

Correlation of Central Column Diaphyseal Angle, Humeral Head Height, Greater Tuberosity to Articular Surface Distance, Age and Fracture Pattern with Constant Murley Score Functional Outcomes in Post-ORIF PHILOS Patients with Proximal Humerus Fracture

I Made Artha Wiguna Sanjaya¹, I Ketut Suyasa², Made Bramantya Karna²

¹ Resident, Department of Orthopaedic and Traumatology, Faculty of Medicine, University of Udayana/Prof. Ngoerah General Hospital, Denpasar, Indonesia.

² Orthopaedic and Traumatology Consultant, Department of Orthopaedic and Traumatology, Faculty of Medicine, University of Udayana/Prof. Ngoerah General Hospital, Denpasar, Indonesia.

Corresponding Author: I Made Artha Wiguna Sanjaya

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ABSTRACT

Introduction: Proximal humerus fractures (PHF) are common injuries, particularly in the elderly population, caused by both direct and indirect trauma. The Proximal Humerus Internal Locking System (PHILOS) is a widely used treatment for displaced or complex PHF. To assess shoulder function, the European Society for Surgery of the Shoulder and the Elbow recommends the Constant–Murley Score (CMS) as a reliable tool for evaluating shoulder joint outcomes.

Materials and Methods: This cross-sectional study was conducted at RSUP Prof I.G.N.G. Ngoerah, Denpasar, Bali, between May 2024 and July 2024. Descriptive analysis was used to determine patient characteristics. The relationships between Central Column Diaphyseal Angle (CCDA), Humeral Head Height (HHH), Greater Tuberosity to Articular Surface Distance (GT-ASD), and CMS were analyzed using Pearson correlation for normally distributed data and Spearman correlation for non-normal data.

Results: Statistically significant relationships were found between CCDA, HHH, and GT-ASD with the CMS in patients who underwent ORIF PHILOS for proximal humerus fractures ($r=0.915$; $p<0.001$). A significant correlation was also observed between fracture pattern and CMS outcomes. However, age did not show a significant relationship with CMS.

Conclusion: CCDA with a cutoff of 109.5 degrees was identified as a primary predictor of functional outcomes. HHH and GT-ASD were also significant, indicating the importance of anatomical restoration for shoulder function recovery. Age did not affect CMS outcomes, emphasizing that the quality of anatomical reconstruction is more critical than age in predicting functional recovery post-surgery.

Keywords: CCDA, HHH, GT, AS, Fracture Pattern, Constant Murley Score

INTRODUCTION

Proximal humerus fractures are common injuries, especially in the elderly population, caused by both direct and indirect trauma.

Whether treated conservatively or operatively, this fracture often leads to complications such as joint stiffness. Joint stiffness caused by fractures is influenced by multiple factors, such as bone positioning and soft tissue damage resulting from Open Reduction and Internal Fixation (ORIF). Bone factors include Central Column Diaphyseal Angle (CCDA), Humeral Head Height (HHH), and Greater Tuberosity to Articular Surface Distance (GT-ASD), which need to be repositioned or restored as anatomically as possible to achieve optimal function. This has prompted researchers to investigate whether there is a relationship between these parameters and the functional outcome measured by the Constant Murley Score (CMS) after ORIF with the Proximal Humerus Internal Locking System (PHILOS). (Chen, C.Y. *et al.* (2020)

Proximal humerus fractures are the seventh most common fracture in adults. Its prevalence ranges from 4 to 10% of all fractures, according to several studies conducted in different populations. Incidence rate varies significantly, depending on the geographic region and the year the study was conducted. It has been suggested that overall fracture rates have increased with the aging population following the post-war period (Iglesias-Rodríguez *et al.*, 2021).

PHILOS is a treatment option for displaced or complex proximal humerus fractures due to its anatomically analogous design, which allows for angular stability and increases bone tensile strength through the use of converging and diverging locked screw construction. However, many studies have reported complications associated with the use of this technique (Relvas Silva *et al.*, 2022).

