ORIGINAL ARTICLE

Modified step-cut osteotomy for post-traumatic cubitus varus: Our experience with 14 children

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KEYWORDS
Cubitus varus; Step-cut; Osteotomy; Lateral prominence; Supracondylar fracture

Summary

Background: Lateral closing wedge osteotomy is a commonly described procedure for correcting cosmetically unacceptable post-traumatic cubitus varus deformity in children. However, complications like residual deformity, lateral prominence, loss of fixation and ulnar nerve palsies commonly contribute to poor outcomes with such an osteotomy.

Patients and methods: Fourteen children (11 boys and three girls) presenting a mal-united extension type supracondylar fracture of the humerus with an average age of 9.07 years (6–14 years) were operated around 3.6 years (1.5–7 years) after the injury using a modified step-cut osteotomy. The average follow-up period was 2.1 years (1–4 years). Objective assessment included measurement of preoperative and postoperative lateral prominence index, carrying angle and range of elbow motion. Results were graded excellent, good or poor as per the Oppenheim criteria.

Results: There were eight excellent, five good and one poor result. A residual varus of more than 10° was seen in the single patient with poor result. None of the patients showed a prominent lateral humeral condyle or formation of hypertrophic scar. Our results were comparable to the published results of the classical lateral closing wedge osteotomy in terms of elbow motion and correction of deformity.

Conclusion: A modified step-cut osteotomy is a safe and simple procedure which prevents lateral prominence and leads to good or excellent outcomes in most of the patients. The step-cut osteotomy procedure, mentioned here, might be beneficial over the conventional lateral closing wedge osteotomy in certain aspects like the lateral humeral condyle prominence, scar acceptability and cosmesis. However, the apparent aforementioned advantages of this osteotomy over the conventional lateral closing wedge osteotomy needs to be further evaluated and confirmed on the basis of large, prospective randomised controlled trials.

Level of evidence: Level IV. Retrospective study.

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Introduction

Supracondylar fracture of humerus is the most common pediatric fracture, typically occurring in children during the first decade of life [1]. Gun stock deformity (cubitus varus) is described as the most common complication following this injury irrespective of the mode of treatment [2,3], although it typically follows an inappropriate conservative management in a displaced supracondylar fracture.

Cubitus varus deformity has multiple components that include varus mal-alignment, hyperextension and internal mal-rotation [4]. Different varieties of supracondylar humeral osteotomies [5–17] have been tried and the literature available on these osteotomies, at present, is immense, albeit, controversial. The most important indication for osteotomy is to achieve a good cosmesis [3].

The traditional supracondylar osteotomy that is still practised by surgeons worldwide is the lateral closing wedge osteotomy. The clinical results following this procedure, however, have been disappointing in some series [14,18]. This procedure, although simple, has been fraught with a few technical pitfalls [19], and its tendency to produce a prominent lateral condyle after correction often compromises the cosmetic outcome [5,15,20,21]. Different techniques of stabilisation following osteotomy have also been described, although fixation with multiple K-wires is procedure most authors have been contented with [4]. The present article includes a series of 14 patients who underwent a modified step-cut osteotomy with a posterior/lateral reconstruction plate fixation and discusses the cosmetic, clinical and radiological outcome in these patients.

Patients and methods

The study included a total of 14 children (11 boys and three girls) who had presented with cubitus varus deformity at the out-patient department of our hospital between April 2007 and August 2009. The main complaint of all the patients at the time of presentation was an unsightly elbow deformity. The mean age of the patients at the time of presentation was 9.07 years (6–14 years). All the patients had a significant history of elbow trauma and were apparently normal prior to that. The mean duration between the injury and presentation at our hospital for the deformity was around 3.6 years (1.5–7 years). The injury causing the deformity was a supracondylar fracture of the humerus of extension variety in all the children. Nine of them had been treated conservatively for the injury by closed reduction and cast at a nearby hospital, two had been treated by local bonesetters, two had the deformity following closed reduction (though were mal-reduced) and K-wire fixation (crossed pinning in both) and one child had the deformity following closed reduction and cross-pinning that seemed adequately reduced in the immediate postoperative radiographs, though it collapsed into varus later.

