Influence Of Neck Shaft Angle Of Humerus In Prosthetic Design

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ABSTRACT:

Background: A better understanding of the proximal humerus is essential for anatomical reconstruction of the glenohumeral joint during prosthetic replacement. The neck-shaft angle is critical for correct calcar screw positioning when fixing a proximal humeral fracture with a locking plate. It's essential for exact implant placement and treatment of any soft-tissue or bone pathology. Improper implants cause discomfort and post-operative complications, therefore understanding the humeral neck shaft angle is fundamental in the design and manufacturing of prostheses. This study looked into the necessity regional data of the humeral neck shaft angle (NSA) and its importance in shoulder prosthesis manufacturing.

Method: This cross-sectional investigation was conducted on 300 dry cadaveric humeri of unknown gender and age that were free of damage or deformity. The Goniometer was used to measure the neck shaft angle. The data was analysed using SPSS software. The standard deviation and mean were calculated. The statistical difference between the right and left humeri was assessed using the students' t’ test.

Observations: The NSA of the humerus was 131.26±5.82º on average. The NSA mean values were substantially higher on the right side. A statistically significant difference between the right and left humeri was revealed by a P value of 0.001.

Conclusion: Success of the shoulder arthroplasty demands anatomical reconstruction of the normal neck-shaft angle of the humerus. Racial variations in the morphometry of the neck-shaft angle needs to be considered in prosthesis design.

KEY WORDS: Arthroplasty, Humerus, Neck-shaft angle, Prosthesis design, Shoulder joint
Introduction

In the late 1990s, a thorough investigation of shoulder anatomy as it relates to prosthetic geometry commenced. It has become evident that normal anatomy demonstrates a considerable measure of individual variation. Humeral implants have been widely popular in recent times, owing to a broader understanding of shoulder anatomy and function. Surgeons executing shoulder arthroplasty should have a comprehensive understanding of glenohumeral anatomy and modern design components. Fracture of Proximal humerus are more frequent among older people with osteoporosis and it constitutes about 4 - 5 percent of all fractures [1]. These minimally displaced fractures can, in most situations, be treated conservatively [2]. Surgical intervention is essential in 15-20% of displaced cases [1].

In shoulder arthroplasty, the neck-shaft angle is a critical factor in defining the varus and valgus angles of the prosthesis [3]. The neck-shaft angle, also known as inclination angle is produced by a line passing between the shaft's central intramedullary axis and a line perpendicular to the articular segment's base. It is a method of determining the coronal displacement of the proximal humerus [4,5]. It may be used to plan arthroplasty and osteotomy, as well as to assess the effects of osteosynthesis. Neck-shaft angle is approximately 135° in most of the cases [6]. A prosthetic design with a fixed NSA allows for the reproduction of the humeral center of rotation with a simple and more cost-effective prosthetic solution.

Surgeons executing shoulder arthroplasty should have a comprehensive understanding of glenohumeral anatomy and modern design components. It has become evident that normal anatomy demonstrates a considerable measure of individual variation. Same kind of implants are not suitable for different populations.
as the angulations varies with populations. The current study aimed to make a baseline data on the neck-shaft angle of humerus in Western Indian population.

**Materials and Methods**

The cross sectional analytical study was approved by the Institutional Ethics Committee. The dried and preserved humeri (300, 150 Right & 150 Left) for the study were obtained from the Anatomy department of Medical Institutes of Western India during the period 2019 June -2021 December. The permission for the study was obtained from the head of the institute prior to the study. The specimen were placed on a flat surface. Lower end of the humerus was slightly rotated laterally to negate the torsion of upper epiphysis so that the neck shaft angle is clearly seen. A midpoint of the anatomical neck was marked on the anterior aspect using Vernier Calliper. A line intersecting this point was marked as the head - neck axis. Axis of the shaft was recognized by finding midpoints of the shaft using Vernier Calliper. The angle formed between these two axes was measured using Goniometer [7](Figure1). The measurements were recorded by single observer and repeated thrice to remove intra-observer variation.

**Inclusion criteria:** Non pathological intact dry humeri of unknown age and gender were used for the analysis.

**Exclusion criteria:** Bones with defects, arthritic deformity or damage were excluded.

**Statistical analysis**

The statistical analysis of the study was performed by SPSS (Statistical Package for the Social Sciences) for windows version 18.0 (SPSS Inc., Chicago, IL, USA). Mean and standard deviation were calculated. Unpaired student’s ‘t’ test was used to
compare the means. A value of \( p < 0.05 \) value was accepted as statistically significant.

