous bone during the intraoperative osteotomy and then miraculously found that there was no obvious opening phenomenon after the osteotomy. The surgical case in Figures 4 to 6 appears to demonstrate a neutral wedge osteotomy.

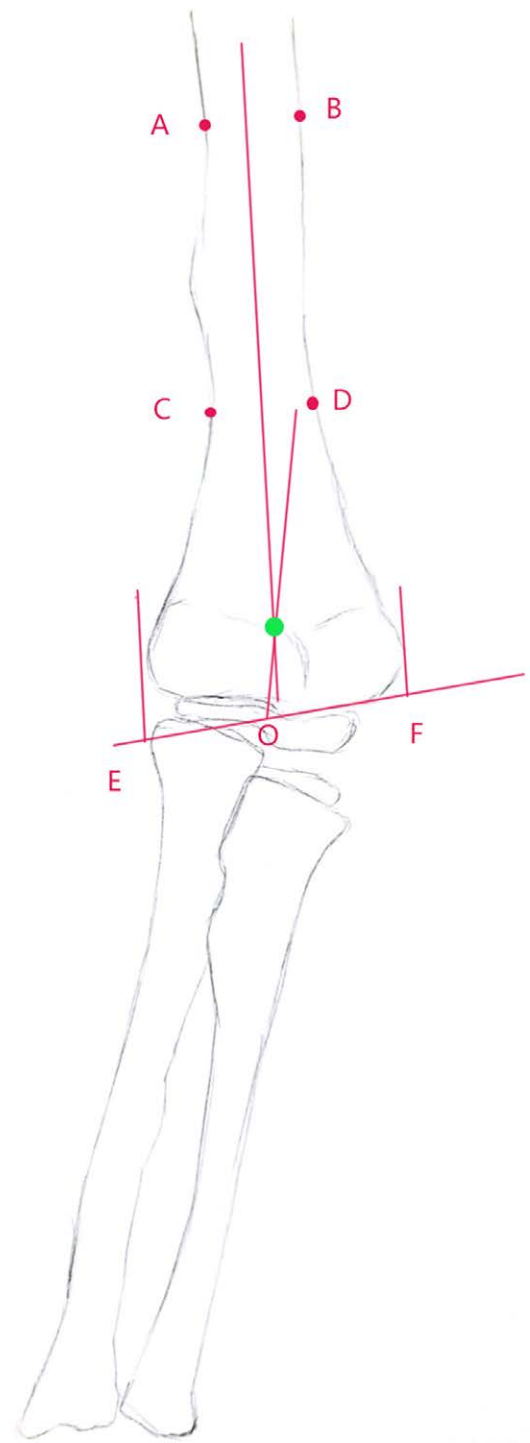

Figure 1. PAA was obtained by connecting the center points of the inner and outer cortical bones in any 2 planes of the proximal humerus. The Baumann angle is the angle between the PAA and the line along the epiphyseal plate of the lateral epicondyle of the humerus. DAA was obtained using the Baumann angle of the contralateral side. The intersection of PAA and DAA is the CORA point of the distal humeral varus deformity; the angle between the 2 axes is the cubitus varus deformity angle Mag. CORA = center of rotation of angulation, DAA = distal anatomic axis, PAA = proximal anatomic axis.

2.4. Postoperative management

After operation, the elbow of the patient was fixed with a cast in the flexion position. Tubular plaster was used for the younger group (<5 years), and posterior splint was used for the older group (>5 years). The new callus healed across the osteotomy line at an average of 1 month after the operation, and the plaster