All the pre- and postoperative clinical and radiological assessments were carried out by the same surgeon (Dr PS). Preoperative clinical assessment (Fig. 1) included measurement of the carrying angle in full extension (0°) was measured on both sides in all patients clinically using a goniometer. The preoperative range of motion of the affected limb was assessed using the goniometer and the status of the limb and complications such as cosmetic issues, pain, instability, neurovascular issues and any loss of motor power were recorded.

Anterior and lateral radiographs of the affected extremity were taken with elbow in full extension and forearm in full supination. Carrying angle (Humerus-Elbow-Wrist angle) was measured on both sides and the angle of correction was estimated (Fig. 1). Humeral-ulnar wrist angle (Oppenheim’s angle) [22] has been regarded as the most accurate representation of the carrying angle of the elbow and, therefore, was selected as the index to measure the correction achieved.

The lateral prominence index (LPI) was calculated (using the method described by Wong et al. [21]) on the affected side as the difference between the measured medial and lateral widths of the bone from the longitudinal midhumeral axis and was expressed as a percentage of the total width of the distal humerus to minimize errors from magnification and variation of the size of individual humeri.

Patients in whom the difference in the Humeral-Elbow-Wrist angle between the affected and contra-lateral limbs was at least 20° and in whom the parents wanted correction of the deformity were considered for supracondylar humerus osteotomy. All the patients, after an informed consent, were operated by a modified step-cut osteotomy, as described subsequently. All the surgeries were performed by the same surgeon (Dr. PS). Postoperative radiographs were also taken in both AP and lateral views (Fig. 2).

Planning for the step-cut osteotomy (Fig. 3a–3d):

- A template of the distal humerus with its deformity is created on a plain sheet of paper and the Humeral-Ulnar-Wrist angle is measured. The valgus angle on the contra-lateral elbow is also measured and the difference between the two carrying angles is noted;
- A straight line AB is drawn on the distal humerus around 1.5 to 2 cm proximal to the olecranon fossa perpendicular to the lateral supracondylar ridge (that is mostly a straight line in these cases);
- Another line BC is drawn of the same length as AB at the plane of angle of correction (ipsilateral varus angle + contra-lateral carrying angle);
- The wedge of bone to be removed is thus planned and the alignment after this step-cut osteotomy assessed. Any additional piece of bone from the proximal fragment that may need to be trimmed in order to maintain alignment and to avoid any lateral prominence (due to the resultant translation) is also planned preoperatively.

The surgery was performed in lateral position (Fig. 4) using the standard posterior approach to distal humerus (triceps split approach) under tourniquet control. A template corresponding to the amount of correction required was placed as lateral closing wedge just superior to the olecranon fossa. The apex of the angle was placed medially with superior edge perpendicular to the humerus shaft, another line was dropped at right angle from the superolateral edge of the osteotomy site towards the base thereby outlining a triangular area. The triangular area was marked by electrocautery and multiple drill holes using a 2.5 mm drill bit care was taken not to over drill the anterior cortex to prevent damage to anterior neurovascular structures.
Modified step-cut osteotomy for post-traumatic cubitus varus

Figure 1  Preoperative clinical and radiological pictures of a patient.

Figure 2  Postoperative clinical and radiological pictures of the same patient.
The triangular piece of bone was removed by connecting the drill holes using an osteotome leaving a lateral spike on the distal fragment. The lateral cortex of the proximal fragment usually required some trimming for close approximation with the spike on the distal fragment. The distal fragment was translated laterally for reduction with the proximal fragment, the reduction was provisionally held by Kirschner wires and assessed under C-arm. If the radiological and gross examinations showed an insufficient correction, an additional correction was attained by further osteotomy and moving the apex medially; any overcorrection was adjusted by moving the apex laterally. After ascertaining correction in coronal sagittal and horizontal planes the reduction was rigidly secured using a small fragment plate (reconstruction plate) with screws. We usually found two bi-cortical purchases on either side of osteotomy sufficient. In four patients, laterally placed plate with additional lag screw fixation was done. In all other patients, the osteotomy site was stabilised with a posteriorly positioned plate (Fig. 5). Postoperatively, a posterior long arm POP slab applied in all the patients. This was removed after one week and controlled elbow mobilization started thereafter.

