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ORIGINAL ARTICLE

Functional and Radiological Outcomes of Three-Dimensional versus Modified French Osteotomy in Pediatric Gunstock Deformity

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Debashish Dey[1], Nazrul Islam[2], Golam Shaikh Ferdous[3], Aminur Rasul[4], Aynun Nahar Rabeya Diba[5], Mahfujur Rahman[6]

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Correspondence to
Debashish Dey

ORCID
https://orcid.org/0009-0001-8570-3674

ABSTRACT

Background: *Cubitus varus (gunstock deformity) is a common complication of malunited supracondylar humerus fractures in children, causing functional impairment and cosmetic concerns. Traditional Modified French osteotomy corrects angular deformity but often fails to address rotational and sagittal components.* ***Aim of the study:*** *To compare the functional and radiological outcomes of Three-Dimensional (3D) Osteotomy versus Modified French Osteotomy in pediatric cubitus varus.* ***Methods & Materials:*** *A prospective comparative study was conducted on 40 patients (aged 8–20 years) at BSMMU, Dhaka. Participants were equally divided into 3D Osteotomy and Modified French Osteotomy groups (n=20 each). Perioperative outcomes, radiographic parameters, functional recovery (MEPS), patient satisfaction, and complications were evaluated. Statistical significance was set at p<0.05.* ***Result:*** *3D Osteotomy demonstrated significantly shorter union time (10.25±1.29 vs 12.25±1.71 weeks), better correction of carrying angle (11.10°±2.13 vs 9.40°±2.62; p=0.035), reduced internal rotation deformity (2.25°±1.65 vs 5.60°±1.76; p=0.001), and improved humeral alignment (p=0.007). Functional scores were higher (MEPS 91.50±5.64 vs 86.00±7.18; p=0.015), with more excellent outcomes (75% vs 40%) and greater patient satisfaction (85% vs 55%). Complications such as nerve injury and loss of correction were more common in the Modified French group.* ***Conclusion:*** *Three-dimensional osteotomy offers superior functional restoration, radiological accuracy, and patient satisfaction compared to Modified French osteotomy, despite longer operative time and higher blood loss. It provides a more comprehensive correction for pediatric cubitus varus deformity.*

Keywords: *Cubitus varus, Pediatric osteotomy, Three-dimensional osteotomy, Modified French osteotomy, Supracondylar fracture, Elbow deformity*

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1. *DGHS, Deputed to Bangladesh Medical University, Dhaka, Bangladesh*
2. *DGHS, Deputed to Bangladesh Medical University, Dhaka, Bangladesh*
3. *DGHS, Deputed to Bangladesh Medical University, Dhaka,Bangladesh*
4. *DGHS, Deputed to Bangladesh Medical University, Dhaka, Bangladesh*
5. *Department of Orthopaedic, Bangladesh Medical University, Dhaka, Bangladesh*
6. *Deputed to Bangladesh Medical University, Dhaka, Bangladesh*

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 [1]. Supracondylar humerus fracture is the most common elbow injury in children worldwide, accounting for approximately 50 to 70% of all pediatric elbow fractures, and it often results from falls on an outstretched hand, potentially leading to complications such as malunion, neurovascular injury, and subsequent deformities if not managed appropriately [2]. In Bangladesh, different studies have reported that the incidence of cubitus varus deformity varies widely, ranging between 9% and 57% according to various authors [3]. Hyperextension associated with cubitus varus occurs in the natural plane of elbow movement and can partially remodel over time. In contrast, cubitus varus itself does not remodel spontaneously and therefore requires surgical correction [4]. And it also deformity is characterized by medial angulation, medial rotation, and extension of the distal humeral fragment. In some cases, injury to the medial condyle epiphysis causes growth disturbance, further worsening the deformity [5]. In the short term, a malunited forearm fracture can cause persistent pain, limited range of motion, joint instability, decreased function, and noticeable cosmetic deformity, affecting daily activities and quality of life. Over the long term, it may lead to abnormal joint mechanics and early-onset osteoarthritis in adjacent joints, resulting in chronic pain, stiffness, and further functional impairment [6]. Surgical correction of cubitus varus in adults is challenging due to poor remodeling, risk of osteotomy nonunion, infections, stiffness, and neurovascular complications, necessitating careful planning and precise technique. The modified French osteotomy is widely recognized as the standard procedure for correcting cubitus varus deformity [7]. In French osteotomy, the axis for correcting the angulation is positioned above the center of rotation of the varus deformity, which leads to lateral displacement and prominence of the

lateral condyle [8]. Where Three-dimensional CT scans reveal the morphological changes in cubitus varus elbows, including posterior trochlear overgrowth and increased internal rotation of the distal humerus at the posterior joint line. The proximal ulna undergoes adaptation by shifting the trochlear notch laterally, lengthening the articular surface in the anteroposterior direction, and moving downward and toward the midline, resulting in greater external rotation and flexion than the opposite arm [9]. Therefore, it is ideal for the patient to undergo an osteotomy that simultaneously corrects all three components of the cubitus varus deformity, restoring proper anatomical alignment of the elbow joint [10]. The aim of this study is to compare the functional and radiological outcomes of Three-Dimensional osteotomy versus Modified French osteotomy in the surgical correction of pediatric cubitus varus (gunstock deformity), with a focus on restoring anatomical alignment, correcting all components of the deformity, and evaluating postoperative range of motion, cosmetic results, and complication rates.

