Clin Orthop Relat Res (2013) 471:1564–1571
DOI 10.1007/s11999-012-2756-y

Clinical Orthopaedics and Related Research®
A Publication of The Association of Bone and Joint Surgeons®

CLINICAL RESEARCH

Surgical Technique

Spike Translation: A New Modification in Step-cut Osteotomy for Cubitus Varus Deformity

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Received: 28 June 2012 / Accepted: 7 December 2012 / Published online: 25 January 2013

Abstract

Background Various methods of osteotomy have been proposed for the treatment of cubitus varus. We designed a modification of the step-cut osteotomy to achieve more correction of the deformity. We describe this new technique called spike translation step-cut osteotomy and report the clinical and radiographic outcomes (deformity correction, ROM, function, osteotomy healing, complications) in a series of patients treated for cubitus varus using this technique.

Description of Technique The technique involves a kind of closing-wedge osteotomy with a lateral spike to correct cubitus varus. To avoid lateral epicondyle prominence, the spike is translated medially and embedded in the proximal segment.

Methods We treated 13 patients with cubitus varus using the new technique between 2005 and 2010. We compared preoperative and postoperative clinical and radiographic parameters (humerus-elbow-wrist angle, lateral prominence index, arc of elbow motion, DASH score) for all patients. Time to union was recorded. Postoperative evaluation was performed according to the modified criteria of Oppenheim et al. Minimum followup was 16 months (average, 27 months; range, 16–43 months).

Results The average humerus-elbow-wrist angle improved from −26° to 11°. The mean lateral prominence index did not differ after correction of deformity compared with the normal side. By using our rehabilitation protocol, all patients regained preoperative arcs of elbow motion in a mean of 2.5 months (range, 1.50–3.50 months) postoperatively, and the mean union time was 1.65 months. According to the criteria of Oppenheim et al., there were 11 excellent and two good results.

Conclusions Our spike translation step-cut osteotomy with a larger contact surface of cancellous bone can be a reasonable alternative for correction of a cubitus varus deformity, with satisfactory deformity correction, reliable healing of osteotomy, and low complication rates.

Level of Evidence Level IV, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Angular and rotational malunions, especially after supracondylar fractures of the humerus, are well-known complications that occur in pediatric fractures of the distal humerus. Owing to physeal growth arrest or malunion, lateral condyle fractures also are assumed to be associated with varus or valgus malalignment [11].

These malunions frequently are associated with rotational malalignment. It is thought the deformity consists of extension, internal rotation, and varus angulation [3, 14, 20].

A relatively high rate (50%) of these complications has been reported in supracondylar fractures [11], and the incidence of cubitus varus has been reported to range from 9% to 57% [5, 11, 22]. Modern protocols have been developed to treat these fractures using closed reduction and pin fixation with a dramatic reduction of such complications [14]. Although the malalignment rarely leads to malfunction, the appearance of the extremity frequently is unacceptable to the patient [6, 14, 15].

In the past, because of the high rate of complications of valgus osteotomies, such as stiffness, loss of fixation, infection, myositis ossificans, and neurovascular injury, corrective osteotomies were rarely performed [6, 16]. However, various types of osteotomy and fixation have been proposed to correct this deformity [18, 29, 31, 32]. Step-cut osteotomy, as described by DeRosa and Graziano [7], is one of the most popular techniques of corrective osteotomy. In this closing-type osteotomy technique, a lateral spike remains on the distal part, which is further fixed to the proximal segment with a screw. This technique corrects varus deformity effectively; however, lateral displacement of the distal part is a common complication of the technique, which affects appearance after osteotomy [3, 7, 11].

We designed a new modification of the technique described by DeRosa and Graziano called spike translation step-cut osteotomy, which not only corrects this complication but also creates a large contact area for rigid fixation and early union and can correct the deformity in three dimensions. A similar osteotomy was described for the distal tibia called the wave osteotomy to eliminate prominence of the distal fragment in two patients through a curvolinear line [19]. We describe our new technique and report the clinical and radiographic outcomes in a series of patients treated for cubitus varus using this technique. We assessed improvement in (1) elbow alignment (humerus-elbow-wrist [HEW] angle and lateral prominence index [LPI]), (2) ROM, (3) function (DASH score); (4) osteotomy healing; and (5) complications. The overall result was judged using the modified criteria of Oppenheim et al. [26].