**Results**

The data related to the findings of the study is tabulated in the Table 1. The mean NSA of the humerus (300) was 131.26±5.82 \(^\circ\). The findings of the study were similar to those of reported by various authors[6,7,8]. Statistically significant difference were discovered between right and left bones (\( P \)-value = 0.001). The left humeri showed the average NSA of 130.15±3.06\(^\circ\) and the right bones it was 132.37 ±7.48\(^\circ\).

**Discussion**

The use of shoulder prostheses started in 1973 [10]. Many investigations have been done since then to characterize the pathological variations in the proximal humerus and the importance of restoration of normal anatomy [10-13]. Several biomechanical studies showed that a modular prosthetic design brings better clinical results [13-15]. Variable inclination angle implants require the surgeon to respect the humeral head as much as possible along the anatomic neck, and later offer either variable or adjustable geometries to fit the resulting inclination angle. Implants with a set inclination angle (anywhere within the usual region), on the other hand, direct the surgeon to perform an osteotomy at this inclination, then modify the fit with further canal preparation and amendments as needed.

The mean NSA of the humerus falls in the range of 135\(^\circ\) to 140\(^\circ\), but the literature demonstrates significant individual variation (range, 125\(^\circ\)–150\(^\circ\)) [7]. The mean NSA of the humerus in the present work was 131.26\(^\circ\)±5.82\(^\circ\). Malavolta et al evaluated the neck-shaft angle of 18 cadaveric humeri in different positions and reported an NSA of 137\(^\circ\)±4\(^\circ\) in the neutral position [16]. Assunçao JH et al documented a mean NSA of 132±6\(^\circ\) in Brazilian population [6]. Iyem C et al reported 136.4\(^\circ\) ± 3.5\(^\circ\) NSA in
the Turkish population [3]. These authors measured anteroposterior radiographs of
the shoulder joint. Jeong et al studied 2058 humeri and noted an average neck-shaft
angle of 134.7° [17]. Goldberg RW et al studied the NSA and version of 1104
cadaveric humeri and reported that the variables are independent of sex and age.
They found substantial disparities between NSA and race [18]. Hertel R et al
measured the NSA directly on 200 dry humeri and reported that the NSA ranged
between 132° and 142° [10].
NSA is an important parameter in shoulder arthroplasty as the angular movement of
the post operative shoulder joint is greatly related to the varus and vulgus angle of
the prosthesis. Iannotti discovered a link between NSA and the humeral head size
[7]. He also stated that any NSA variation in the humeral component other than the
anatomical NSA results in a lower displacement of the humeral head's rotational
center; hence, results in the prominent greater tubercle [7]. Extreme varus and valgus
are found to affect the postoperative results of humeral fracture and prosthetic
restoration [19]. Takase K et al analysed the impact of NSA on the geometry of the
glenohumeral joint, especially with lateral humeral offset. They did not find any
correlation between the both [20].
Longo U G et al. observed a positive outcome in terms of the range of motion like
abduction, external rotation, and forward bending in the groups with an NSA of 155°,
145°, and 135°. They observed that an implant with NSA of 145° is good in terms of
postoperative forward flexion and of with 135° is good in external rotation [21].
Gobezie et al. [22] were unable to detect any differences between humeral inclinations
of 135° and 155° in postoperative forward flexion and external rotation values. Werner
B et al in their study found implant with lesser NSA enjoys impingement-free motion
range and suggested the use of a 135° NSA model implant for smooth functioning of
the post-operative shoulder [23].

The impact of NSA of reverse humeral on anterior dislocation force, abduction
moment, as well as impingement-free motion range were examined by Oh JH et al.
They tested six cadaveric shoulders with 155°, 145°, and 135°. The 135° neck-shaft
angle at 30° of external rotation and the 155° of internal rotation both greatly increased
the anterior dislocation force. Although it was more stable when internally rotated, the
155° NSA was more susceptible to scapular impingement during adduction [24]. Bart
Middernacht et al. in a critical review suggested the use of a prosthesis with 135° for
gain in adduction motion and reduced notching. They pointed out that designs with an
inclination of 155° increase the incidence of scapulohumeral conflict [25].

