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EVALUATION OF TREATMENT OUTCOMES OF INTERCONDYLAR HUMERUS FRACTURES IN ADULTS USING PLATE FIXATION WITH PREOPERATIVE COMPUTED TOMOGRAPHY AND 3D PRINTING

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ABSTRACT

Background: *Distal humerus intercondylar fractures are challenging intra-articular injuries characterized by comminution and instability, especially in osteoporotic bone. Anatomical reduction and early mobilization are essential to restore elbow function and minimize stiffness. Among various surgical options, dual plating fixation-either perpendicular or parallel configuration-has been shown to offer reliable stability. In recent years, the integration of 3D printing and preoperative CT-based planning has improved surgical precision, reduced operative time, and optimized outcomes in complex cases. However, clinical studies evaluating the effectiveness of 3D-assisted fixation in Vietnam remain limited.* ***Objective:*** *This study aims to evaluate the clinical and functional outcomes of treating intercondylar humerus fractures using plate fixation assisted by preoperative 3D Computed Tomography reconstruction and 3D printing.* ***Materials and methods:*** *A total of 35 adult patients (≥18 years old) diagnosed with intercondylar humerus fractures (13C AO classification) were included. All patients underwent preoperative 3D Computed Tomography reconstruction and 3D model printing to assist in open reduction and internal fixation (ORIF) at Can Tho Central General Hospital and Can Tho University of Medicine and Pharmacy Hospital from October 2022 to July 2024. This prospective, descriptive study utilized convenient sampling and evaluated outcomes based on clinical examination, functional scores, and radiographic imaging.* ***Results:*** *The mean patient age was 42.5 ± 8.9 years, with a male-to-female ratio of 1:3. The leading causes of injury were traffic accidents (54.3%) and domestic falls (34.3%). The mean operative time was 87.2 ± 18.5 minutes, and intraoperative blood loss averaged 110 ± 22 mL. Postoperatively, 74.3% of patients achieved excellent or good functional outcomes according to Cassebaum's rating system, and 80% had excellent to good results according to the Mayo Elbow Performance Score (MEPS).* ***Conclusion:*** *Preoperative 3D printing significantly enhanced surgical planning, reduced operative time and blood loss, and improved functional outcomes in treating intercondylar distal humerus fractures. This technique is a valuable adjunct in managing complex intra-articular injuries.*

Keywords: *intercondylar humerus fracture, 3D printing, preoperative planning, plate fixation.*

I. INTRODUCTION

Intercondylar fractures of the distal humerus are complex intra-articular injuries commonly seen in adults, especially in those with osteoporotic bone [1]. These fractures are often comminuted and unstable, leading to challenges in achieving anatomical reduction

and long-term functional recovery [2]. Without proper surgical intervention, complications such as joint stiffness, pain, and limited range of motion are frequently observed [3].

To restore elbow function, stable fixation and early mobilization are critical. Dual plating-either in perpendicular or parallel configuration-has become a well-established method that provides adequate stability [4], [5]. However, in complex fracture patterns, traditional imaging may be insufficient for accurate preoperative planning, contributing to longer surgical duration and higher complication rates [6], [7].

In this context, three-dimensional (3D) printing and CT-based planning have emerged as powerful tools in orthopedic trauma surgery. These techniques allow for accurate visualization of fracture morphology, pre-contouring of implants, and surgical simulation, leading to improved intraoperative decision-making [8]. Several studies have demonstrated that 3D-assisted fixation can reduce operative time, decrease blood loss, and enhance functional outcomes [9], [10], [11].

Despite these advantages, the application of 3D printing in managing distal humerus fractures remains underreported in Vietnam. Therefore, this study aims to evaluate the clinical and functional outcomes of intercondylar distal humerus fractures treated with plate fixation assisted by preoperative CT-based 3D modeling.

II. MATERIALS AND METHODS

2.1. Materials

Our study focuses on two main objectives:

1. Describing the clinical and radiographic characteristics of closed intercondylar humerus fractures.

2. Evaluating the treatment outcomes of these fractures in adults using plate fixation assisted by 3D printing and preoperative 3D Computed Tomography reconstruction.