To evaluate the integrity of the medial calcar region in cases of proximal humerus fractures, it is recommended to measure the CCDA. This measurement represents the angle formed by the intersection of the perpendicular line of the anatomical neck of

the humerus with the axis of the humeral shaft. A higher CCDA value indicates a greater shift and disruption of the medial calcar, which is associated with more complex and unstable postoperative fractures. HHA measurement is obtained by measuring the distance between two parallel lines: the upper edge of the humeral head and the proximal end of the plate. This measurement helps assess the risk of subacromial impingement. The GT-ASD measurement is used to evaluate the reduction of the humeral head (Relvas Silva *et al.*, 2022).

To assess shoulder and elbow function across various diagnoses, the European Society for Surgery of the Shoulder and the Elbow has recommended using the Constant Murley Score (CMS) as a reference for evaluating shoulder joint functional outcomes (Vrotsou *et al.*, 2018). CMS was first introduced in 1987 as an instrument to evaluate overall shoulder function, regardless of the underlying diagnosis (Vrotsou *et al.*, 2018). This score has been approved by the executive committee of the European Society for Surgery of the Shoulder and the Elbow and has since been widely used as a method for assessing shoulder function (Vijan and Saoji, 2020). The CMS scale measures four aspects of shoulder pathology: two subjective (pain and daily activities) and two objective (range of motion and strength) (Schumaier and Grawe, 2018). Although CMS remains a popular functional assessment method in the context of proximal humerus fractures, challenges regarding its reliability and applicability to various shoulder pathologies continue to be discussed in the literature (Beks *et al.*, 2018).

Proximal humerus fractures are common in the elderly, with various fracture patterns, and are often considered pathological fractures due to osteoporosis. However, they can also occur in younger individuals due to trauma. To date, no studies have evaluated the relationship between radiological measurements, age, and fracture patterns

with CMS in patients with proximal humerus fractures, particularly in Indonesia.

MATERIALS & METHODS

This study employed a cross-sectional design to assess the relationship between radiological parameters and functional outcomes in patients with proximal humerus fractures post-ORIF using PHILOS. The variables measured included Central Column Diaphyseal Angle (CCDA), Humeral Head Height (HHH), and Greater Tuberosity to Articular Surface Distance (GT-ASD), which were interpreted by a radiologist. Functional outcomes were evaluated using the Constant Murley Score (CMS) questionnaire. The target population comprised all patients with proximal humerus fractures, while the study sample included patients who had undergone ORIF with PHILOS at RSUP Prof. Dr. IGNG Ngoerah and returned for a six-month postoperative evaluation. Consecutive sampling was used until the required sample size was reached.

Inclusion criteria:

1. Patients aged 40-80 years.
2. Patients with Neer 2-part, 3-part, or 4-part fractures.
3. Patients who underwent ORIF with PHILOS performed by the same surgical team.
4. Titanium PHILOS plate used as the implant.
5. Patients who had surgery at least six months prior to the study.
6. Willingness to participate in the study.

Exclusion criteria:

1. Patients with proximal humerus fractures accompanied by ipsilateral upper extremity fractures.

2. Patients with chronic conditions such as diabetes mellitus or obesity.
3. Postoperative complications such as infection, malunion, nonunion, or avascular necrosis affecting functional outcomes.
4. Severe comorbidities like stroke or paralysis affecting rehabilitation.

Data were analyzed using SPSS version 29, with correlation analyses applied to explore the relationship between radiological parameters and CMS.

RESULT

This study included a sample of 24 patients who underwent Open Reduction Internal Fixation (ORIF) with the Proximal Humerus Internal Locking System (PHILOS) for proximal humerus fractures at RSUP Prof. Dr. I.G.N.G. Ngoerah in Denpasar, Bali. The study aimed to explore the relationship between Central Column Diaphyseal Angle (CCDA), Humeral Head Height (HHH), Greater Tuberosity to Articular Surface Distance (GT-ASD), fracture pattern, and age with the functional outcome measured by the Constant Murley Score (CMS) in a single group of patients.

The research results are presented as mean \pm standard deviation due to the numerical variable data. Normality testing was then conducted using the Shapiro-Wilk test because the total sample size was less than 50. Homogeneity testing was subsequently performed using the Levene test, which showed that the data for age, Central Column Diaphyseal Angle, Humeral Head Height, and Greater Tuberosity to Articular Surface Distance had a homogeneous data distribution ($p > 0.05$), while the data for the Constant Murley Score had a heterogeneous distribution ($p < 0.05$).

