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Surgical management of pediatric cubitus varus: Outcomes of modified French versus three-dimensional osteotomy

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Abstract
Background: Pediatric cubitus varus is a common post-traumatic elbow deformity that can lead to functional impairment and cosmetic concerns. Surgical correction is indicated when significant deformity persists.
Aim of the study: To compare clinical, radiological, and functional outcomes of Modified French osteotomy versus Three-Dimensional (3D) osteotomy in the management of pediatric cubitus varus.
Methods: A prospective comparative study was conducted at BSMMU and New Life Hospital, Dhaka, from October 2022 to September 2024. Forty pediatric patients were allocated to 3D osteotomy (n=20) or Modified French osteotomy (n=20). Outcomes included carrying angle, internal rotation correction, elbow range of motion, Mayo Elbow Performance Score (MEPS), and complications. Statistical significance was set at $p<0.05$.
Result: 3D osteotomy achieved significantly better carrying angle (11.10°±2.13 vs. 9.40°±2.62; $p=0.035$), internal rotation correction (24.90°±2.67 vs. 22.00°±1.74; $p=0.001$), elbow flexion (132.90°±2.32° vs. 130.20°±3.25°; $p=0.008$), and MEPS (91.50±5.64 vs. 86.00±7.18; $p=0.015$). Excellent outcomes were more frequent in the 3D group (75% vs. 40%; $p=0.045$). Complications were lower with 3D osteotomy. Operative time and blood loss were higher, but union occurred faster.
Conclusion: Three-dimensional osteotomy provides superior functional and radiological outcomes with fewer complications, whereas Modified French osteotomy remains a viable option in resource-limited settings.

Keywords: Pediatric cubitus varus, three-dimensional osteotomy, modified French osteotomy, mayo elbow performance score, corrective osteotomy.

Introduction
Cubitus varus, also known as gun-stock deformity, is a post-traumatic malalignment of the elbow characterized by varus deviation, often associated with hyperextension and internal rotation, resulting from malunion of supracondylar humerus fractures. It is the most frequent late complication of pediatric supracondylar humerus fractures, with significant cosmetic and functional implications [1]. Globally, the prevalence of cubitus varus following such fractures ranges from 9%–58% [2]. In Bangladesh, hospital-based studies at NITOR and Kushtia General Hospital reported an incidence of cubitus varus ranging between 20% and 35% among children with malunited supracondylar humerus fractures, highlighting its persistent burden in clinical practice [3]. Although frequently regarded as a cosmetic concern, cubitus varus can lead to functional impairment and secondary complications such as ulnar nerve palsy, posterolateral rotatory instability, snapping of the triceps, increased risk of lateral condyle fractures, and chronic elbow pain [4]. The deformity is complex and three-dimensional, involving coronal, sagittal, and rotational malalignment. This complexity makes surgical correction challenging, as simple uniplanar osteotomies may fail to address all components, resulting in residual deformity or recurrence [5]. Since non-operative options are ineffective once the deformity is established, corrective osteotomy remains the standard treatment [6]. Several osteotomy techniques have been developed for cubitus varus correction. Among these,

the modified French osteotomy, a lateral closing-wedge procedure, is widely used because of its technical simplicity, predictable correction in the coronal plane, and reproducibility [7]. However, as it primarily addresses the varus deformity, it is less effective in correcting internal rotation or hyperextension. To achieve more comprehensive correction, three-dimensional osteotomy techniques have been introduced [8]. These procedures allow simultaneous correction in coronal, sagittal, and rotational planes, thereby providing a more anatomical restoration of alignment, better cosmetic results, and improved functional outcomes [9]. Recent literature comparing different techniques has shown that three-dimensional osteotomy yields higher rates of excellent outcomes and fewer complications compared to conventional methods. Systematic reviews have reported that the vast majority of patients treated with three-dimensional osteotomy achieved excellent results, with no reported infections and only a very small proportion experiencing poor outcomes [10]. Clinical studies in Bangladesh have also demonstrated favorable results, indicating consistently high rates of bone union within a relatively short period, minimal postoperative complications, and overall satisfactory functional outcomes [11]. While dome and modified French osteotomies continue to produce good results and remain valuable due to their simplicity, shorter operative time, and reduced technical demands, their limitations in addressing rotational deformity make them less ideal for complete correction [12]. Overall, current evidence indicates that although three-dimensional osteotomy provides superior anatomical and functional outcomes, the modified French osteotomy continues to play an important role in resource-limited settings and among surgeons less familiar with complex techniques [13]. A direct comparison of these two approaches is therefore essential to inform surgical decision-making and optimize management of pediatric cubitus varus [14]. The aim of this study is to compare the clinical and radiographic outcomes of modified French osteotomy and three-dimensional osteotomy in the surgical management of pediatric cubitus varus.