Surgical Technique

Patients underwent surgery under tourniquet control and in the lateral decubitus position. A posterior longitudinal skin incision in the posterior midline of the distal humerus was made, while the ulnar nerve was decompressed and protected. In complicated cases in which we needed high degrees of correction of the axial (> 10° correction needed) and sagittal planes, we used an olecranon osteotomy for better exposure and fixation (Table 1), but in children and for simple coronal corrections, we used the paratricipital approach. A closing-wedge osteotomy was performed corresponding to the amount of correction by comparing the HEW angle of both upper extremities. In contrast to the technique described by DeRosa and Graziano, the inferior margin of this right triangle (Line AB) (Fig. 1) was outlined parallel to the joint line 0.5 cm above the olecranon fossa (Fig. 1A). Then, from the medial end (Point B) of this first line, the second line (BC) was drawn, which made an angle (Angle B) between the first and second lines equal to the desired corrective HEW angle. Next, from the lateral end of the second line (Point C), the third line

Table 1. Patients' radiographic data preoperatively and postoperatively compared with the normal side

Patient	Age (years)	Sex	HEW angle (°)		LPI			Olecranon osteotomy
			Preoperative	Postoperative	Preoperative	Postoperative	Normal	
1	9	Female	−18	12	−5	−6	−7	No
2	31	Female	−38	13	1	3	2	Yes
3	18	Male	−26	10	−9	6	1	No
4	19	Male	−34	4	−14	−5	3	Yes
5	12	Female	−22	16	−11	−9	−5	No
6	12	Male	−24	14	−7	1	−3	No
7	17	Female	−16	12	−9	−3	−1	No
8	23	Female	−14	8	−4	−6	−6	No
9	20	Male	−40	15	−13	−8	−14	Yes
10	25	Male	−30	6	−12	0	5	Yes
11	17	Female	−19	13	−5	1	−2	No
12	21	Female	−21	9	−5	−3	−5	No
13	28	Male	−23	11	−1	0	0	No
Mean	19.4		−25.8	11.0	−7.23	−2.23	−2.46	

HEW = humerus-elbow-wrist; LPI = lateral prominence index.