Characteristic	Total n=24 (%)
Age	
<50 years	8 (33,3)
50-60 years	5 (20,8)
>60 years	11 (45,83)
Gender	
Male	9 (37,5)
Female	15 (62,5)
Body Mass Index (BMI)	
Underweight	0 (0)
Normal	15 (62,5)
Overweight	5 (20,8)
Obesity I	4 (16,6)
Obesity II	0 (0)
Obesity III	0 (0)
Fracture Pattern	
Neer 2 parts	15 (62,5)
Neer 3 parts	4 (16,6)
Neer 4 parts	5 (20,8)
Greater Tuberosity	0 (0)
Lesser Tuberosity	0 (0)
Constant Murley Score	
Baik (≥ 56)	15 (62,5)
Buruk (< 56)	9 (37,5)

Table 1. Characteristics of Patients After ORIF PHILOS for Proximal Humerus Fracture

Characteristic	Total n=24 (%)	Normality Test	Homogeneity Test
Age(year) (mean±SD)	55,04±20,15	0,055	0,344
Central Column Diaphyseal Angle (mean±SD)	121,29±10,61	0,028	0,616
Humeral Head Height (mean±SD)	10,64±3,67	0,081	0,520
Greater Tuberosity to Articular Surface Distance (mean±SD)	7,86±2,64	0,037	0,694
Constant Murley Score (mean±SD)	76,791±16,30	0,006	0,015

Table 2. Research Results and Normality Test on the Research Sample

I Made Artha Wiguna Sanjaya et.al. Correlation of central column diaphyseal angle, humeral head height, greater tuberosity to articular surface distance, age and fracture pattern with constant Murley score functional outcomes in post-ORIF PHILOS patients with proximal humerus fracture

Central Collumn Diaphyseal Angle (N=24)	Mean ± sb		r	p
	Variable	Constant Murley Score		
Central Collumn Diaphyseal Angle	121,29±10,61	76,79±16,30	0,915	<0,001
Humeral Head Height	10,64±3,67	76,79±16,30	0,994	<0,001
Greater Tuberosity to Articular Surface Distance	7,86±2,64	76,79±16,30	0,900	<0,001
Age (Year)	55,04±20,15	76,79±16,30	-0,198	0,830

Table 3. Correlation Analysis of Variables with Constant Murley Score in Proximal Humerus Fracture after ORIF PHILOS