The normal variability of the humeral neck-shaft angle creates some difficult choices
for prosthetic design. Anatomical restoration is successful only if the NSA of an
implant system matches the NSA of the native humerus into which it is being
implanted [7]. An anatomical head varus osteotomy results when the neck-shaft angle
of a fixed-angle implant is smaller than that of the natural humerus. A valgus
osteotomy is made for the anatomical NSA if the prosthesis' angle exceeds that of the
natural humerus [7].

Changes in prosthesis design are necessary because of demographic or racial
differences. Thus, the use of population-specific implants increases the functionality
of the prosthesis. For prosthesis design, certain knowledge about the normal
morphometry of proximal epiphysis of the humerus and glenoid part is critical [18].
Morphometric data of the proximal humerus thus play a vital role in the appropriate
design of the humeral component [11].
This study is important because compatibility with normal anatomic structure must be taken into consideration in the design of the humeral component. The restricted shoulder motion and subluxation might result from an improper prosthesis [3]. The main reason for most shoulder arthroplasty post-operative problems is the inability of several current shoulder replacement methods to restore normal morphometry [26].

This study aims to demonstrate that each population's morphometric data differs from one another, and that prosthesis applications will be more successful if these variations are taken into account. In Table 2, the results of the present research are contrasted with those of investigations that were done on other ethnic communities. These findings demonstrated that there are variations in morphometric data of proximal humerus in different populations. Prosthesis manufacturers should consider these differences for postoperative success.

**Limitations**

Prosthesis manufacturers should consider these differences for postoperative success. The significant drawback of the study was that the humeri investigated were of unknown origin, age, and gender. The previous clinical conditions of the donors were unknown. It would have been better if these data were available.

**Conclusion**

The present study tried to make baseline data on the NSA of the humerus in the Western Indian people. The NSA values of this study were lesser than the data of western countries. These results show each population has variations in the NSA of the humerus. These differences between populations described could form a database for prosthesis manufacturers designing the humeral component. It is important to
take care while calculating the NSA values since an excessive varus angle may result in subluxation and an excessive valgus angle can cause impingement in adduction.

Reference


### TABLES

#### Table 1. Neck shaft angle of humerus

<table>
<thead>
<tr>
<th>Author And Year Of Study</th>
<th>Population</th>
<th>NSA±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study (2022)</td>
<td>India</td>
<td>131.26° ± 5.82°</td>
</tr>
<tr>
<td>Goldberg RW et al. (2020) [18]</td>
<td>America</td>
<td>137° ± 6°</td>
</tr>
<tr>
<td>Iyem C et. al. (2017) [3]</td>
<td>Turkey</td>
<td>136.4° ± 3.5°</td>
</tr>
<tr>
<td>Zhang et al. (2007) [8]</td>
<td>China</td>
<td>132.4° ± 4.7°</td>
</tr>
<tr>
<td>Takase K et al. (2004) [20]</td>
<td>Japan</td>
<td>140.4° ± 4.1°</td>
</tr>
<tr>
<td>McPherson et al. (1997) [27]</td>
<td>USA</td>
<td>141° ± 8.6°</td>
</tr>
</tbody>
</table>

*Students’ ‘t’ test for the difference of means; p-value <0.0001 was considered as statistically significant.

#### Table 2. Neck shaft angle of humerus reported in different population.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (±S.D.)</th>
<th>Std. Error of Mean</th>
<th>t-value</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left Humerus</strong></td>
<td>150</td>
<td>130.15 ±3.06°</td>
<td>0.25</td>
<td>3.35</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Right Humerus</strong></td>
<td>150</td>
<td>132.37 ±7.48°</td>
<td>0.61</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>300</td>
<td>131.26 ±5.82°</td>
<td>0.34</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

*Students’ ‘t’ test for the difference of means; p-value <0.0001 was considered as statistically significant.
Figures

Figure 1. Measurement of neck shaft angle using goniometer.

Figure 2. Neck shaft angle of Right humerus 144°

Figure 3. Neck shaft angle of Right humerus 120°
Figure 4. Neck shaft angle of Left humerus 135°

Figure 5. Neck shaft angle of Left humerus 125°
Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: