Cemented humeral shoulder arthroplasty: Because it works!

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ABSTRACT

Durable humeral component fixation in shoulder arthroplasty is important to prevent loosening. Humeral component designs include metaphyseal fitting, diaphyseal fitting with traditional stem length, short stem, and stemless designs. Stem geometry helps resist rotational and axial stress. Stem collars may prevent subsidence, and may be smooth for full cementation or textured proximally for bone ingrowth. Ideally, the humeral component has solid initial fixation, durable long-term fixation, minimizes humeral stress shielding, has low intra-operative complication rates, and can easily be revised. Excellent outcomes can be achieved, but there remain relative indications and contraindications for cementing or press-fitting the humeral component.

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1. Introduction to the geometry of the proximal humerus

Humeral component design and fixation techniques are directly tied to the morphology of the proximal humerus. Modern components are generally modular to account for the wide variability between patients. Textured proximal coating may promote bone ingrowth or ongrowth to create biologic implant fixation, while cementation eliminates this biologic fixation [1]. While fixation is paramount, recreating the geometry of the proximal humerus is important to restore the mechanics of the glenohumeral joint. The arc of the articular surface of the humeral head extends approximately 150; the head thickness ranges from 12–24 mm and is linked to the humeral head radius of curvature in a 3:4 ratio [2–5]. Work by Robertson and coauthors has demonstrated an average humeral retroversion of 19 (range 9–31) and canal diameters ranging from 9–16 mm [2]. When considering the placement of a stemmed humeral component, it is important to note that the proximal humeral endosteal canal is not round, but ellipsoid, with its long axis running from medial to lateral in the axial plane. This axis becomes increasingly retroverted more distally in the humerus. The center of rotation of the humeral head is offset posteriorly by a mean of 2 mm and medially by a mean of 7 mm. There is also an approximately 4-fold tapering of the canal from the surgical neck to 340 mm² at the diaphysis [2].

2. Humeral stem fixation

Stemmed humeral components have long been cemented in the humeral canal. Cement can be placed down the diaphysis...
to fill the canal all the way to the humeral neck cut to provide a complete mantel surrounding the implant (Fig. 1). Alternatively, it can be packed around the metaphyseal aspect of the implant in a more limited partial proximal cementation technique. Both techniques have been shown to be equivalent to press-fitting a smooth-stemmed diaphyseal fitting component with regard to initial axial micromotion [6]. Initial rotational stability in this setting is better with cementation. No difference was seen between partial proximal and full cementation [7]. To improve initial purchase and prevent loosening, humeral components intended to achieve metaphyseal fit have been introduced (Fig. 2). They do not rely on three-point contact between a straight stem and an ellipsoid canal, but instead obtain purchase by reaming the metaphysis to accept an implant of corresponding size [8]. Some implants incorporate a textured surface to promote boney ingrowth or ongrowth. This coating may cover the proximal metaphyseal portion of the implant or extend down the length of the implant to the diaphyseal portion of the stem [9].

3. Stem loosening

Aseptic loosening of standard length humeral components, cemented or press-fit, is fortunately rare. Barrett reported on 44 patients undergoing total shoulder arthroplasty using a cemented humeral component. At an average of 3.5 years of follow-up, only one humeral component had been revised; humeral component survival was 98% in the series [10]. A study by Throckmorton reported zero loosening in 76 patients undergoing total shoulder arthroplasty using a circumferential metaphyseal porous-coated press-fit stem at an average of 52 months of follow-up [9]. Cil and colleagues found that humeral stem loosening occurred in isolation in only 4 of 1,112 (0.03%) of total shoulder arthroplasty cases. Examining revision for any reason, there was 96.2% survival of cemented components and 91.2% survival of noncemented components at 10 year follow-up ($p < 0.1$) [11]. In a prospective randomized controlled trial of 161 patients, Litchfield found...
no evidence of humeral loosening in either cemented or non-
cemented humeral components [12]. Keener and coauthors
pooled the results of several large shoulder arthroplasty stud-
ies [8,9,11–14]. They found a weighted mean aseptic loosen-
ing rate of 0.2% with cemented implants and 0.9% for
nuncemented implants and an overall revision rate of 2.6%
for cemented implants and 7.47% for nuncemented implants
[15]. Keener also noted that some bias may be inherent in
these series, as cemented humeral stems can be difficult to
revise and have a significant complication rate [15,16].