All patients were followed up at two weeks, six weeks, 12 weeks, six months, one year and, thereafter yearly, for a maximum of four years after the surgery. The average follow-up period was 2.1 years (1–4 years). Objective clinical and radiological assessment included measurement of carrying angle, any prominent implant felt on palpation, range of elbow motion, lateral prominence index, hypertrophied scar, instabilities, nerve examination or any other complications.

Results were graded as per criteria laid by Oppenheim et al. [14] as excellent, good and poor. The patients were also assessed during their follow-up for their satisfaction quotient with the help of a questionnaire on following topics:

- Are they happy with the correction of the varus deformity per se?
- Are they happy with the appearance of the limb postoperatively?
- Any lateral bump or swelling that bothers them postoperatively?
- Any other complications that disturb the child or the parent postoperatively.

The questionnaire was answered by the parents in yes/no format. The results were considered fully satisfactory if they had answered the first two questions with a ‘yes’ and the last two with a ‘no’. partly satisfied if the parent’s perception differed in not more than two questions. When there was a discrepancy in more than two questions, the procedure was deemed unsatisfactory for the patient/parent.
Results

The details regarding the general profile of the patients, preoperative range of motion, mechanism of initial injury and the treatment following the initial injury have been tabulated in Table 1. Table 2 compares the preoperative and postoperative results in the patients. There were no cases with preoperative nerve palsies, instabilities, local pain or any complications other than the deformity in our series.

The mean preoperative range of motion was about 127° (range 115–140°), while the mean range of motion at the time of the last follow-up was about 122 (range 110–135°). This difference was not statistically significant (Wilcoxin Signed Rank Test). There were nine children (64.28%) with a postoperative decrease in the range of motion of less than or equal to 5°, while the decrease in the range of motion was between 5 and 10° in five patients (35.71%). No patient had a decrease in motion of more than 10°.

The mean preoperative difference in carrying angle (HEW Angle) between the two limbs was 29.64 (range 25–38°) while postoperatively and at follow-up, the difference was 2.79 (−2 to 11°). There was no loss of correction once achieved, observed in any of our patients following modified step-cut osteotomy. Most of the patients had a correction of HEW angle to within 5° of the contra-lateral arm. However, the HEW angle difference between the two limbs was 7° in one patient and 12° in another.

The preoperative LPI averaged 0.07% (range −8.4% to 5.6%) in our study. The mean postoperative LPI was −0.85% (range −9.2% to 4.7%). A negative LPI value indicates a greater medial prominence at the elbow. Compared with the preoperative values, the LPI actually decreased after the surgery in all our patients.

On the basis of the Oppenheim’s criteria, there were eight patients (57.14%) with excellent results, five patients (35.71%) with good results and one patient (7.14%) with poor result. None of the patients had wound infection,
nerve palsies, instabilities or any significant postoperative complications. All of them demonstrated good solid union at 12 weeks. Of the four patients with laterally placed plate, two (50%) had good results and two (50%), excellent results. Of the remaining 10 patients with posterior reconstruction plating, six had excellent results, 3 had good results, while there was a single patient with a residual deformity of more than 10° that was considered poor. There were no fractures of the bone spike at the apex intra- or postoperatively.

Eight patients who had step-cut osteotomy with posterior plating were fully satisfied with their outcome. However, one patient with poor outcome was only partly satisfied with the result and another patient who had a decrease of 10° was only partially satisfied.

In the children with lateral plating, two of the parents were concerned with the prominence of the plate laterally (lateral bump), though they had a reduced lateral prominence index. The parents, however, felt that the final appearance of the limb was much improved and they were satisfied with it. Two other patients, who had a reduced range of motion of 10°, had some disappointment about it. There was one female patient bothered about her unsightly posterior scar. However, none of the patients had a hypertrophic scar formation.