Methodology and Materials

This prospective comparative study was carried out in the Department of Orthopaedic Surgery at Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka, and New Life Hospital, Dhaka, between October 2022 and September 2024. The study population consisted of pediatric patients with cubitus varus (gunstock) deformity who presented to the outpatient department during the study period. A total of 40 patients were selected using a simple random sampling method. Based on the odd–even sequence of admission numbers, patients were allocated to undergo either Three-Dimensional Osteotomy or Modified French Osteotomy, resulting in two equal comparative groups of 20 patients each.

Inclusion criteria

- Age up to 20 years.
- Presence of cubitus varus deformity following malunited supracondylar or lateral condyle fracture.
- Deformity duration of at least 12 months.
- Availability for regular follow-up.

Exclusion criteria

- Patients with associated complications such as nerve palsy, Volkmann's ischemic contracture, or myositis ossificans.
- Presence of marked osteoarthritic changes in the elbow joint on radiographs.
- Patients deemed unfit for surgery due to medical or anesthetic reasons.

Ethical Considerations

This study adhered to the principles of the Helsinki Declaration (1964). The objectives and procedures were explained in detail to all participants, and written informed consent was obtained prior to enrollment. Participation was entirely voluntary, with the right to refuse or withdraw at any stage. Privacy, anonymity, and confidentiality of patient information were strictly maintained. The research protocol was reviewed and approved by the Academic Committee of the Department of Orthopaedic Surgery and received ethical clearance from the Institutional Review Board (IRB) of BSMMU, Dhaka.

Data Collection

Clinical and radiological information was obtained using a structured proforma. Demographic characteristics such as age, sex, and body mass index (BMI) were recorded, along with baseline features including the involved limb, cause of deformity, and duration of injury. Perioperative findings such as operative time, intraoperative blood loss, length of hospital stay, and time to union were documented. Radiological and clinical outcomes were assessed by measuring carrying angle, correction of internal rotation, elbow flexion–extension, and the Mayo Elbow Performance Score (MEPS). Patient-reported outcomes were evaluated using functional grading (excellent, good, fair, poor) based on MEPS. Complications including superficial wound infection, pin tract infection, nerve injury, and under-correction were also recorded.

Statistical Analysis

Data were analyzed using standard statistical methods. Qualitative variables were presented as frequency and percentage and compared using the Chi-square test. Quantitative variables were expressed as mean±standard deviation (SD) and analyzed with the Student's t-test for parametric data and the Mann–Whitney U test for non-parametric data. All analyses were performed using SPSS software, version 26 (IBM Corp., Armonk, NY, USA). A p-value <0.05 was considered statistically significant.

Results

The demographic characteristics of the study population (N=40) are presented in Table 1. The mean age of patients was comparable between the 3D osteotomy group (11.55±2.54 years) and the Modified French osteotomy group (11.00±2.36 years). Similarly, mean BMI was comparable between the two groups (17.82±1.64 vs. 18.29±1.72; $p=0.41$). In terms of gender distribution, males predominated in both groups, representing 60.0% of the 3D osteotomy group and 70.0% of the Modified French group. The side of involvement showed no significant difference between groups, with equal distribution in the 3D osteotomy group (right: 50.0%, left: 50.0%) compared to 40.0% right and 60.0% left involvement in the Modified French group ($p=0.525$). The underlying cause was predominantly supracondylar fracture in both groups (95.0% vs. 90.0%), with only a few lateral condyle fractures reported. The mean duration of injury was slightly longer in the 3D osteotomy group (46.10±18.57 months) compared to the Modified French group (41.50±17.56 months). Categorically, a greater proportion of patients in the 3D osteotomy group had injuries lasting more than 35 months