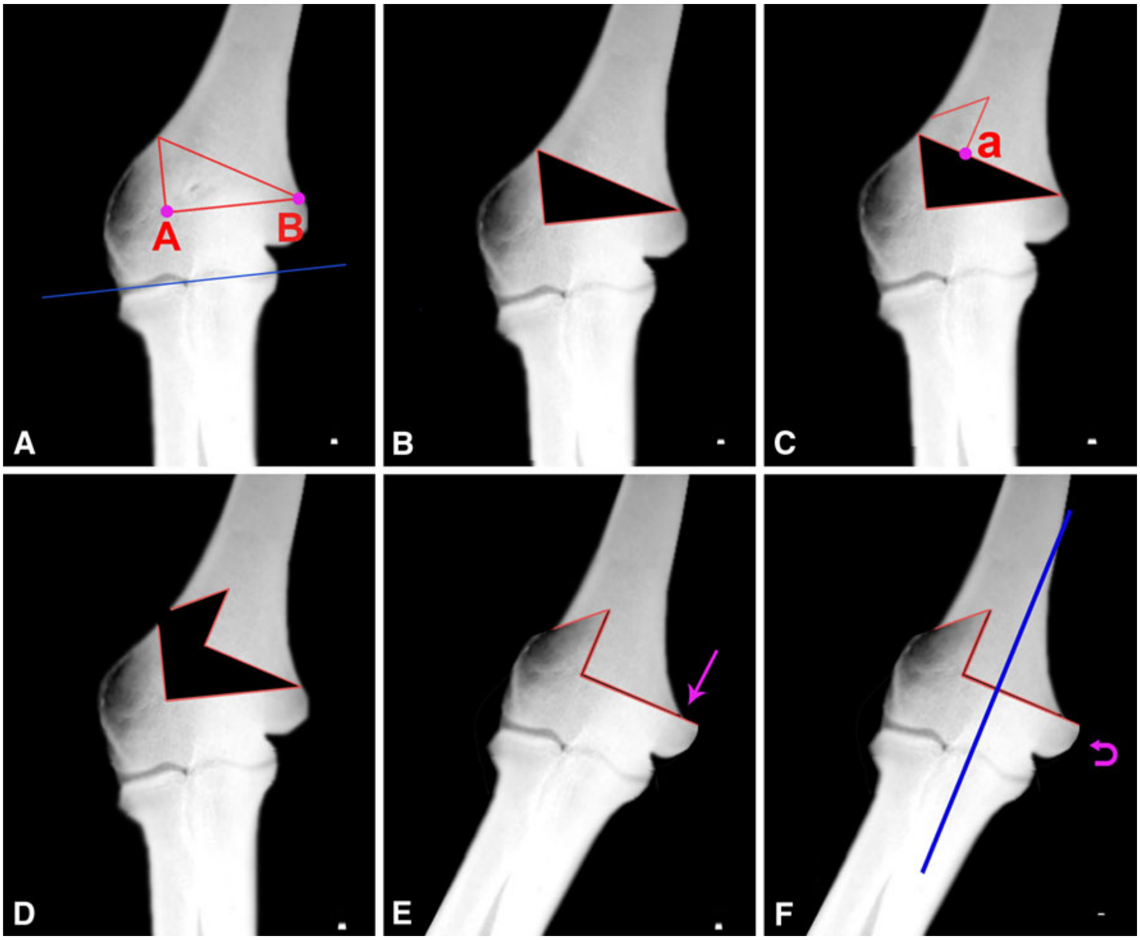

Fig. 1A–F (**A**) The proposed triangle is shown. AB is parallel to the articular surface and 0.5 cm above the olecranon fossa, Angle B is as much as the coronal correction, and Angle A is 90°. (**B**) The triangle is removed and the lateral bone spike remains on the distal fragment. (**C**) In the proximal fragment, according to the amount of translation required at Point a, the notch for the distal fragment spike is proposed. (**D**) The second triangle is removed. (**E**) Coronal correction of the deformity is achieved and translation applied as needed. (**F**) Excessive internal rotation deformity is corrected using the middle of the inferior margins as a hinge.

perpendicular to the first line (CA) was drawn. Finally, our desired right triangle was outlined and removed (Fig. 1B, Fig. 2A).

By comparing the LPI of both upper extremities preoperatively, we calculated the amount of required horizontal displacement and corrected it by displacement of the distal fragment, and then we cut a notch on the proximal fragment corresponding to the spike of the distal fragment (Fig. 1C) and the second triangle was removed (Fig. 1D). Any remaining bony prominence at the edge of the osteotomy was trimmed. Coronal correction of the deformity was achieved and translation applied as needed (Fig. 1E). Any excessive internal rotation deformity was corrected using the middle of the inferior margin as a hinge and rotating the distal part as much as was measured preoperatively (Fig. 1F; Fig. 2). Because of previous surgery, some patients lost full elbow extension. We corrected any flexion deformity by sloping the inferior margin of the osteotomized triangle for superior aesthetic results.

The osteotomy was prefixed with two Steinmann pins. Then, we checked the HEW angle, medial and lateral prominence, and elbow ROM. To obtain rigid fixation, one interfragmentary lag screw through the spike and corresponding notch was used. For adults or if there was any doubt concerning possible fixation, we applied a reconstruction plate. Active assisted ROM exercises began 2 weeks after removal of sutures. The posterior splint was used for protection between exercise periods until radiographic and clinical union had occurred.

Patients and Methods

Between 2005 and 2010, 13 patients, six males and seven females, with malunited distal humeral fractures were admitted to our hospital and underwent corrective elbow surgery using the spike translation step-cut osteotomy (Table 1). The average age of the patients was 19 years