Table 1  Patient profile.

<table>
<thead>
<tr>
<th>Serial No</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Duration of injury (months)</th>
<th>Preoperative Flexion</th>
<th>Preoperative Extension</th>
<th>Type of fracture</th>
<th>Mode of injury</th>
<th>Mode of previous treatment</th>
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</tr>
<tr>
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<td>Fall while playing</td>
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CR: Closed Reduction.

Table 2  Preoperative and postoperative details of range of motion (ROM), Humerus-Elbow-Wrist (HEW) angle difference and lateral prominence index (LPI). Also mentioned are the results on the basis of Oppenheim’s criteria and the plate fixation technique utilized.

<table>
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<tr>
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<th>Preoperative ROM</th>
<th>Postoperative ROM</th>
<th>Preoperative HEW angle difference</th>
<th>Postoperative HEW angle difference</th>
<th>Preoperative LPI</th>
<th>Postoperative LPI</th>
<th>Results</th>
<th>Plate fixation technique</th>
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<td>-4.2%</td>
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<td>Posterior</td>
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<td>2.8%</td>
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<td>Lateral</td>
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<tr>
<td>5</td>
<td>125</td>
<td>115</td>
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Modified step-cut osteotomy for post-traumatic cubitus varus

The main purpose of surgery in post-traumatic cubitus varus is to achieve a good appearance and cosmesis of the limb [3,20]. However, the corrective osteotomy procedures have themselves been fraught with a multitude of cosmetic complications [18]: lateral prominence of the distal humerus following a simple lateral closing wedge osteotomy, hypertrophic scar following a lateral approach [20], recurrence of the varus deformity [4] especially when the rotational element is corrected or when less rigid fixation techniques are used, prominent anterior ledge following an overcorrected rotational deformity and prominence of any high-profile implants used. A number of non-cosmetic complications are also described in association with these osteotomies: iatrogenic nerve palsies [4,14] (ulnar and radial nerve palsies), iatrogenic instabilities [5] (posterolateral and lateral), elbow joint stiffness, triceps snapping or infections. Among these, the cosmetic issues especially deserve to be addressed and avoided following these corrective surgeries to achieve a good patient satisfaction.

The literature has mostly supported the use of multiple K-wires for fixation following supracondylar osteotomy. However, step-cut osteotomies with lag screw or plate fixation have also been described [23–27]. A rigid fixation may be necessary, especially in older children, to prevent any loss of correction with time. We observed that step-cut pattern of osteotomy enhanced stability, as the spikes in the proximal and distal fragments interlocked with each other, preventing motion in the coronal and rotational planes. The cortical spike, here, functions in the same manner as an intact periosteal hinge, allowing control of the osteotomy. We had also used reconstruction plates in our patients as the mode of fixation. We had placed the plates posteriorly in 10 patients and laterally in four patients. There were no cases of loss of correction or any other complications following plate fixation in our patients. Proper care was taken so as not to violate the physis, disturb the local biology or jeopardise the blood supply to the growth plate.

We recommend the plate to be placed posteriorly using the posterior approach as there might be perception of troublesome prominence in case of laterally placed implants. The posterior approach also provides a much better appearance to the limbs, as the scars are less noticeable and obvious. The lateral approach, on the other hand, crosses the Langer’s lines perpendicularly that might result in hypertrophic scar formation [3,20]. There is also a risk of postoperative extensor weakness due to injury of radial nerve in case of lateral approach. The posterior approach, however, may make it difficult for us to complete the osteotomy on the anterior cortex (due to the apprehension regarding the proximity of the vessels and the relatively poor visibility of the anterior structures of the cubital fossa). The surgeon should be cautious about this problem, lest a hyperextension deformity may result.

