



The Humeral Head is Not a Sphere

More than 50 Years of Scientific Evidence

Introduction:

Historically, the glenohumeral joint has been described as spherical and this theory has been the basis for the design of Humeral Head (HH) prostheses. However, for more than 50 years, evidence has been growing to show that the humeral head is non-spherical (Figure 1) (1-17). Despite the fact that biomechanical principles call for a reconstruction of the native humeral geometry (2), spherical implants continue to dominate shoulder arthroplasty.

Historical Evidence:

With the introduction of modern shoulder arthroplasty by Neer in 1955, the author acknowledged that the superior edge of the humeral head was flattened (1). Over the course of more than five decades the shape of the humeral head was frequently described as non-spherical with a major axis going from superior/inferior (SI) and a minor axis anterior-posterior (AP). Several studies, using a variety of different methodologies are in agreement that the SI and AP mismatch is between 2 and 3mm (Table 1).

The fixed geometry of most prosthetic systems is limiting the surgeon's ability to recreate the original anatomy of the humeral head (7) leading to significant biomechanical consequences such as the displacement of the center of rotation from its original position (mean: 14.6 mm) (10).

A recent report by Jun et al. (17) showed that a custom, non-spherical prosthetic head more accurately replicated the native humeral head shape, rotational range of motion, and glenohumeral joint kinematics than a spherical head when compared with the native anatomy.

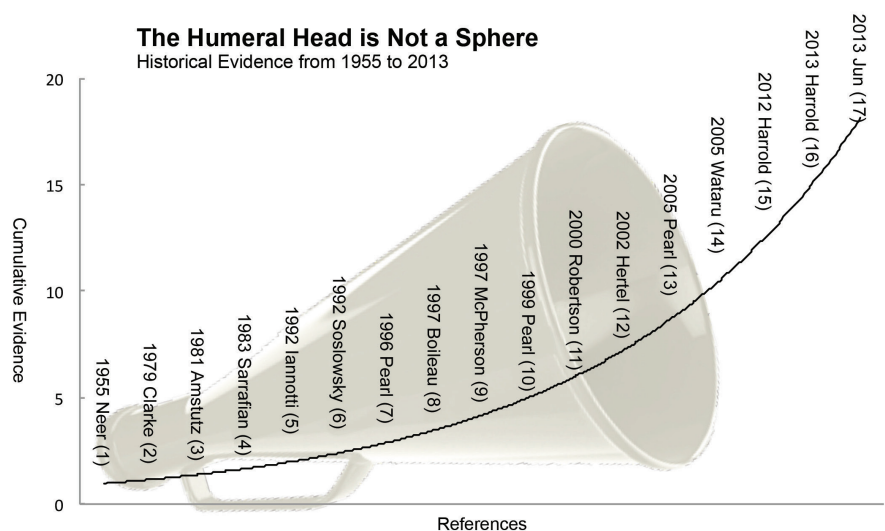


Figure 1: 50 Years of Evidence Showing Non-Spherical Humeral Head Geometry

Author	Non-Spherical Mismatch (mm)
Sarrafian 1983 (4)	3
Iannotti 1992 (5)	2
Hertel 2002 (12)	3
Wataru 2005 (14)	2
Harrold 2013 (16)	2
Jun 2013 (17)	2

Table 1: Humeral Head Mismatch in mm: Superior/Inferior and Anterior/Posterior

Shoulder Inlay Arthroplasty:

Based on the historical evidence, the HemiCAP Shoulder Inlay Arthroplasty System (Arthrosurface, Franklin MA) was developed and introduced with FDA approval in 2003. Today, the system includes more than 40 different sizes and shapes to address the spherical and non-spherical aspects of the humeral head in partial inlay arthroplasty and includes non-spherical sizes for hemi- and total shoulder replacement (Figure 2).

The patient specific design concept was supported by Hammond et al. (18) who showed that the center of rotation was more closely restored with inlay arthroplasty than with stemmed hemiarthroplasty. This resulted in less eccentric loading and potentially better functioning for the patient as the biomechanics of the joint and the moment arms of the rotator cuff and deltoid more closely resemble the intact condition. Philips et al. presented their results from a biomechanical humeral head investigation comparing spherical and non-spherical shape models. The authors concluded that the ovoid shape best replicated the osteo and chondral surfaces of the humeral head (Figure 3) (19).

