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Spherical versus elliptical prosthetic humeral heads: a comparison of anatomic fit

C. Scott Humphrey, MD[a], Andrea L. Gale, MD[b,*]

[a]*Humphrey Shoulder Clinic, Eagle, ID, USA*
[b]*Idaho Shoulder Education and Research Foundation, Eagle, ID, USA*

Background: The aim of this study was to quantify the influence of prosthetic humeral head shape, as well as the number of available prosthetic head sizes, on replicating the normal humeral head anatomy during shoulder reconstructive surgery.
Methods: Computer modeling software was used to create virtual sets of both spherical and elliptical prosthetic heads, which were virtually implanted into 3-dimensional computed tomography scan–based models of 79 proximal humeri. Anatomic replication was considered successful if the measured parameters (diameters of the base of the head in the frontal and sagittal planes, radii of curvature in the frontal and sagittal planes, and humeral head height) were all reproduced within 3 mm. The Fisher exact test was used to compare the percentage of successful replications for both head types and to compare differences resulting from the use of sets with fewer or more available head sizes. Statistical significance was set at $P \leq .05$.
Results: Regardless of the number of available head sizes per set, it was possible to replicate the normal anatomy within 3 mm in a higher percentage of specimens using elliptical (96%-100%) as opposed to spherical (41%-78%) prosthetic heads ($P \leq .0013$).
Conclusion: Compared with use of spherical prosthetic heads, use of elliptical heads resulted in improved replication of the normal humeral head shape. In light of the emerging evidence that use of anatomically shaped prosthetic humeral heads might lead to better shoulder function and possibly improved implant survivorship, the findings of this study may have important clinical and economic implications.
Level of evidence: Basic Science Study; Computer Modeling

Keywords: Humeral head; shape; size; dimensions; elliptical; spherical; formula; anthropometry

Much emphasis has been placed on replicating normal, prepathologic anatomy during shoulder reconstructive surgery. The underlying belief is that more accurate replication will lead to better functional outcomes.[4,17-20,23] This notion is supported by recent biomechanical studies in which it was found that rotational range of motion and glenohumeral joint kinematics were improved in vitro during shoulder reconstruction by using a prosthetic humeral head with an anatomically accurate shape.[6,12,13]

That the humeral head is ovoid has been well documented,[1,2,4,6,8-10,17,19,21,24,25] yet implantation of spherical prosthetic heads during shoulder reconstructive surgery remains the norm. It has been reported that adverse effects on glenohumeral biomechanics might result if the size and position of the articular surface are altered by 4-5 mm during shoulder arthroplasty surgery.[7,12,14,15,20,26] A potential concern based

No institutional review board approval was needed for this basic science study using deidentified material.

*Reprint requests: Andrea L. Gale, MD, Idaho Shoulder Education and Research Foundation, 3381 W Bavaria St, Eagle, ID 83616, USA.

E-mail address: Agale13@gmail.com (A.L. Gale).

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on this is that the mismatch often exceeds 4 mm when comparing normal anatomic measurements with those of a humerus that has been reconstructed with a spherical prosthetic head.[9]

Though it is generally accepted that the normal anatomy might not be perfectly replicated with use of spherical prosthetic heads, no study has quantified the anatomic fit of spherical versus elliptical prosthetic heads. More specifically, no study has directly compared the ability of both prosthetic head types to reproduce the normal anatomic relationships when implanted in multiple humeral specimens of various sizes.

The purpose of this basic science study was to compare the potential of 2 different prosthetic head types to accurately replicate the normal, anatomic humeral head dimensions. The prosthetic head types studied included (1) traditional spherical heads and (2) elliptical heads that conformed to dimensions based on a previous study.[9] The primary goal of our study was to quantify the ability of each prosthetic head type to replicate the normal anatomy when applied to a bone database representing a sample of the population. A secondary goal was to evaluate how increasing the number of available prosthetic head sizes per set might improve a set's ability to replicate the normal anatomy. It was hypothesized that elliptical heads would achieve replication of the normal anatomy in a higher percentage of cases compared with spherical heads and that increasing the number of heads per set would enhance the ability of both head types to reproduce the normal anatomic relationships.