We preferred to correct the deformity in the coronal plane only. The hyperextension and internal rotation deformities were left alone as correction of these deformities are known to reduce the osseous contact area and, thereby, compromise the stability of fixation [4]. The present literature also indicates no significant advantages of 3-dimensional osteotomies over single plane osteotomies. We also observed no functional limitations or cosmetic issues in any of our children, despite neglecting these additional deformities.

Some previous researchers have discussed their experiences with modified step-cut osteotomies. In 1988, DeRosa and Graziano [24] described the step-cut humerus valgus osteotomy using one cortical screw for fixation to correct cubitus varus deformity in 11 patients. Kim et al. [25], in 1998, had observed satisfactory results in 28 patients following modified step-cut translation osteotomy and fixation with a Y-shaped humeral plate in 31 children with post-traumatic cubitus varus deformity. Yun et al. [26,27] Butt et al. [28] and W. Laupattarakasem et al. [10] had similarly described modified osteotomies in their patients with good results.

The concern regarding the ugly bulging of the lateral epicondyle has been widely addressed by various researchers and this deformity is most noticeable when the medial cortex has been used as a hinge [3] (as in French’s technique). This ‘lazy S’ deformity (as described by Laupattarakasem et al. [10]) is due to lateral protrusion of the distal osteotomised fragment (due to incongruity in width between the proximal and distal fragments) and is made more prominent when there is atrophy of the flexor muscles of the forearm. This lateral prominence after a simple lateral closing wedge osteotomy may be decreased by medialisation of the distal fragment after stripping the medial periosteum (whose intactness is however important for the stability of the fragments). The modified step-cut osteotomy uses a template for removing a triangular piece of bone,

![Image](https://via.placeholder.com/150)

**Figure 5** Plate placement: Posterior in one patient and lateral in the other.

**Discussion**

The main purpose of surgery in post-traumatic cubitus varus is to achieve a good appearance and cosmesis of the limb [3,20]. However, the corrective osteotomy procedures have themselves been fraught with a multitude of cosmetic complications [18]: lateral prominence of the distal humerus following a simple lateral closing wedge osteotomy, hypertrophic scar following a lateral approach [20], recurrence of the varus deformity [4] especially when the rotational element is corrected or when less rigid fixation techniques are used, prominent anterior ledge following an overcorrected rotational deformity and prominence of any high-profile implants used. A number of non-cosmetic complications are also described in association with these osteotomies: iatrogenic nerve palsies [4,14] (ulnar and radial nerve palsies), iatrogenic instabilities [5] (posterolateral and lateral), elbow joint stiffness, triceps snapping or infections. Among these, the cosmetic issues especially deserve to be addressed and avoided following these corrective surgeries to achieve a good patient satisfaction.

The literature has mostly supported the use of multiple K-wires for fixation following supracondylar osteotomy. However, step-cut osteotomies with lag screw or plate fixation have also been described [23–27]. A rigid fixation may be necessary, especially in older children, to prevent any loss of correction with time. We observed that step-cut pattern of osteotomy enhanced stability, as the spikes in the proximal and distal fragments interlocked with each other, preventing motion in the coronal and rotational planes. The cortical spike, here, functions in the same manner as an intact periosteal hinge, allowing control of the osteotomy. We had also used reconstruction plates in our patients as the mode of fixation. We had placed the plates posteriorly in 10 patients and laterally in four patients. There were no cases of loss of correction or any other complications following plate fixation in our patients. Proper care was taken so as not to violate the physis, disturb the local biology or jeopardise the blood supply to the growth plate.

We recommend the plate to be placed posteriorly using the posterior approach as there might be perception of troublesome prominence in case of laterally placed implants. The posterior approach also provides a much better appearance to the limbs, as the scars are less noticeable and obvious. The lateral approach, on the other hand, crosses the Langer’s lines perpendicularly that might result in hypertrophic scar formation [3,20]. There is also a risk of postoperative extensor weakness due to injury of radial nerve in case of lateral approach. The posterior approach, however, may make it difficult for us to complete the osteotomy on the anterior cortex (due to the apprehension regarding the proximity of the vessels and the relatively poor visibility of the anterior structures of the cubital fossa). The surgeon should be cautious about this problem, lest a hyperextension deformity may result.

We preferred to correct the deformity in the coronal plane only. The hyperextension and internal rotation deformities were left alone as correction of these deformities are known to reduce the osseous contact area and, thereby, compromise the stability of fixation [4]. The present literature also indicates no significant advantages of 3-dimensional osteotomies over single plane osteotomies. We also observed no functional limitations or cosmetic issues in any of our children, despite neglecting these additional deformities.

Some previous researchers have discussed their experiences with modified step-cut osteotomies. In 1988, DeRosa and Graziano [24] described the step-cut humerus valgus osteotomy using one cortical screw for fixation to correct cubitus varus deformity in 11 patients. Kim et al. [25], in 1998, had observed satisfactory results in 28 patients following modified step-cut translation osteotomy and fixation with a Y-shaped humeral plate in 31 children with post-traumatic cubitus varus deformity. Yun et al. [26,27] Butt et al. [28] and W. Laupattarakasem et al. [10] had similarly described modified osteotomies in their patients with good results.

The concern regarding the ugly bulging of the lateral epicondyle has been widely addressed by various researchers and this deformity is most noticeable when the medial cortex has been used as a hinge [3] (as in French’s technique). This ‘lazy S’ deformity (as described by Laupattarakasem et al. [10]) is due to lateral protrusion of the distal osteotomised fragment (due to incongruity in width between the proximal and distal fragments) and is made more prominent when there is atrophy of the flexor muscles of the forearm. This lateral prominence after a simple lateral closing wedge osteotomy may be decreased by medialisation of the distal fragment after stripping the medial periosteum (whose intactness is however important for the stability of the fragments). The modified step-cut osteotomy uses a template for removing a triangular piece of bone,
creating two fragments in which the distal fragment exactly fits into the proximal one. This decreases the protrusion of the medial or lateral condyle, basically attaining the required degree of medial or lateral translation. The location of the apex of the triangular cut determines the amount of correction of the cubitus varus deformity [23]. The lateral prominence index even in our series following modified step-cut osteotomy was $-0.85\%$ as compared to a preoperative value of 0.07%.

A dome osteotomy [20] can reorient the distal fragment in both the coronal and the horizontal plane; thus, residual prominence of the medial and lateral condyles can be avoided. However, because of contracture of the surrounding soft tissue, it is often difficult to rotate the distal portion in the coronal plane and frequently some prominence of the condyles remains [23,29]. Pentagonal osteotomy also abolishes the lateral prominence, though it is technically complicated and difficult to perform consistently. The external fixation method decreases the protrusion of the lateral condyle by translating the distal fragment medially [30,31]. It may, however, be associated with neurovascular injury, and the technique may cause discomfort to the patient [23].

Despite good results, there were a few potential limitations of our study. We could evaluate only 14 patients in our study. A larger sample size might have ensured better and more reliable results. However improvements in medical care have progressively decreased the incidence of such deformities. Another potential limitation was the absence of a control group. We had performed modified step-cut osteotomy in all the patients and did not compare the outcome with any other standard corrective osteotomies for cubitus varus.

Nevertheless, we found the results of the modified step-cut osteotomy with plate fixation comparable to those of lateral closing wedge, dome and step-cut osteotomies described by various authors in terms of the correction of carrying angle, preservation of elbow movements, and the incidence of complications (infection, neuapraxia, etc.). We reported superior results as compared to those of the lateral closing wedge osteotomy in terms of the prominence of the lateral humeral condyle, acceptability of the scar, and cosmesis. There was no case of deformity recurrence in any of our patients during the follow-up period (primarily attributed to the stable construct we had achieved by this technique).

To conclude, we believe that a step-cut osteotomy with plate fixation for the correction of the cubitus varus deformity is associated with an excellent outcome and low complication rates. We thus recommend it as a satisfactory surgical option for patients (especially children older than 10 years) requiring deformity correction for post-traumatic cubitus varus.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

Modified step-cut osteotomy for post-traumatic cubitus varus