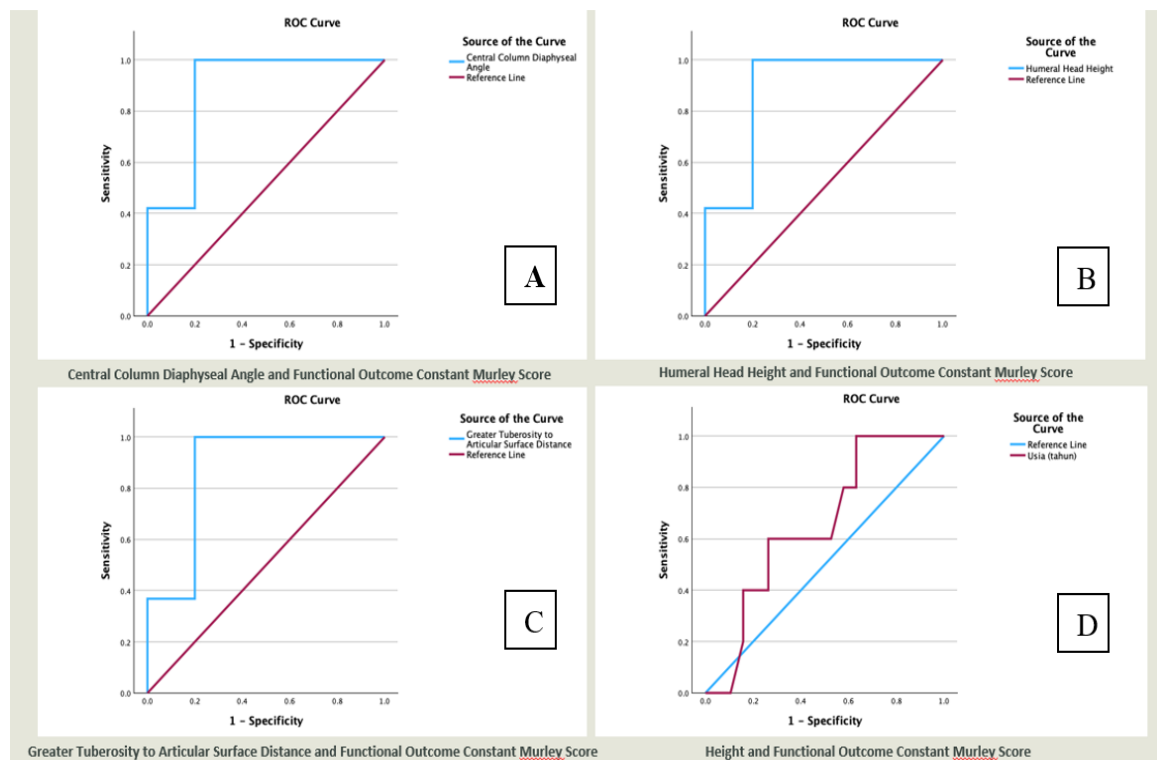
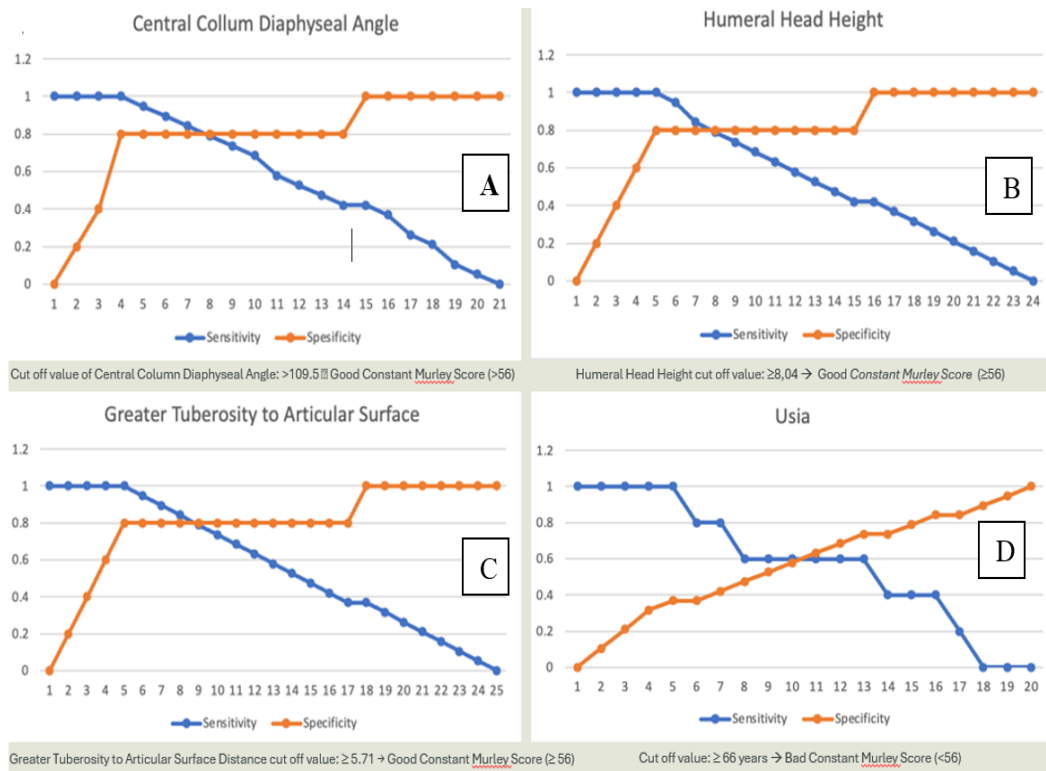


Figure 1. A: ROC Curve the relation between Constant Murley Score and (A) CCDA, (B) HHH, (C) Greater Tubercle, (D) Age