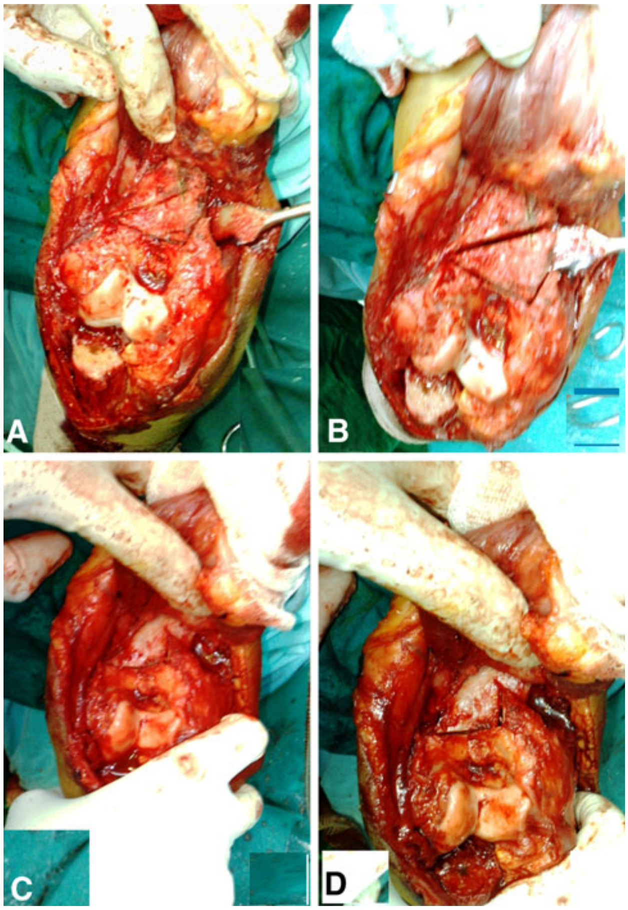

Fig. 2A–D (**A**) The proposed triangle was cut and the lateral bone spike remained on the distal fragment. (**B**) The triangle was removed and according to the amount of translation needed, the notch was made for the distal fragment spike in the proximal fragment. (**C**) Coronal correction of the deformity was achieved and translation applied as required. (**D**) The excessive internal rotation deformity was corrected using the middle of the inferior margins as a hinge (white curved arrow).

(range, 9–31 years). The interval between the initial trauma and the corrective osteotomy averaged 14.5 years (range, 5–27 years). Minimum followup was 16 months (average, 27 months; range, 16–43 months). The reason for referral to surgery was aesthetic and not functional problems such as ulnar nerve paresis or elbow instability.

We determined the correction values for patients by comparing the HEW angles and LPIs of both sides. We constructed our provisional osteotomy after tracing the radiographs of the deformed elbow on paper, considering the desired corrections based on the compared HEW and LPI on both sides. We then calculated the amount of distal fragment translation to correct the lateral prominence during the operation and the operation was performed according to the surgical technique described above.

We evaluated all patients postoperatively until maximal elbow ROM was achieved and union was completed

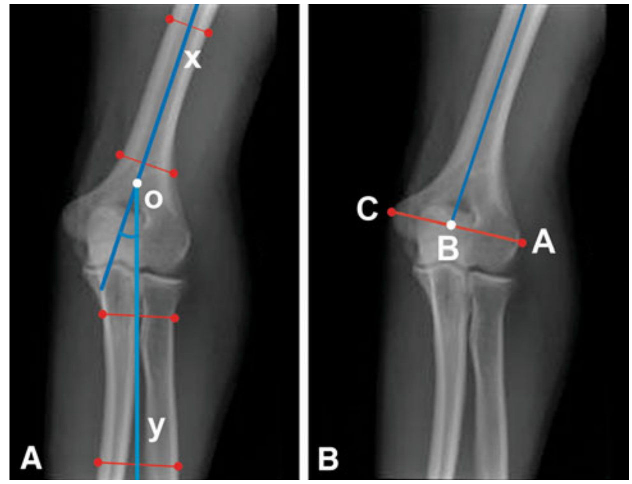

Fig. 3A–B Measurements of the (**A**) HEW angle and (**B**) LPI are shown. A is the most prominent lateral point and C is the most prominence medial point. x is axial axis of the humerus and y is the axial axis of the forearm. HEW angle = xOy angle. LPI = (AB − BC)/AC%.

without any complications. The patients were followed 2, 6, and 12 weeks after surgery and then every 3 months. At each followup, radiographs were taken of the elbow to check healing progression of the osteotomy, and elbow ROM was checked using a goniometer.

Preoperatively and postoperatively, we made clinical and radiographic assessments. The HEW angle and LPI were assessed radiographically (Fig. 3). On films taken of the extended upper extremity with a fully supinated forearm, the angle made at the intersection point of the longitudinal axes of the forearm and humeral shaft was measured as the HEW angle. The longitudinal axis of the forearm was determined by using the midpoints of the upper and lower transverse lines, limited to the medial and lateral cortexes of the ulna and radius, respectively [15]. To avoid any negative effects of radiographic magnifications and individual variations, we used the method of Wong et al. [33] to calculate the elbow LPI. In this method, the humeral longitudinal axis divides the transepicondylar line into lateral and medial parts. The ratio of the lateral-medial part difference to the total transepicondylar length was measured as the LPI.

The flexion-extension arc of both elbows was measured. To avoid the effect of rotation on the flexion-extension arc, the medial and lateral condyles were held on a horizontal plane [15]. According to Yamamoto et al. [34], with the elbow in 90° flexion and the shoulder in hyperextension, the angle made between the forearm and back was measured as the rotational alignment. If the difference in rotational alignment in both sides was greater than 10°, we noted it as excessive and considered correction of the rotational deformity.