(60.0% vs. 50.0%) (Table 2). The mean operative time was significantly longer in the 3D osteotomy group (75.2±10.3 minutes) compared to the Modified French group (58.6±8.7 minutes; $p<0.001$). Intraoperative blood loss was also significantly higher in the 3D osteotomy group (58.4±15.6 ml vs. 42.3±12.5 ml; $p=0.002$). Conversely, union time was significantly shorter in the 3D osteotomy group (10.25±1.29 weeks) compared to the Modified French group (12.25±1.71 weeks; $p=0.001$). Length of hospital stay was slightly longer in the 3D osteotomy group (3.1±0.9 vs. 2.6±0.8 days; $p=0.04$) (Table 3). Radiological and clinical outcomes (Table 4) showed significantly better final carrying angle (11.10±2.13° vs. 9.40±2.62°; $p=0.035$), greater correction of internal rotation (24.90±2.67° vs. 22.00±1.74°; $p=0.001$), and superior elbow flexion (132.90±2.32° vs. 130.20±3.25°; $p=0.008$) in the 3D osteotomy group. Extension was similar across both groups ($p=0.432$). The mean MEPS score was significantly higher in the 3D osteotomy group (91.50±5.64) compared to the Modified French group (86.00±7.18; $p=0.015$). A higher proportion of patients in the 3D osteotomy group achieved an excellent outcome (75.0% vs. 40.0%), with significantly fewer fair outcomes compared to the Modified French group ($p=0.045$). Although complication rates were relatively low overall, nerve injuries (10.0%) and pin tract infections (10.0%) were observed only in the Modified French group (Table 5).

Table 1: Demographic characteristics of the study population (N=40)

Variable	3D Osteotomy (n=20)		Modified French (n=20)		P-value
	n	%	n	%	
Age (years), Mean±SD	11.55±2.54		11.00±2.36		0.58
BMI (kg/m²), Mean±SD	17.82±1.64		18.29±1.72		0.41
Gender					
Male	12	60.00	14	70.00	0.52
Female	8	40.00	6	30.00	

Table 2: Baseline characteristics of the study population (N=40)

Variable	3D Osteotomy (n=20)		Modified French (n=20)		P-value
	n	%	n	%	
Involved limb					
Right	10	50.00	8	40.00	0.525
Left	10	50.00	12	60.00	
Cause					
Supracondylar Fracture	19	95.00	18	90.00	0.548
Lateral Condyle Fracture	1	5.00	2	10.00	
Duration of Injury					
Duration (months)	46.10±18.57		41.50±17.56		0.284
≤ 35 month	8	40.00	10	50.00	0.525
> 35 month	12	60.00	10	50.00	

Table 3: Perioperative findings among participants

Variable	3D Osteotomy (Mean±SD)	Modified French (Mean±SD)	P-value
Operative time (minutes)	75.2±10.3	58.6±8.7	<0.001
Intraoperative blood loss (ml)	58.4±15.6	42.3±12.5	0.002
Union time (weeks)	10.25±1.29	12.25±1.71	0.001
Hospital stay (days)	3.1±0.9	2.6±0.8	0.04

Table 4: Radiological and clinical outcomes among patients

Outcome	3D Osteotomy (Mean±SD)	Modified French (Mean±SD)	P-value
Final carrying angle (°)	11.10±2.13	9.40±2.62	0.035
Correction of internal rotation (°)	24.90±2.67	22.00±1.74	0.001
Elbow flexion (°)	132.90±2.32	130.20±3.25	0.008
Elbow extension (°)	3.20±1.32	3.45±1.43	0.432
MEPS (0–100)	91.50±5.64	86.00±7.18	0.015

Table 5: Patient-Reported outcomes and complications of patients (N=40)

Variable	3D Osteotomy (n=20)		Modified French (n=20)		P-value
	n	%	n	%	
Final Outcome					
Excellent (>90)	15	75.00	8	40.00	0.045
Good (75-89)	5	25.00	10	50.00	
Fair (60-74)	0	0.00	2	10.00	
Poor (<60)	0	0.00	0	0.00	
Complication					
Superficial wound infection	1	5.00	1	5.00	0.185
Pin tract infection	0	0.00	2	10.00	
Nerve injury	0	0.00	2	10.00	
Under-correction	1	5.00	3	15.00	
None	18	90.00	8	40.00	