This study involved 35 patients aged 18 and older diagnosed with intercondylar humerus fractures. All patients underwent preoperative Computed Tomography imaging and 3D model printing to assist with open reduction and internal fixation surgery. The study was conducted from October 2022 to July 2024 at Can Tho Central General Hospital and Can Tho University of Medicine and Pharmacy Hospital.

- **Inclusion Criteria:**

+ Adult patients (≥18 years old) with closed or grade I open intercondylar humerus fractures (13C AO classification).

+ Patients can provide informed consent.

+ Fractures suitable for open reduction and internal fixation based on imaging (Xray, Computed Tomography)

- **Exclusion Criteria:**

+ Open fracture

+ Pathologic fractures

+ Patients with a history of elbow joint disease or prior humerus surgery.

+ Inability to undergo follow-up for at least 6 months postoperatively.

2.2. Methods

- **Research Method:** This is a prospective, descriptive study without a control group, utilizing convenient sampling.

- **Data Analysis and Processing:** Statistical analysis was performed using SPSS version 20.0.

III. RESULTS

3.1. General characteristics of study subjects

The average age of the study group was 42.5 ± 8.9 years. In this study, 8 out of 35 patients (22.8%) were male, while 27 out of 35 patients (77.2%) were female.

The causes of injury were as follows: traffic accidents accounted for 54.3% (19/35 patients), work-related accidents accounted for 11.4% (4/35 patients), and domestic accidents accounted for 34.3% (12/35 patients).

The right side was affected in 18 out of 35 patients (51.4%), while the left side was affected in 17 out of 35 patients (48.6%).

The average surgical time was 87.2 ± 18.5 minutes.

The average intraoperative blood loss was 110 ± 22 ml.

Regarding clinical symptoms, among 35 patients, 100% experienced pain and limited mobility. Swelling was observed in 23 patients (65.7%), while bone crepitus was noted in 19 cases (54.3%). Bruising was present in 17 patients (48.6%), and deformity was recorded in 14 cases (40%). Numbness was reported in 8 patients (22.9%). No cases of vascular loss were documented.

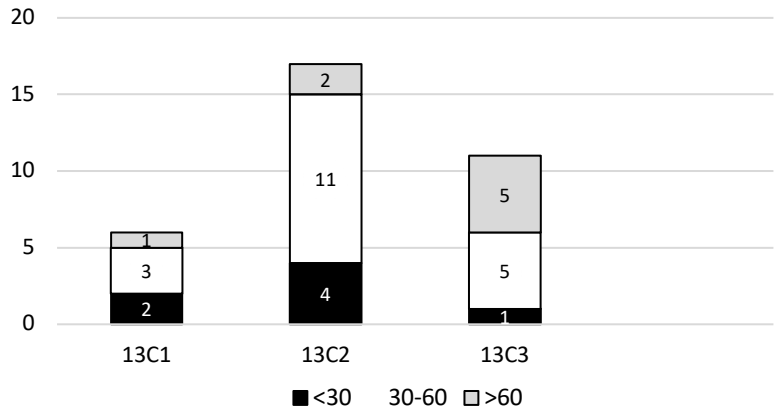

Chart 1. Distribution of ao classification by age group.

In the 13C1 group (n = 6), most patients were aged <30 (33.3%) or 30–60 (50%). The 13C2 group (n = 17) had the highest proportion in the 30–60 age group (64.7%), while only 11.8% were >60. For 13C3 (n = 12), 41.7% were over 60.

3.2. Treatment outcomes

Table 1. Evaluation of fracture reduction outcome based on aitken and rorabeck criteria

Outcome	Number	Percentage
Good	29	82.8%
Acceptable	6	17.2%
Poor	0	0%

Achieving satisfactory fracture reduction, the evaluation based on the Aitken and Rorabeck Criteria showed that the majority of patients (82.8%) had a good reduction outcome. An additional 17.2% had an acceptable outcome, while no cases (0%) were classified as poor.