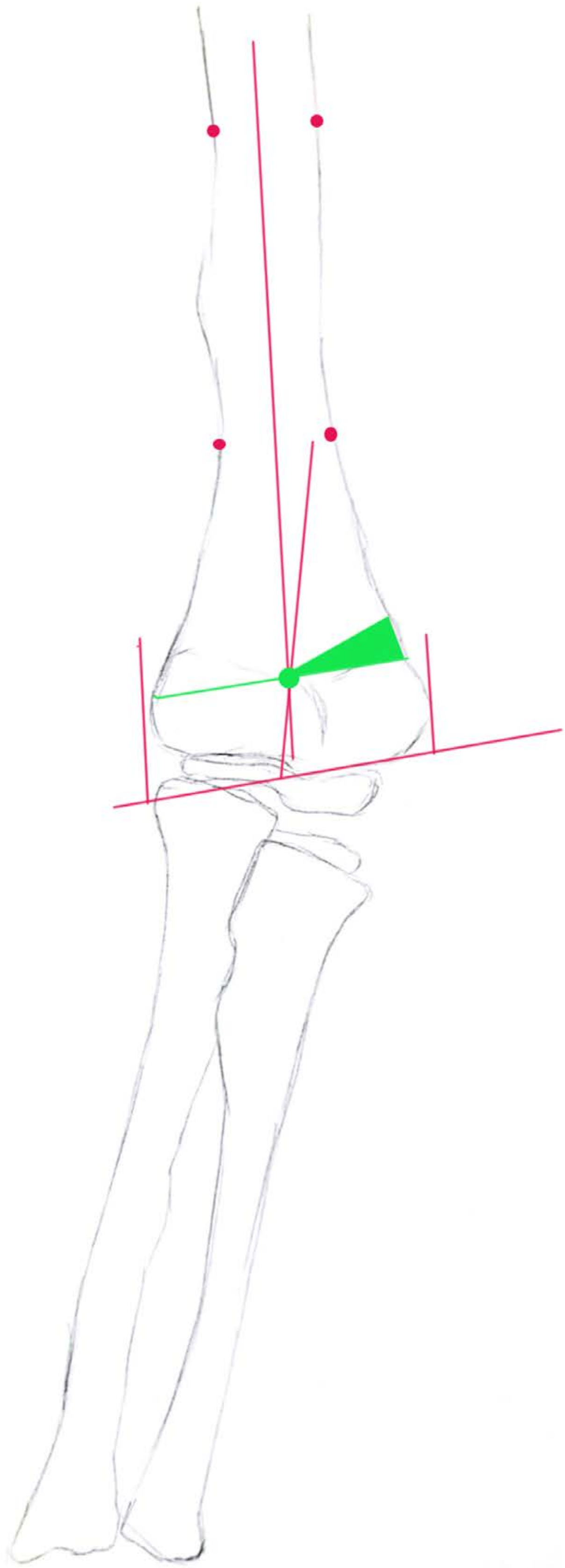

Figure 2. The distal osteotomy line was through the CORA point parallel to the epiphyseal line of the lateral epicondyle of the humerus. The proximal osteotomy line was obtained with the CORA point as the vertex and the Mag angle as the included angle. CORA = center of rotation of angulation.

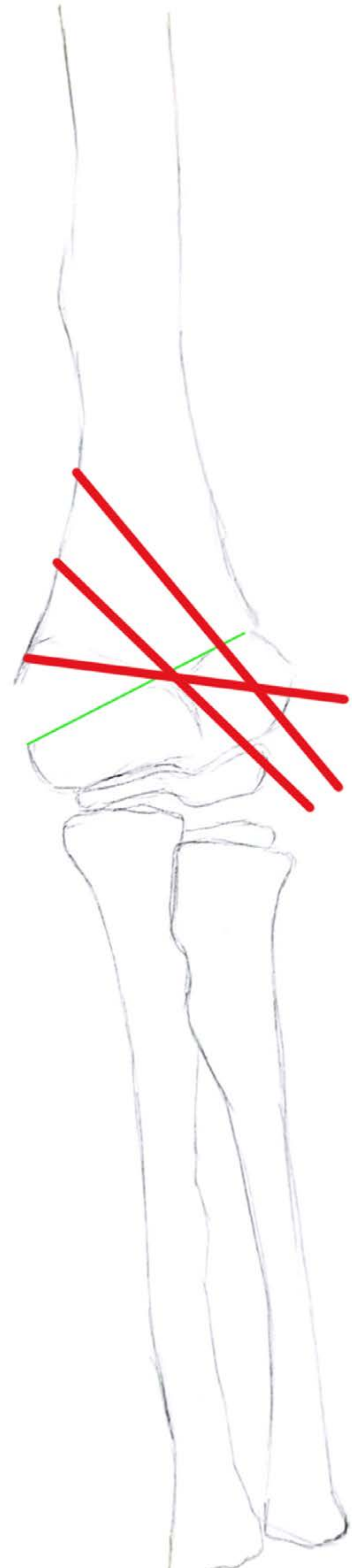

Figure 3. Taking the CORA point as the center of rotation, the distal end of the humerus was turned outward to the osteotomy surface to correct the cubitus varus deformity; 3 Kirschner wires were inserted through the lateral condyle of the humerus for fixation. CORA = center of rotation of angulation.