METHODS & MATERIALS

A comparative prospective study was conducted to evaluate the functional and radiological outcomes of Three-Dimensional (3D) Osteotomy versus Modified French Osteotomy in the management of pediatric cubitus varus (gunstock deformity). The study included a total of 40 pediatric patients who underwent corrective osteotomy between October 2022 to September 2024 at the Department of Orthopaedic Surgery, Bangabandhu Sheikh Mujib Medical University (BSMMU), Shahbagh, Dhaka. Eligible participants were divided into two equal groups (n=20 each) based on the osteotomy technique employed: 3D Corrective Osteotomy and Modified French Biplanar Osteotomy.

Inclusion Criteria:

- Children aged 8–20 years.
- Presence of cubitus varus (gunstock) deformity secondary to malunited supracondylar fracture of the humerus.
- Duration of fracture >1 year.
- No prior corrective surgery on the same limb.
- Intact neurovascular status of the affected extremity.

Exclusion Criteria:

- Congenital deformities or deformities due to bone dysplasia or systemic skeletal disease.
- Pathological fractures or fractures secondary to infection or tumor.
- Open fractures or fractures with associated neurovascular injury.
- Recurrent or residual deformities following previous corrective osteotomy.
- Associated ipsilateral upper limb fractures (forearm, humerus, or shoulder).
- Patients with metabolic bone disease (e.g., rickets, osteogenesis imperfecta).

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki (1964) for medical research involving human subjects. The purpose and procedures were clearly explained to all participants, and voluntary participation was ensured. Written informed consent was obtained prior to enrollment, with strict maintenance of privacy, anonymity, and confidentiality of all patient data. Participants retained the right to refuse or withdraw at any stage without consequence. The research protocol was first reviewed by the Academic Committee of the Department of Orthopaedic Surgery, BSMMU, and subsequently approved by the Institutional Review Board (IRB) of BSMMU, Dhaka. All collected data were securely stored and used solely for research purposes.

Surgical Techniques

Both surgeries were performed under general anesthesia with a pneumatic tourniquet. In the 3D Osteotomy group, a preoperative three-dimensional correction plan was used to restore the carrying angle, rotational alignment, and sagittal plane deformity. In contrast, the Modified French Osteotomy group underwent lateral closing wedge osteotomy with step-cut fixation. Fixation was achieved using two or three K-wires, followed by plaster immobilization for 4–6 weeks in both groups.

Data Collection

Data were collected prospectively for all enrolled patients using a structured case record form. Perioperative parameters such as operative time, intraoperative blood loss, duration of hospital stay, and time to radiological union were recorded for each case. Radiological union was defined as the presence of bridging callus across at least three cortices on both anteroposterior and lateral radiographs. Radiographic assessments were performed preoperatively and at the final follow-up using standard anteroposterior and lateral elbow views. The measured parameters included the carrying angle, humeral alignment deviation, and internal rotation angle, each evaluated independently by two observers, with the mean values used for analysis.

Functional recovery was assessed through measurements of elbow flexion and extension lag using a goniometer, the time required to regain full range of motion, the elbow stability score (0–5), and the Mayo Elbow Performance Score (MEPS) for overall functional grading (Excellent: >90; Good: 75–89; Fair: 60–74; Poor: <60). Patient satisfaction was evaluated using a three-point Likert scale (highly satisfied, moderately satisfied, dissatisfied), while postoperative pain was measured by the Visual Analogue Scale (VAS; 0–10). The time to return to school or regular activity was also documented.

All participants were followed up for a minimum of six months postoperatively. During each follow-up visit, clinical and radiographic evaluations were performed to detect any postoperative complications, including wound infection, pin tract infection, nerve injury, or loss of correction.

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) and compared using the independent samples t-test. Categorical variables were presented as frequency and percentage (%) and analyzed using the Chi-square test or Fisher's exact test, as appropriate. A p-value < 0.05 was considered statistically significant.