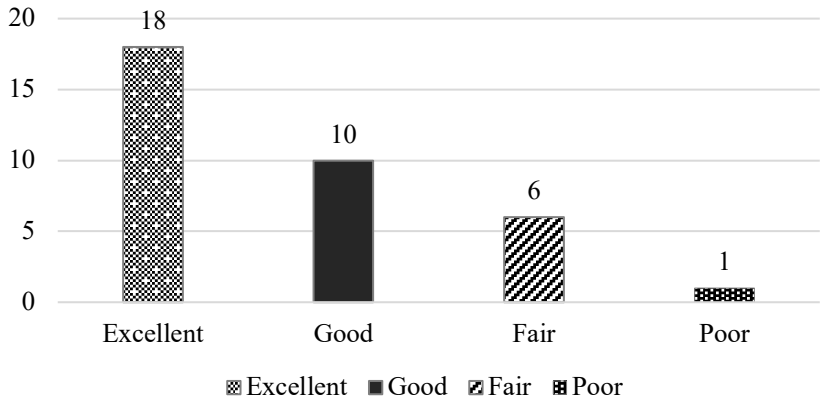

Chart 2. Evaluation functional outcomes based on mayo elbow performance score.

Our study showed 80% of patients achieved excellent or good outcomes, with 51.4% classified as excellent and 28.6% as good. Fair outcomes accounted for 17.1%, while only 2.9% had poor recovery.

These results highlight effective fracture reduction, stable fixation, and optimized rehabilitation, aided by preoperative 3D planning. Poor outcomes were limited to severe comminuted fractures (AO C3), requiring extended physiotherapy. This reinforces the benefits of advanced surgical planning in improving functional recovery.

Table 2. Evaluation of rehabilitation outcome based on Cassebaum's rating system

Rating	Extension Deficit	Flexion Range	Number of Patients
Excellent	≤ 15 degrees	≥ 130 degrees	14 (40%)
Good	15 - 30 degrees	120 - 130 degrees	12 (34.28%)
Fair	30 - 40 degrees	90 - 120 degrees	6 (17.14%)
Poor	> 40 degrees	< 90 degrees	3 (8.58%)

Based on cassebaum's rating system, our study showed promising functional outcomes, with 14 (40%) patients achieving excellent results, 12 (34.28%) patients rated as good, only 6 (17.14%) patients categorized as fair, and a small group of 3 (8.58%) patients had poor outcomes.

Table 3. Complications

Complications	Number of patients
Superficial infection	0 (0%)
Ulnar Nerve Neuropraxia	2 (4.7%)
Incisional bleeding	0
Elbow stiffness	0 (0%)
Nonunion	0 (0%)
Hardware pain	0 (0%)
Olecranon bursitis	0 (0%)

In the study, complications included 2 cases (4.7%) of ulnar nerve neuropraxia. There were no reports of deep infections or hardware-related complications, and all complications were resolved with appropriate management, demonstrating the safety of the surgical approach used in this cohort.

IV. DISCUSSIONS

Evaluation of fracture reduction outcomes: Achieving anatomical reduction is crucial for optimizing functional outcomes in intercondylar humerus fractures. In our study, 100% of patients achieved either good (82.8%) or acceptable (17.2%) reduction, with no poor outcomes. Compared to prior studies, our results show a higher proportion of good reductions: Mai Dinh Duy reported 67.4% good, while Shuang recorded 52.6% [7], [12].

A Chi-square test confirmed a statistically significant difference, suggesting that our improved reduction rates are likely due to enhanced surgical techniques, particularly preoperative 3D planning and printing. Unlike Kumar and Mai Dinh Duy [7], our study utilized 3D modeling, allowing for better fracture visualization, implant positioning, and intraoperative planning, leading to improved precision.

Most acceptable reductions were in AO/ASIF type C2 and C3 fractures, which are highly comminuted and technically demanding. Achieving optimal reduction in these cases requires meticulous planning, a well-selected approach, and precise fixation. The posterior approach with olecranon osteotomy is preferred for complex fractures, offering better joint exposure and fragment manipulation [5].

Evaluation of functional outcomes: Elbow function recovery requires assessing pain, range of motion, stability, and daily activities [6]. The Mayo Elbow Performance Score (MEPS) is widely used for this purpose. In our study, 80% of patients had Excellent (51.4%) or Good (28.6%) outcomes, while Fair and Poor accounted for 17.1% and 2.9%, respectively.