Figure 4. During the operation, 2 Kirschner wires were inserted to mark the proximal and distal osteotomy line.

and the Kirschner wire were removed. Functional exercise of the elbow joint was then initiated.

2.5. Follow-up and evaluation of clinical outcomes

Patients were followed up at 4 weeks, 3 months, 6 months, 1 year, and 2 years after the operation. Follow-up sessions mainly recorded the elbow joint flexion and extension function, postoperative scar and body surface carrying angle. On the second day, 4 weeks, 3 months, 6 months, 1 year, and 2 years after the operation, X-rays of the elbow joint were conducted and the carrying angle and Baumann angle were measured.

2.6. Statistical analysis

Using IBM SPSS 23.0 statistical software, the measurement data were first determined whether the data were normally distributed, in which the preoperative and postoperative carrying angle and Baumann angle were normally distributed. The homogeneity of variance was expressed as $x \pm s$, and 2 independent sample *t* tests were used for comparing the preoperative and postoperative *t* test. A *P* value of <.05 was considered statistically significant.

Figure 5. Osteotomy was performed parallel to the preoperatively marked proximal and distal osteotomy lines. The distal end of the humerus was turned outward, and crossed Kirschner wires were inserted for fixation.

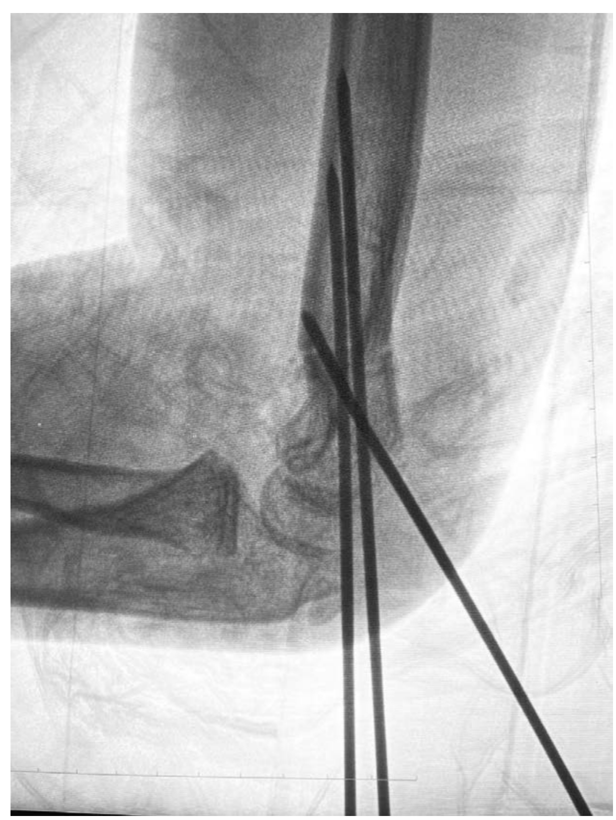

Figure 6. Lateral view of elbow joint after varus deformity correction and Kirschner wire fixation.

3. Results

3.1. Preoperative findings

The average age of the patients was 7.8 years. Patients were followed up for an average of 29.3 months (range 24–36 months). The average interval between surgery and injury was 12 months. The mean preoperative Baumann angle and carrying angle were 99° (range 90°–115°) and –14° (range –10° to –30°), respectively (Table 1).

3.2. Postoperative findings

All patients completed the final follow-up. Among the 20 patients, 16 patients had excellent outcome and 4 patients had good outcome. The elbow hyperextension of 8 patients was 5 degrees above neutral and close to normal, and the elbow hyperextension of the rest of the patients reached neutral. The elbow flexion of all patients was above 110°. The flexion of 5 patients flexion was <130°, while the elbow flexion of 15 patients was >130°, with an average of 133.1°. The mean postoperative Baumann angle and carrying angle was 76° (70°–80°) and 13.6° (10°–18°), respectively (Table 2). One patient whose varus was corrected for 40° during the operation experienced numbness and tingling in the ulnar nerve distribution area after the operation. These symptoms disappeared after 3 months of follow-up. No patients showed fixation failure or correction failure before removing the plaster and the Kirschner wire.