Discussion

Pediatric cubitus varus, a common post-traumatic deformity of the elbow, can be surgically corrected using various osteotomy techniques, including the Modified French and Three-Dimensional approaches [15]. In our study of 40 pediatric patients, there were no significant differences in age, BMI, or gender distribution between the 3D osteotomy and modified French osteotomy groups. The mean age was 11.55±2.54 years in the 3D group and 11.00±2.36 years in the French group (p=0.58), and the gender ratio was comparable (male 60% vs. 70%, p=0.52). These findings suggest that baseline demographics were well-matched, minimizing confounding effects on functional or radiological outcomes. Similar age and gender distributions were reported in prior studies evaluating pediatric cubitus varus correction, ensuring comparability of results across osteotomy techniques [16]. The etiology of cubitus varus was predominantly post-supracondylar fracture (95% in 3D osteotomy, 90% in French, p=0.548), with equal distribution of involved limbs. Duration of deformity was also similar, with mean durations of 46.10±18.57 months and 41.50±17.56 months (p=0.284). These baseline similarities support a fair comparison of surgical outcomes. Prior studies have also identified supracondylar fractures as the leading cause of pediatric cubitus varus, consistent with our cohort [17]. Perioperative outcomes favored the 3D osteotomy in some aspects and the modified French in others. Operative time was significantly longer in the 3D group (75.2±10.3 vs. 58.6±8.7 min, p<0.001), likely reflecting the meticulous multiplanar correction required. Intraoperative blood loss was also higher in 3D osteotomy (58.4±15.6 vs. 42.3±12.5 ml, p=0.002). Conversely, union time was shorter in the 3D group (10.25±1.29 vs. 12.25±1.71 weeks, p=0.001), suggesting that precise alignment facilitates faster healing. Hospital stay was slightly longer in the 3D group (3.1±0.9 vs. 2.6±0.8 days, p=0.04). Similar perioperative trends have been reported in studies comparing 3D osteotomies to conventional techniques, with enhanced precision often compensating for slightly longer operative time [7, 18]. 3D osteotomy achieved superior correction of the carrying angle (11.10°±2.13 vs. 9.40°±2.62, p=0.035) and internal rotation deformity (24.90°±2.67 vs. 22.00°±1.74, p=0.001). Elbow flexion was slightly better in the 3D group (132.90°±2.32 vs. 130.20°±3.25, p=0.008), while extension showed no significant difference. MEPS was higher in the 3D group (91.50±5.64 vs. 86.00±7.18, p=0.015). These results align with prior research indicating that 3D corrective osteotomy allows precise multiplanar correction, improving both radiological parameters and functional scores [19]. Patient-reported outcomes demonstrated a higher proportion of excellent results in the 3D group (75% vs. 40%, p=0.045). Complications were less frequent with 3D osteotomy: pin tract infections and nerve injuries were observed only in the modified French group (10% each), and under-corrections were also more common (15% vs. 5%). These findings are consistent with previous reports indicating that while modified French osteotomy remains a reliable option, 3D osteotomy offers improved precision and reduced risk of under-correction or neurovascular compromise [7, 20].

Limitations of the study: This study has certain limitations. Being hospital-based, the findings may not fully represent the broader pediatric population or practices across different regions. The follow-up period was relatively short, limiting assessment of long-term outcomes, recurrence, or late complications. Additionally, the study was conducted at only two centers, and variations in surgical expertise could have influenced perioperative and functional outcomes, introducing potential operator-dependent bias. Future multicenter studies with longer follow-up are warranted to validate these results.

Conclusion

Three-dimensional osteotomy provides superior radiological and functional outcomes compared to the modified French osteotomy in the surgical management of pediatric cubitus varus. Patients undergoing 3D osteotomy demonstrated significantly better correction of carrying angle, internal rotation, and elbow flexion, along with higher Mayo Elbow Performance Scores and a greater proportion of excellent patient-reported outcomes. Although operative time and intraoperative blood loss were higher with 3D osteotomy, union occurred faster, and complication rates were lower than with the modified French technique. Modified French osteotomy remains a reliable option, particularly in resource-limited settings, but 3D osteotomy should be considered the preferred approach for precise multiplanar correction and optimal functional restoration.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee.

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