**RECONSTRUCTION OF ANATOMIC HUMERAL HEAD RETROVERSION FOLLOWING 4-PART FRACTURES OF THE PROXIMAL HUMERUS: A COMPARISON OF TWO TECHNIQUES**

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**Introduction**

Accurate reconstruction of anatomic humeral head retroversion is a significant concern in treatment of 3 & 4 part fractures of the proximal humerus. Inadequate reconstruction (i.e. attaching the greater and lesser tuberosities to the prosthesis in too much or too little version) alters muscle lever-arms, rotator cuff tension, stability, & joint kinematics. Combined, these factors can impede or hinder tuberosity healing …ultimately leading to tuberosity complications: an important predictor of poor outcomes. The purpose of this study is to quantify the accuracy associated with 2 different techniques to reconstruct anatomic humeral head retroversion (HHR). The first technique relates to using the distal bicipital groove as an anatomic landmark by which the anterior/lateral fin of the proposed fracture humeral stem should be aligned during implantation. The second technique relates to the conventional method of orienting the fracture stem according to a fixed value of 20°, relative to the epicondylar axis. The specific aim is to evaluate the null hypothesis that there is no difference in the ability of the two techniques to accurately reconstruct anatomic humeral head retroversion.

**Methods**

A total of 49 dried cadaveric humeri (31 left, 18 right) were obtained from the Anatomy Lab at Bordeaux Medical University, France (Prof. Vital) and used in this study to characterize the three-dimensional (3-D) geometry of the proximal humerus. Particular attention was paid to the 3-D geometry of the bicipital groove: a CMM (MC 850, Zeiss) was used to digitize the length of the bicipital groove, relative to the intramedullary axis (1st axis), the humeral head equatorial plane (HHEP, 2nd axis), and the axis orthogonal to the previous two (3rd axis). This technique was associated with an angular accuracy of ±1° & a linear accuracy of 20.75 mm. It should be noted that the HHEP is defined as the plane that is perpendicular to the anatomic neck that passes through the superior & inferior points on the articular surface. This data was used to quantify the anterior offset & lateral offset of the bicipital groove at four different heights: H1, H2, H3, & H4. It should be noted that anterior offset (BGAO) is defined as the distance between the bicipital groove and the intramedullary axis in the anterior/posterior plane. Similarly, lateral offset (BGLO) is defined as the distance between the bicipital groove and the intramedullary axis in the medial/lateral plane. It was observed that the anterior offset of the distal bicipital groove was relatively constant for each humeri & parallel to the HHEP (see Table 1 & Figure 1); therefore, the bicipital groove orientation (BGO) can be related to HHEP by Equation 1:

\[
BGO = \text{ARCTAN} (\text{BGAO}/\text{BGLO}) \quad \text{Equation 1}
\]

An asymmetric fracture stem with an anterior/lateral fin was designed to have an anterior fin offset (FAO) that accommodates for the observed orientation of the distal bicipital groove; doing so enables this prosthesis to use the bicipital groove as an anatomic landmark to determine stem version. For each of the humeri observed in this study, the accuracy of this technique to reconstruct the anatomical humeral head retroversion can be described by Equation 2:

\[
\text{Retroversion Error 1} = BGO - \text{ARCTAN} (\text{FAO}/\text{BGLO}) \quad \text{Equation 2}
\]

Alternatively, the version of the fracture stem can be determined using a fixed angle of 20° relative to the epicondylar axis. For each of the humeri observed in this study, the accuracy of this technique to reconstruct the anatomical humeral head retroversion can be described by Equation 3:

\[
\text{Retroversion Error 2} = \text{HHR} - 20° \quad \text{Equation 3}
\]

For further clarification, the relationships between each parameter are depicted in Figure 1, where HHPO describes the humeral head posterior offset & HHR is measured relative to the epicondylar axis.

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**Results**

The average humeral head retroversion (HHR) for each of the 49 humeri observed in this study was determined to be 20.1° ± 11.0° (1.1° – 41.5°). The BGAO and the BGLO at each of the specified heights are presented in Table 1. A review of this data reveals that the BGAO is fairly constant at the distal end (the location of the groove that would still be visible in the presence of a 3 or 4 part proximal fracture). Therefore, the FAO chosen for the aforementioned fracture stem design was 7.5 mm. The mean angular errors associated with each of the aforementioned techniques used to reconstruct the anatomic humeral head retroversion for each of the humeri used in this study are presented in Table 2.

**Discussion**

The results of this study indicate that the distal bicipital groove can be used as an anatomic landmark to reconstruct anatomic humeral head retroversion in case of fractures and can be facilitated by a prosthesis that accommodates for the orientation of the bicipital groove. This analysis indicates that a fracture stem with a FAO = 7.5 mm, is associated with ~ 115% greater accuracy than the conventional technique which utilizes a fixed angle of 20° relative to the epicondylar axis. Furthermore, not only is this technique more accurate, it is also more precise, having ½ of the observed variation associated with the presence of a 3 or 4 part proximal fracture. Therefore, the FAO chosen for the aforementioned fracture stem design was 7.5 mm. The mean angular errors associated with each of the aforementioned techniques used to reconstruct the anatomic humeral head retroversion for each of the humeri observed in this study are presented in Table 2.

**References**


**Acknowledgements**

We are grateful to Prof. Vital for his assistance in the completion of this study.

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**Table 1. Bicipital Groove Anatomic Data at Specified Heights**

<table>
<thead>
<tr>
<th>Height (mm)</th>
<th>BGAO (avg ± STD)</th>
<th>BGLO (avg ± STD)</th>
</tr>
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<tbody>
<tr>
<td>H1</td>
<td>7.3 ± 2.8</td>
<td>10.9 ± 1.9</td>
</tr>
<tr>
<td>H2</td>
<td>7.6 ± 2.2</td>
<td>10.9 ± 1.9</td>
</tr>
<tr>
<td>H3</td>
<td>7.4 ± 1.8</td>
<td>10.9 ± 1.9</td>
</tr>
<tr>
<td>H4</td>
<td>7.1 ± 1.6</td>
<td>10.9 ± 1.9</td>
</tr>
</tbody>
</table>

**Table 2. Comparison of Accuracy of Techniques to Restore HHR**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Technique 1</td>
<td>0.2 – 11.5</td>
</tr>
<tr>
<td>Technique 2</td>
<td>0 – 3.5</td>
</tr>
</tbody>
</table>

**Table 3. Comparison of Differences in Bicipital Groove Orientation**

<table>
<thead>
<tr>
<th>Percent Difference</th>
<th>11.47</th>
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