Our findings align with previous studies, such as Mai Dinh Duy [7] and Swagat Mahapatra (2017). However, a Chi-square test ($\chi^2 = 46.17$, $p = 0.00028$) confirmed a significant difference, suggesting that our superior outcomes are likely due to preoperative 3D planning and printing.

Despite overall success, complex C2, C3 fractures remain challenging. Our single poor case (2.9%) involved an AO C3 fracture with difficult reduction and delayed rehab, leading to stiffness. However, extended physiotherapy improved function, emphasizing the need for early mobilization to prevent long-term deficits.

Intraoperative blood loss: Intraoperative blood loss in our study was recorded at 110 ± 22 mL, which falls between the results of Yang [10] and Zheng [11], who reported 47 ± 16 mL and 231.1 ± 18.1 mL, respectively. Our blood loss was higher than Yang [10]'s study but significantly lower than Zheng's [11], indicating a favorable outcome regarding intraoperative bleeding. This difference may stem from the use of 3D printing technology in our study, which allowed for more precise preoperative planning and screw positioning, reducing surgical duration and minimizing soft tissue damage. While we recorded more blood loss than Yang *et al*. [10] (likely due to varying surgical complexities), the significant reduction compared to Zheng *et al.* underscores the potential benefit of advanced planning techniques like 3D printing [11].

Operative time: The mean operation time in our study was 87.2 ± 18.5 minutes, shorter than studies using traditional methods without 3D printing. Shuang *et al.* [2] reported 92.3 ± 17.4 minutes, Yang *et al.* 82.0 ± 22 minutes, Zheng *et al.* 92.0 ± 10.5 minutes, and Mai Dinh Duy (2022) 121.5 ± 32.3 minutes, demonstrating the efficiency of preoperative 3D planning in reducing surgical duration.

When compared to studies employing 3D printing, our result (87.2 ± 18.5 minutes) aligns with Shuang [12] reported 70.6 ± 12.1 minutes, Yang [10] 61 ± 13 minutes, and Zheng [11] 76.6 ± 7.9 minutes, reinforcing the time-saving benefits of this technology.

3D printing and CT-based preoperative planning enhance fracture visualization, allow for precise implant customization, and reduce intraoperative adjustments, leading to greater surgical efficiency. Our findings confirm that 3D-assisted planning significantly shortens operation time compared to traditional methods, improving both surgical workflow and patient outcomes.

Complications: Complications in managing intercondylar humerus fractures are critical considerations that can significantly affect patient outcomes.

Nonunion: Previous studies have reported nonunion rates of 6% (Kundel, 1996) [14], particularly in the supracondylar region (O'Driscoll, 2005) [15]. In our study, no nonunion was observed in 35 patients after 6 months, suggesting potential benefits of 3D-printed preoperative planning and custom plates for precise alignment and stable fixation. However, longer follow-up is needed to confirm this outcome.

Ulnar nerve injury: A common complication due to the nerve's proximity to the fracture site. Risk factors include fracture displacement, prolonged tourniquet time, and poor soft tissue handling. Vazquez [13] reported 10.1% immediate post-op ulnar nerve dysfunction, rising to 16% at 12 months. Our study recorded two cases, both of whom recovered fully within two months, emphasizing the importance of early intervention and close monitoring for successful recovery.

V. CONCLUSIONS

The integration of three-dimensional (3D) printing and CT-based preoperative planning offers substantial advantages in the surgical management of intercondylar distal humerus fractures. In this study, 3D-assisted fixation significantly improved anatomical reduction rates, reduced intraoperative blood loss, and shortened operative time when compared with traditional techniques. These findings align with previous research, further supporting the role of 3D printing in enhancing surgical precision and postoperative functional outcomes. With 80% of patients achieving good to excellent functional recovery and a low incidence of complications-particularly regarding ulnar nerve injury and nonunion-our results affirm the clinical efficacy and safety of this approach. When compared with both local and international reports, the outcomes underscore the effectiveness of individualized preoperative planning based on 3D modeling in managing complex intra-articular fractures. Therefore, 3D printing should be considered a valuable adjunct in the treatment of intercondylar distal humerus fractures, particularly in cases involving severe comminution or complex anatomical challenges.

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