RESULTS

Table I demonstrated that the mean age was comparable between groups (11.55±2.54 years) vs (11.00±2.36 years); p=0.584. Males comprised 60% of the 3D Osteotomy group and 70.00% of the Modified French group (p=0.507). Most patients were right-hand dominant 95.00% and 85.00%, and the distribution of the involved limb was similar between

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groups. Falls were the most frequent cause of fracture in both groups 75.00% and 85.00%. The mean operative time was significantly shorter for the Modified French technique 58.6 ± 8.7 minutes compared with the 3D Osteotomy group 75.2±10.3 minutes. However, the 3D Osteotomy group demonstrated significantly reduced union time 10.25±1.29 weeks vs. 12.25±1.71 weeks. Intraoperative blood loss was also higher in the 3D Osteotomy group 58.4 ± 15.6 ml compared with 42.3±12.5 ml, while the mean hospital stay was marginally longer 3.1±0.9 in comparison to 2.6±0.8 days (Table II). As shown in Table III postoperative carrying angle improved significantly in both groups, but correction was greater with the 3D Osteotomy (11.10±2.13° vs. 9.40±2.62). Internal rotation deformity was better corrected in the 3D Osteotomy group (2.25±1.65°) in comparison to Modified French group (5.60±1.76). Postoperative humeral alignment also showed superior correction with 3D Osteotomy (1.8±0.9°) in contrast to Modified French group (3.2±1.1°). The patients in the 3D Osteotomy group achieved a greater flexion range (132.9±2.32° vs. 130.2±3.25), faster time to full range of motion (8.9±1.8 vs. 11.3±2.5 weeks), and higher elbow stability scores (4.8±0.3 in comparison to 4.2±0.6; p=0.002). The mean Mayo Elbow Performance Score (MEPS) was significantly higher in the 3D Osteotomy group (91.5±5.64 vs. 86.0±7.18; p=0.015) (Table IV). According to Table V excellent functional grades were more frequent in the 3D Osteotomy group (75% relative to 40%; p=0.045), with higher patient satisfaction (85% vs. 55%; p=0.032) and lower postoperative pain (VAS 2.1±0.8 vs. 3.5±1.0; p=0.001). Postoperative complications in both groups had minimal complications, though the Modified French group showed slightly higher incidences of pin tract infection and nerve injury 10%, and loss of correction 15% (Table VI).

Table – I: Baseline characteristics of the study population (*n*=40)

Parameter	3D Osteotomy (n=20)		Modified French (n=20)		P-value
	n	%	n	%	
Age (years), Mean± SD	11.55± 2.54		11.00± 2.36		0.584
Gender					
Male	12	60.00	14	70.00	0.507
Female	8	40.00	6	30.00	
Hand Dominancy					
Right	19	95.00	17	85.00	0.404
Left	1	5.00	3	15.00	
Involved limb					
Right	10	50.00	8	40.00	0.525
Left	10	50.00	12	60.00	
Cause of Fracture					
Fall	15	75.00	17	85.00	0.681
Others	5	25.00	3	15.00	

Table – II: Perioperative features of the study population (*n* = 40)

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 – III: Radiological Angles of the study

Parameter	3D Osteotomy, Mean ± SD (Min-Max)	Modified French, Mean ± SD (Min-Max)	P-value
Carrying angle (°)			
Preoperative	-21.15 ± 3.33 (-27 to -14)	-19.75 ± 3.45 (-26 to -13)	0.644
Postoperative	11.10 ± 2.13 (5–14)	9.40 ± 2.62 (3–12)	0.035
Internal rotation (°)			
Preoperative	27.15 ± 4.32 (20–36)	27.60 ± 3.50 (22–34)	0.745
Postoperative	2.25 ± 1.65 (0–5)	5.60 ± 1.76 (2–9)	0.001
Humeral alignment (° deviation)			
Preoperative	8.2 ± 2.3	8.0 ± 2.5	0.84
Postoperative	1.8 ± 0.9	3.2 ± 1.1	0.007

Table – IV: Functional outcomes among patients

Variable	3D Osteotomy (Mean ± SD)	Modified French (Mean ± SD)	P-value
Flexion range (°)	132.90 ± 2.32	130.20 ± 3.25	0.008
Extension lag (°)	3.20 ± 1.32	3.45 ± 1.43	0.432
Time to full range of motion (weeks)	8.9 ± 1.8	11.3 ± 2.5	0.001
Elbow stability score (0–5)	4.8 ± 0.3	4.2 ± 0.6	0.002
MEPS	91.50 ± 5.64	86.00 ± 7.18	0.015

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Table – V: Overall outcomes among patients (*n*=40)

Parameter	3D Osteotomy (n=20)		Modified French (n=20)		P-value
	n	%	n	%	
Functional Grades					
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	
Patient satisfaction (self-rated)					
Highly satisfied	17	85.00	11	55.00	0.032
Moderately satisfied	3	15.00	7	35.00	
Dissatisfied	0	0.00	2	10.00	
Postoperative pain score (VAS 0–10)	2.1 ± 0.8		3.5 ± 1.0		0.001
Return to school/activity (weeks)	7.2 ± 1.3		9.5 ± 2.0		0.002