4. Discussion

The cubitus varus deformity in children, which cannot be reshaped with growth, is mostly caused by the excessive varus of the distal humerus after supracondylar fracture of the humerus.[9] The cubitus varus deformity not only causes serious

Table 1

Patient preoperative clinical and radiographic data.

No.	Age (yr)	Sex	Side	Follow-up (mo)	Carrying angle (°)	Baumann angle (°)
1	7	M	Right	26	–10	95
2	10	F	Right	24	–15	100
3	11	F	Left	30	–15	100
4	8	F	Right	28	–12	97
5	5	M	Left	28	–10	95
6	9	F	Right	26	–16	101
7	5	F	Left	32	–15	100
8	7	M	Left	36	–15	100
9	12	M	Right	28	–30	115
10	10	F	Left	26	–15	100
11	8	F	Right	36	–10	95
12	7	F	Left	28	–10	95
13	10	M	Right	32	–18	103
14	6	F	Left	24	–15	100
15	9	M	Left	32	–10	95
16	4	M	Right	36	–10	95
17	10	F	Right	26	–15	100
18	6	M	Left	28	–15	100
19	7	F	Left	30	–14	99
20	6	F	Right	30	–10	95

F = female, M= male.

Table 2

Postoperative data.

No.	Post-op flexion	Post-op extension	Carrying angle post-op (°)	Change in carrying angle (°)	Baumann angle post-op (°)	Results
1	130	0	18	28	70	Excellent
2	125	5	15	30	75	Good
3	135	0	14	29	78	Excellent
4	135	0	15	27	76	Excellent
5	130	0	15	25	75	Excellent
6	125	5	10	26	80	Good
7	135	0	10	25	74	Excellent
8	135	0	10	25	76	Excellent
9	110	5	10	40	80	Good
10	130	0	15	30	75	Excellent
11	135	5	17	27	70	Excellent
12	135	0	17	27	77	Excellent
13	120	5	10	28	79	Good
14	135	0	10	25	75	Excellent
15	130	0	15	25	75	Excellent
16	135	0	15	25	76	Excellent
17	135	0	12	27	78	Excellent
18	130	0	15	30	77	Excellent
19	130	0	12	26	80	Excellent
20	135	0	17	27	75	Excellent

Post-op = postoperative.

observable abnormalities (Fig. 7 and 8), but also alters the upper limb weight-bearing alignment, resulting in an increased risk of lateral humeral condyle fracture.[10] Additionally, long-term abnormal pressure resulting from the alteration of the upper limb alignment can easily cause inflammatory pain in the lateral condyle of the humerus and can also cause delayed ulnar nerve palsy.[11]

Most cubitus varus deformities in children need to be corrected by osteotomy.[12] Osteotomies currently used in the clinic include lateral closed wedge osteotomy, medial open wedge osteotomy, step-cut osteotomy, and dome-shaped osteotomy.[13] After osteotomy, most of the osteotomy ends are fixed with Kirschner wires. U-shaped nails and screws combined with steel wires are also used for fixation.[14] For older children, the osteotomy ends can be fixed with steel plates or external fixators.[15]

For the correction of cubitus varus deformity, the carrying angle of the elbow joint was often used to evaluate the preoperative deformity and the postoperative correction effect.[16] Because the cubitus varus deformity is the distal varus deformity caused by the fracture of the distal humerus, the Baumann angle increases on the anteroposterior radiograph of the humerus.[17] Therefore, both the Baumann angle and the carrying angle were used in this study to evaluate the preoperative deformity of the distal humerus and the postoperative deformity correction effect.

Because the cubitus varus deformity originates from the varus deformity of the distal humerus, the purpose of treatment is to restore the normal anatomical relationship of the humerus as much as possible.[18] In this study, we measured the proximal and distal anatomical axis of the humerus and used the CORA method similar to that of the lower limbs for preoperative measurement and evaluation.[19]