For assessing aesthetic results, which included ROM, appearance, and scars, we filled out a checklist for each patient at the end of patient evaluations. For ulnar nerve assessment, pin-prick and light-touch sensibility were evaluated by Semmes-Weinstein monofilament testing and motor function was tested with interosseous muscle strength.

We determined the correction of the HEW angle and LPI by comparing radiographs obtained before surgery and after achieving union. Functional outcome was evaluated using the Persian version of the DASH score [24]. Finally, postoperative evaluation was performed according to the criteria of Oppenheim et al. [26] as modified by Kim et al. [15] (Table 2) for comparison with previous studies.

We used SPSS® v17 (SPSS Inc, Chicago, IL, USA) for descriptive and statistical analysis. For comparing two dependent means of variables in patients (normal side with injured side), we used the paired t-test. A p value less than 0.05 was deemed significant.

Table 2. Modified criteria of Oppenheim et al. [26] as modified by Kim et al. [15]

Results	Correction of the HEW angle (°)	Loss of ROM (°)	Complications
Excellent	0–5	0–5	None
Good	6–10	6–10	Scarring or a lazy-S deformity
Poor	> 10	> 10	Other complications (infection, myositis ossificans, and neurovascular injury)

HEW = humerus-elbow-wrist.

Results

The radiographic elbow alignment improved in this series of patients. The average HEW angle improved from −26° to 11°. The difference in the HEW angle between the osteotomized side and the normal elbow was only 0.2° and showed no difference ($p = 0.83$). The average normal-side HEW angle was 11°. The postoperative LPI averaged −2.2 (range, −9 to 6) compared with the mean preoperative value of −7.2 (range, −14 to 1) (Table 1). The mean LPI did not differ ($p = 0.84$) after correction of the deformity compared with the normal side (mean, −2.5; range, −14 to 5).

By using our rehabilitation protocol, all patients regained preoperative arcs of elbow motion in an average of 2.5 months (range, 1.50–3.50 months) postoperatively. The average preoperative and postoperative ranges of motion were 127° and 128°, respectively, showing no difference ($p = 0.436$) (Table 3). The forearm supination-pronation did not change postoperatively. Compared with the normal side, the average preoperative internal rotation was 16° (range, 0°–30°), which was corrected to 7.5° (range, 0°–10°) postoperatively. Before the operation, eight patients had more than 10° internal rotation, but after the operation, no patient had more than 10° internal rotation deformity.

The average of the Persian version of the DASH score was 5.1 points (range, 0–13.2 points), which was compatible with excellent results [24].

Based on the criteria of Oppenheim et al. [26], there were 11 excellent and two good results. The average union time was 1.7 months (range, 1–2 months). All patients had complete bone union by 8 weeks postoperatively, good alignment, and the desired ROM of their elbow (Fig. 4).

Table 3. Patients' clinical data preoperatively and postoperatively compared with the normal side

Patient	Age (years)	Sex	Preoperative ROM (°)		Postoperative ROM (°)		Elbow internal rotation (°)	
			Extension	Flexion	Extension	Flexion	Preoperative	Postoperative
1	9	Female	−5	140	0	140	10	10
2	31	Female	20	115	5	110	25	10
3	18	Male	−10	120	5	135	20	0
4	19	Male	15	120	5	130	30	10
5	12	Female	5	145	5	145	15	10
6	12	Male	0	135	0	135	10	10
7	17	Female	−5	120	0	125	25	0
8	23	Female	0	140	0	140	0	5
9	20	Male	15	145	−5	130	20	5
10	25	Male	15	125	5	115	20	0
11	17	Female	0	140	5	140	10	10
12	21	Female	−5	135	0	135	5	5
13	28	Male	15	125	10	120	20	0
Mean	19.4		4.62	131.15	2.69	130.77	16.2	5.8

Fig. 4A–E (**A**) A 20-year-old man had a 58°-varus deformity compared with the contralateral side. (**B**) After the osteotomy, 55° of the deformity was corrected. His elbow ROM is shown after 8 weeks in these views with his arm (**C**) flexed and (**D**) extended. (**E**) A radiograph shows the elbow after 8 weeks.

No patient had ulnar nerve palsy and wound problems. Two patients complained of the hypertrophic scar. In four patients in whom the olecranon osteotomy was performed, we routinely removed olecranon devices at an average of 9 months after union was achieved.