Table – VI: Postoperative complications of respondents (*n*=40)

Complication	3D Osteotomy (n=20)		Modified French (n=20)		P-value
	n	%	n	%	
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	
Loss of correction	1	5.00	3	15.00	

DISCUSSION

Pediatric cubitus varus (gunstock deformity) remains a challenging post-traumatic deformity, often requiring precise surgical correction to restore function and aesthetics. In this study, we compared three-dimensional (3D) osteotomy and modified French osteotomy in 40 pediatric patients. Baseline characteristics were comparable between groups, including age, gender, hand dominance, involved limb, and cause of fracture (all p>0.05), indicating well-matched studies and minimizing confounding factors. Comparable demographics are consistent with prior studies by Kim et al. [11] and Miyake et al. [12], supporting balanced study groups in pediatric osteotomy trials. Perioperative features demonstrated that 3D osteotomy required significantly longer operative time (75.2±10.3 vs 58.6±8.7 minutes, p<0.001) and higher intraoperative blood loss (58.4±15.6 vs 42.3±12.5 ml, p=0.002). Despite these challenges, 3D osteotomy achieved faster union (10.25±1.29 vs 12.25±1.71 weeks, p=0.001) and slightly longer hospital stay (3.1±0.9 vs 2.6±0.8 days, p=0.04). Longer operative times with 3D osteotomy are consistent with prior reports emphasizing the technical complexity of multiplanar corrections [13]. Radiological outcomes favored 3D osteotomy. Postoperative carrying angle (11.10±2.13° vs 9.40±2.62°, p=0.035), internal rotation (2.25±1.65° vs 5.60±1.76°, p=0.001), and humeral alignment deviation (1.8±0.9° vs 3.2±1.1°, p=0.007) were significantly better in the 3D group. These results highlight superior anatomical restoration with multiplanar correction, consistent with Zhang et al. [14] and Hu et al. [15], who reported that 3D planning allows precise correction of rotational and angular deformities. Preoperative angles were comparable between groups, confirming that baseline deformity severity did not bias outcomes. Functional outcomes also favored 3D osteotomy. Flexion range was significantly higher (132.90±2.32° vs 130.20±3.25°, p=0.008), time to full range of motion was shorter (8.9±1.8 vs 11.3±2.5 weeks, p=0.001), and elbow stability scores improved (4.8±0.3 vs 4.2±0.6, p=0.002). MEPS was significantly higher in the 3D group (91.50±5.64 vs 86.00±7.18, p=0.015), indicating superior functional recovery. These findings align with Gurung et al. [16], who emphasized that precise multiplanar correction enhances elbow biomechanics and functional outcomes. Overall outcomes reinforced the superiority of 3D osteotomy. Excellent functional grades were achieved in 75% of patients versus 40% in the modified French group (p=0.045). Patient satisfaction was higher in the 3D group (85% vs 55%, p=0.032), postoperative pain was lower (2.1±0.8 vs 3.5±1.0, p=0.001), and return to school/activity occurred earlier (7.2±1.3 vs 9.5±2.0 weeks, p=0.002). These data highlight both objective and subjective advantages of 3D osteotomy, consistent with prior studies demonstrating enhanced patient-centered outcomes with multiplanar corrections [14]. Postoperative complications were low. Both groups had minimal superficial wound infections (5%), but the modified French group had higher rates of pin tract infection, nerve injury, and loss of correction (10–15%), reflecting the limitations of uniplanar or simpler osteotomies in addressing complex deformities [17]. No permanent neurovascular complications were reported, demonstrating the safety of both procedures when performed meticulously.

Limitations of the study:

This study was limited by its small sample size and single-center design, which may restrict the generalizability of the findings. The short follow-up period (minimum six months) did not allow assessment of long-term functional outcomes, growth-related changes, or recurrence of deformity. Additionally, the use of subjective measures such as patient satisfaction and visual analogue pain scores may have introduced response bias. Advanced imaging like postoperative 3D CT was not uniformly performed to validate rotational corrections in all cases.

CONCLUSION

Three-dimensional corrective osteotomy demonstrated superior functional and radiological outcomes compared to the Modified French osteotomy in treating pediatric cubitus varus deformity. It provided more accurate correction of carrying angle, internal rotation, and humeral alignment, with significantly improved elbow stability, faster restoration of motion, higher MEPS scores, and better cosmetic satisfaction. Additionally, 3D osteotomy resulted in shorter union time, earlier return to daily activities, and lower complication rates, particularly regarding loss of correction and nerve injury.

Although operative time and blood loss were greater, the benefits outweighed these limitations. Therefore, 3D osteotomy offers a more comprehensive and reliable correction strategy for pediatric gunstock deformity than the conventional Modified French technique.

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

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