The lateral closed wedge osteotomy is currently the most commonly used osteotomy method in clinical practice.[20] However, this method results in an inconsistent diameter of the proximal and distal ends of the osteotomy and in obvious deformity of the distal humerus, which is manifested by the appearance of steps of the distal humerus on imaging. In this study, neutral wedge osteotomy was used to correct the varus deformity. During the operation, 2 Kirschner wires were inserted to mark the proximal and distal osteotomy line. To prevent displacement after completely cutting off the distal humerus, the proximal osteotomy was first performed to the CORA point and then distal osteotomy was performed. Taking the CORA point as the center of rotation, the distal end of the humerus was turned outward to the osteotomy surface for correction, and 3 Kirschner wires were inserted through the lateral condyle of the humerus for fixation. Compared with the lateral closed wedge osteotomy, the neutral wedge osteotomy method centers on the CORA point and rotates the distal humerus to correct the varus deformity, which is more in line with the osteotomy principle: both the osteotomy line and the angulation correction axis pass through the CORA point, and the humeral alignment is restored; the osteotomy ends will not be displaced, and the affected limb will not be shortened because of closed wedge osteotomy. The osteotomy method can show the effect of open wedge-shaped osteotomy on the medial part of the humerus. However, we did not find obvious bone opening-like manifestations on the inner side of the distal humerus from the radiographs in the 20 cases after surgery.

For the choice of fixation methods after osteotomy, many options are available such as Kirschner wires, U-shaped nails, screws, steel plates, and external fixators. In this study, 3 Kirschner wires were used for fixation. After the deformity was corrected by osteotomy and turning the distal end of the humerus outward, a Kirschner wire was inserted across the fracture line from the proximal end close to the horizontal direction for fixation, which effectively prevented the displacement of the osteotomy end. Two Kirschner wires were obliquely inserted across

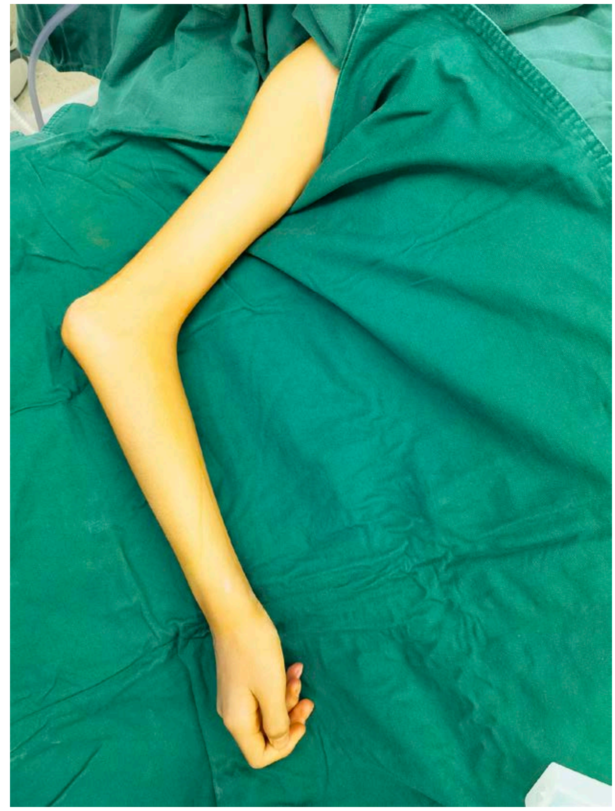

Figure 7. Severe cubitus varus deformity manifests as a pronounced abnormal appearance.

Figure 8. The elbow joint appearance of the patient with cubitus varus deformity after neutral wedge osteotomy.

the osteotomy end from the lateral condyle of the humerus. The angle between the horizontal Kirschner wire and the oblique Kirschner wire should be as large as possible to increase the stability of the fixation. Three Kirschner wires were placed outside the body percutaneously. This fixation method can avoid secondary operation to remove internal fixation. However, the external Kirschner wires increase the risk of pin-track infection. Therefore, the pin track was disinfected and the dressing was changed every week after the operation, and the Kirschner wires were removed in the outpatient clinic at an average of 1 month after the operation.

In summary, our study indicates that when treating cubitus varus deformity in children, the neutral wedge osteotomy assisted with CORA method can achieve precise planning before surgery and restore the appearance of the humerus close to the contralateral side. The bone removed by neutral wedge osteotomy is small, which makes it difficult to develop a step-like deformity on the outer side of the humerus after turning the distal end of the humerus outward. This method corrects the humeral alignment; at the same time, there will be no displacement of the osteotomy end and no shortening of the limbs. Together these findings indicate that the neutral wedge osteotomy assisted with CORA method is simple, safe, and reliable approach to correct cubitus varus deformity in children.

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