Discussion

Various methods of osteotomy have been proposed for the treatment of cubitus varus. We designed a modification of the step-cut osteotomy (spike translation step-cut osteotomy) to achieve more correction of the deformity. We describe this new technique and report the clinical and radiographic outcomes in a series of patients treated for cubitus varus using this technique.

Our study had some limitations. First is the small number of patients in the series. Fortunately, methods of distal humeral fracture management have improved, and these deformities are now uncommon. The short-term followup and lack of a control group were other study limitations.

The first description of a lateral closing-wedge osteotomy for the correction of cubitus varus was by Siris in 1939 [28], which led to many other techniques being developed. These techniques have been grouped into two categories: osteotomy methods and fixation methods. The methods used for fixation include external fixation and internal fixation. Internal fixation is a one-stage operation and further adjustments are not possible after the operation, which is considered the main disadvantage of internal fixation. Thus, accurate planning is emphasized before surgery. Additionally, some authors have reported another disadvantage, hypertrophic scars, compared with the external fixation methods [10, 13, 21]. The external fixation procedure has some advantages: further adjustment and correction are possible after the operation and it does not have bone loss or a prominent device; however, it can lead to pin tract infection or elbow stiffness [17, 21] and is not tolerated as well as internal fixation [10].

Some authors have described corrective osteotomies for cubitus varus. The main methods include the closing-wedge [9, 32], dome [1, 20, 23], simple step-cut [7], step-cut translation [6, 15], lateral invaginating peg [2], and three-dimensional [4] osteotomies. The translation step-cut osteotomy described by Davids et al. [6] is similar to our osteotomy, but for avoidance of lateral prominence, it removes a rectangular segment rather than a triangle. Our osteotomy has more contact area and it is possible to correct the deformity in three dimensions, but the osteotomy of Davids et al. [6] is much simpler and more appropriate for younger patients. In the step-cut translational osteotomy described by Kim et al. [15], the outer surface of the lateral cortex of the distal segment contacts with the osteotomy site. Considering this problem and the fact that the lateral side is the tension side in the daily activities of the distal humerus, this osteotomy potentially may lead to delayed union [25]. In addition, the technique described by Kim et al. is more technically demanding [15]. Lateral condyle protrusion is a disadvantage after the simple step-cut osteotomy or simple lateral closing-wedge osteotomy. In the simple step-cut osteotomy [7], the authors expressed this prominence is accentuated by disuse atrophy of the musculature after surgery. The lateral invaginating peg osteotomy described by Butt et al. [2] overcomes the problem by invaginating the lateral peg in the proximal part of the medulla. A dome osteotomy can redirect the distal fragment in the coronal and horizontal planes. One advantage of this technique is that it does not lead to bone loss and maintains the length of the arm. However, rotation of the distal fragment in the coronal plane is often difficult because of surrounding soft tissue contractures, so often some prominence of the condyle remains [15]. A three-dimensional osteotomy [4] may be associated with nerve palsy or myositis ossificans.

Our technique has several advantages in comparison to other osteotomies. First, the spike that embeds at the notch can provide a larger contact surface of cancellous bone than a simple closing-wedge, simple step-cut, dome, or even step-cut translational osteotomy. Second, compared with the mentioned osteotomies, our osteotomy is more stable, and no callus formation in most of our patients indicates the stability of osteotomy. Third, the axis of derotation of the distal fragment in the correction of the horizontal rotational deformity is the same as the longitudinal axis of the humerus shaft, which saves the distal and proximal contact during horizontal derotation as much as possible, and the spike serves as a guide for correcting the rotational deformity. Finally, compared with other osteotomies, especially the step-cut translational osteotomy, it is technically simple. The disadvantage of this technique, however, is that bone resection is larger than with some techniques such as the step-cut translational [15], transverse closing-wedge [25], or dome [12, 27, 30] osteotomy. However, according to Gong et al. [8], shortening of the humerus was not detectable clinically in most cases after corrective osteotomies for cubitus varus. Another disadvantage is it seems too difficult to perform on much smaller, younger pediatric patients.

Our modified step-cut osteotomy can be a reasonable alternative for correction of a cubitus varus deformity, with satisfactory deformity correction, reliable healing of the osteotomy, and low complication rates.

Acknowledgments We thank all colleagues who referred their patients to us so that we could perform this technique on them. We also thank Hanyeh Ebrahimi, academic secretary of our department, who submitted the manuscript on our behalf.

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