Materials and methods

We obtained deidentified 3-dimensional (3D) computed tomography scan–based models of 79 proximal humeri from white subjects from the United States and Australia (47 male and 32 female subjects; age range, 17-87 years; average age, 56 years). The models were obtained from a second party (Materialise, Leuven, Belgium) and were prescreened to exclude specimens with osteophytes or other obvious degenerative changes. A detailed anthropometric analysis of the humeral specimens used for this study has been documented in a previously published article,[9] and the multiple anthropometric measurements performed on the specimens used for this study were found to be similar to those of other studies.[3,4,6,8,10,11,22,23]

Bone landmark identification methods and measurement techniques were adapted from previously published studies.[8,9] Three-dimensional imaging software (Adobe Acrobat 9 Pro; Adobe Systems, New York, NY, USA) was used to virtually resect each humeral head as would be done during shoulder arthroplasty surgery. Specifically, the cutting plane for head resection for each humeral model was derived using methodology for the identification of the head equator and other bone landmarks as described by Hertel et al.[8] The parameters measured on each of the 79 proximal humeral 3D models included the diameter of the base of the head in the frontal plane (D^F), diameter of the base of the head in the sagittal plane (D^S), radius of curvature in the frontal plane (ROC^F), radius of curvature in the sagittal plane (ROC^S), and humeral head height (HHH) (Fig. 1).

The techniques for measuring D^F, D^S, ROC^F, ROC^S, and HHH were validated in a separate analysis in which both investigators (C.S.H. and A.L.G.) measured all 79 specimens. The average interobserver correlation coefficient was 0.87 (range, 0.64-0.95; SD, 0.13). The difference between the mean values of each head parameter measurement recorded by each observer was 4% or less (Table S1). The average intraobserver correlation coefficient was 0.88 (range, 0.57-0.97; SD, 0.12).

The D^F and D^S measurements used in the final analysis were made by software directly on the virtual models and were recorded to the nearest millimeter. The 3D models were then each rotated on the computer screen to the ideal orientation for measuring ROC^F, ROC^S, and HHH, and the screenshot images were printed on paper to create simulated radiographs based on a previously described method.[9] The printer settings were adjusted to achieve a 1:1 scale based on measurements that were made directly on the virtual models with the software. Digital calipers were used for measuring HHH on the printed images, and the measurements were recorded to the nearest millimeter. Custom-made sizing disks were used to measure ROC^F and ROC^S, and the results were recorded to the nearest millimeter.

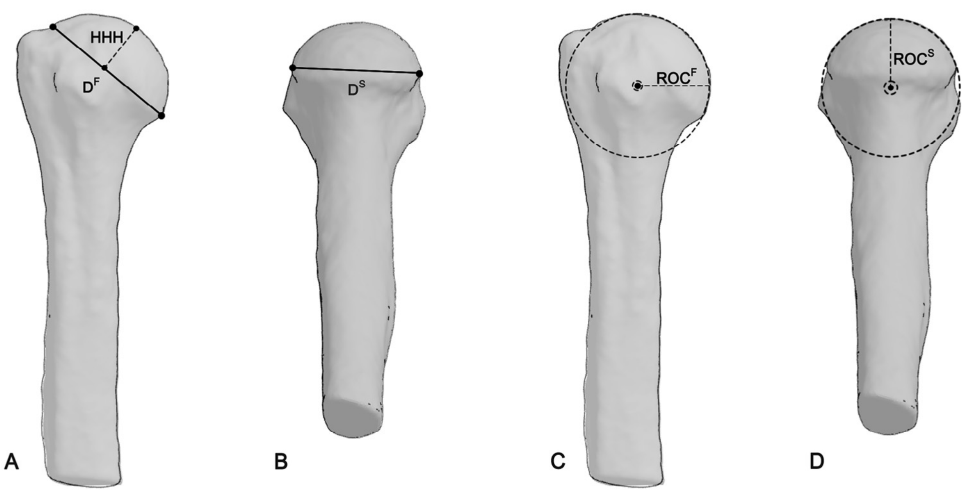

Figure 1 Anthropometric measurements made on 3-dimensional computed tomography scan–based models included humeral head height (*HHH*) and the diameter of the base of the head in the frontal plane (D^F) **(A)**, diameter of the base of the head in the sagittal plane (D^S) **(B)**, radius of curvature in the frontal plane (ROC^F) **(C)**, and radius of curvature in the sagittal plane (ROC^S) **(D)**.