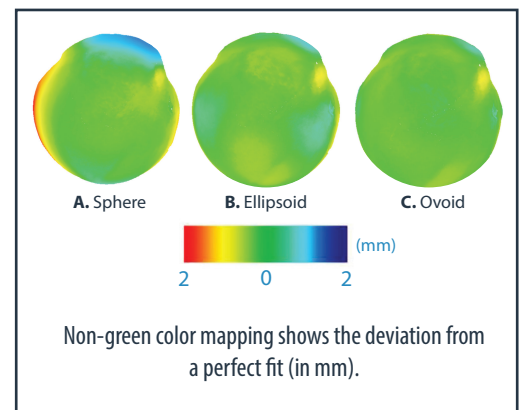
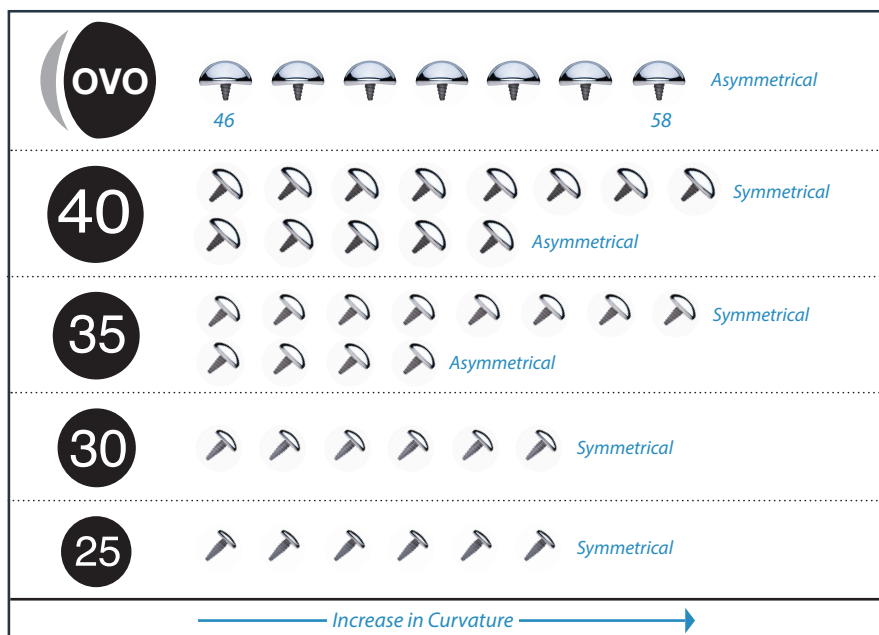


Figure 3: Topology of the Humeral Head Articular Surface: Ovoid Shape Shows 3x Better Match than Spherical Geometry

Figure 2: Shoulder Inlay Arthroplasty System: Size, Shape, and Curvature Matrix

References:

1. Neer CS. Articular replacement of the humeral head. *J Bone Joint Surg* 37A(2):215-228, 1955.
2. Clarke IC, Gruen TAW, Sew Hoy A, Hirschowitz D, Maki S, Amstutz HC. Problems in gleno-humeral surface replacements - real or imagined? *Eng Med* 8: 161- 175, 1979.
3. Amstutz HC, Sew Hoy AL, Clarke IC. UCLA anatomic total shoulder arthroplasty. *Clin Orthop Rel Res* 155:7-20, 1981.
4. Sarrafian S K. Gross and functional anatomy of the shoulder. *Clin Orthop*; (173): 11-9, 1983.
5. Iannotti JP, Gabriel JP, Schneck SL, Evans BG, Misra S. The normal glenohumeral relationships. *J Bone Joint Surg* 76A(4):491-500, 1992.
6. Soslowsky LJ, Flatow EL, Bigliani LU, Mow VC. Articular geometry of the glenohumeral joint. *Clin Orthop Rel Res* 85:181190,1992.
7. Pearl ML and Volk AG. Coronal plane geometry of the proximal humerus relevant to prosthetic arthroplasty. *J Shoulder Elbow Surg* 5:320-26, 1996.
8. Boileau P, Walch G. The three-dimensional geometry of the proximal humerus. Implications for surgical technique and prosthetic design. *J Bone Joint Surg* 79B(5):857- 865, 1997.
9. McPherson EJ, Friedman RJ, An, YH, Chokesi R, Dooley L. Anthropometric study of normal glenohumeral relationships. *J Shoulder Elbow Surg* 6:105-112, 1997.
10. Pearl ML, Kurutz S. Geometric analysis of commonly used prosthetic systems for proximal humeral replacement. *J Bone Joint Surg* 81A(5):66-671, 1999
11. Robertson DD, Yuan JIE, Bigliani LU, Flatow El, Yamaguchi K. Three-dimensional analysis of the proximal part of the humerus: relevance to arthroplasty. *J Bone Joint Surg* 82A(11): 1594- 1602, 2000.
12. Hertel R, Knothe U, Ballmer FT. Geometry of the proximal humerus and implications for prosthetic design. *J Shoulder Elbow Surg* 11:331-318, 2002.
13. Pearl ML. Proximal humeral anatomy in shoulder arthroplasty: Implications for prosthetic design and surgical technique. *J Shoulder Elbow Surg* 14:99S-104S, 2005.
14. Wataru S, Kazuomi S, Yoshikazu N, Hiroaki I, Takaharu Y, Hideki Y. Three-dimensional morphological analysis of humeral heads. *Acta Orthopedica* 76(3):392-396, 2005.
15. Harrold F, Wigderowitz C.A three-dimensional analysis of humeral head retroversion. *J Shoulder Elbow Surg* 21:612-617, 2012.
16. Harrold F, Wigderowitz C. Humeral head arthroplasty and its ability to restore humeral head geometry. *J Shoulder Elbow Surg* 22:115-121, 2013.
17. Jun B-J, Iannotti JP, McGarry MH, Yoo JC, Quigley RJ, Lee TQ. The effects of prosthetic humeral head shape on glenohumeral joint kinematics: a comparison of non-spherical and spherical prosthetic heads to the native humeral head. *J Shoulder Elbow Surg* 22:1423-1432, 2013.
18. Hammond G, Tibone JE, McGarry MH, Jun B-J Lee TQ. Biomechanical comparison of anatomic humeral head resurfacing and hemiarthroplasty in functional glenohumeral positions. *J Bone Joint Surg* 94A: 68-76, 2012.
19. Philips J, Fening S, Runciman R, Miniaci A. Topology of the Humeral Head Articular Surface. ORS Poster 2012.