DISCUSSION

This study investigated the relationship between several anatomical variables and functional outcomes, as measured by the Constant Murley Score (CMS), in patients with proximal humerus fractures following ORIF PHILOS. Central Column Diaphyseal Angle (CCDA) and Functional Outcomes. Our findings revealed a statistically significant correlation between the Central Column Diaphyseal Angle (CCDA) and the Constant Murley Score ($r = 0.915$; $p < 0.001$). The optimal CCDA is critical for maintaining proper anatomical alignment and shoulder function post-surgery. Literature suggests a normal CCDA range of 120° – 137° (Wang et al., 2019), and our study found that a CCDA of $\geq 109.5^{\circ}$ was associated with lower CMS values. Deviations from the optimal CCDA can lead to biomechanical abnormalities, negatively affecting shoulder stability and function. This supports previous findings that surgical adjustments to the CCDA can enhance

functional outcomes (Fjalestad et al., 2005; Wang et al., 2020).

Humeral Head Height (HHH) and Functional Outcomes. The study also demonstrated a significant correlation between Humeral Head Height (HHH) and CMS ($r = 0.994$; $p < 0.001$). A normal HHH is vital for optimal shoulder biomechanics, and deviations can lead to mechanical imbalance, pain, and reduced mobility. The cut-off HHH value in our study was ≥ 8.04 mm, which was higher than previously reported values in the literature (Wang et al., 2018). Maintaining proper HHH alignment during surgery can reduce complications such as malunion and improve functional recovery (Boileau et al., 2002; Robinson et al., 2003).

Greater Tuberosity to Articular Surface Distance (GTASD) and Functional Outcomes. There was a significant relationship between Greater Tuberosity to Articular Surface Distance (GTASD) and CMS ($r = 0.900$; $p < 0.001$). The cut-off value of GTASD in this study was ≥ 5.71

mm, which was slightly lower than the normal value of 7.2 mm reported in previous studies (Dheenadhayalan et al., 2019). Ensuring proper GTASD during internal fixation reduces stress on the rotator cuff and minimizes the risk of malunion, contributing to better functional outcomes (Platzer et al., 2008; Osterhoff et al., 2011).

Fracture Pattern and Functional Outcomes. The study identified a statistically significant association between fracture pattern and CMS ($p = 0.047$). Patients with Neer 2-part fractures were 11.2 times more likely to achieve higher CMS scores compared to those with more complex fractures, such as Neer 3- and 4-part fractures. Less complex fracture patterns are associated with better functional recovery due to less disruption to the rotator cuff and surrounding structures (Court-Brown, Garg, and McQueen, 2001).

Age and Functional Outcomes. Although age is often considered a factor influencing functional outcomes, this study found no statistically significant correlation between age and CMS in patients following ORIF PHILOS ($r = -0.198$; $p = 0.830$). While older patients generally experience slower recovery due to reduced healing capacity and higher risk of complications, this study did not observe a strong age-related decline in shoulder function. This finding contrasts with previous research that highlights the challenges faced by older patients, such as muscle degeneration and comorbidities, in achieving optimal CMS scores (Spross et al., 2019).

CONCLUSION

This study found significant relationships between various anatomical parameters and functional outcomes based on the Constant Murley Score (CMS) in patients post-ORIF with PHILOS plates for proximal humerus fractures. Specifically, Central Column Diaphyseal Angle was strongly and significantly correlated with functional outcomes, with a statistically significant cutoff point of 109.5° . Humeral Head

Height showed a strong and statistically significant relationship with CMS, with a cutoff point of 8.04 mm. Greater Tuberosity to Articular Surface Distance also had a strong, statistically significant relationship with CMS, with a cutoff point of 5.71 mm. Fracture Pattern was found to have a statistically significant relationship with CMS.

However, there was no significant relationship between age and functional outcomes, with a weak negative correlation and a cutoff point of 66 years. In summary, anatomical alignment factors such as Central Column Diaphyseal Angle, Humeral Head Height, and Greater Tuberosity to Articular Surface Distance are critical for predicting functional recovery in patients with proximal humerus fractures, while age does not appear to be a strong predictor of functional outcomes

Declaration by Authors

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