4. Radiographic evaluation of humeral stems

Radiographic changes and functional outcomes have been
studied in standard length cemented and uncemented stems.
As described by Denard, stress shielding of the proximal
humerus results from sharing of physiologic load between

the remaining humeral bone and the implanted humeral
prosthesis. Stress shielding may manifest as tuberosity
resorption, cortical thinning, or calcar osteolysis (Fig. 3). It has
been linked to humeral implant characteristics such as stem
length and diameter fill ratio [1]. Osteolysis may result from
stress shielding, but it has also been linked to glenoid polyeth-
ylene wear and debris [13]. Glenoid component wear charac-
teristics may introduce confounding variables into the
evaluation of stress shielding of the proximal humerus based
on humeral implant design and fixation technique. Humeral
implants that are circumferentially proximally cemented or
coated with an ongrowth surface may be less susceptible to
distal particulate-induced osteolysis [13,15]. At long term fol-
low-up, high rates of radiolucent lines can be seen in both
cemented (Fig. 4) and uncemented components, but these
lines have not been linked to loosening or revision [13,17].
Looking at functional outcomes, the only Level 1 data avail-
able suggests that cemented humeral components may

Figure 2 – Press-fit metaphyseal fitting humeral stem during total shoulder arthroplasty. 2 years after press-fit metaphyseal fit-
ting humeral stem during total shoulder arthroplasty without evidence of calcar resorption, but mild tuberosity stress shielding.
outperform uncemented non-coated diaphyseal press-fit components at 24 months of follow-up. Cemented components demonstrated a significant improvement in the Western Ontario Osteoarthritis of the Shoulder (WOOS) score over uncemented components. There was no significant difference in the American Shoulder and Elbow Surgeons (ASES) Standardized Shoulder Assessment or McMaster-Toronto Arthritis Patient Preference Disability Questionnaire (MACTAR) [12].

5. Short and stemless humeral stems

In recent years, there has been increasing usage of short stem and stemless humeral components. While these implants may be compatible with cemented fixation, many surgeons are moving toward press-fit implantation of these components [18-21]. The use of short stems may preserve bone stock in the setting of a revision surgery. Stemless components not only preserve bone, but may they be useful in settings where the distortion of native proximal humeral anatomy makes the use of a stemmed humeral component difficult (Fig. 5). Many of these short stem and stemless components also feature ingrowth or ongrowth surface coatings [19]. There is significant design variation in short stem shape, taper, and collar. There are also a variety of metaphyseal engagement mechanisms among the stemless humeral components [1].

Because short-stem and stemless implants are relatively new, little long-term data on loosening and revision is
available. However, short-term follow-up results using a grit blasted short-stem press-fit humeral component without a proximal porous coating demonstrated aseptic humeral loosening in 4/73 (5.48%) patients, 2 (2.74%) of whom underwent revision arthroplasty for aseptic humeral loosening. There were radiolucent zones noted on 71% of radiographs at 24 months follow-up [18]. A mid-term follow-up on the same implant by Schnetzke reported a 37% rate of high boney adaptation and a 66% rate of cortical narrowing and osteopenia at the calcar in a group of 66 patients at a mean follow-up of 5.3 years. The authors reported no evidence of humeral component loosening [22]. Morwood and coauthors reported outcomes following the release of an new version of the implant with the addition of a proximal ingrowth coating [19]. In their comparison of 34 proximally coated and 34 uncoated implants at an average of 27.3 months of follow-up, they found a significantly higher incidence of humeral lucency and “at-risk” humeral stems among the uncoated group. No humeral component required revision. Only one stem was found to be loose, and it was in the uncoated group. Romeo reported on the use of a short-stem press-fit humeral component and found 9% of stems to be “at-risk” for loosening on radiographs but no gross loosening or revision for any reason at mean 25 months of post-operative follow-up [20].

6. Reverse shoulder humeral stems

Reverse total shoulder arthroplasty was designed to alter the fundamental biomechanics of the shoulder joint to compensate for a deficient rotator cuff. Reverse total shoulder arthroplasty changes the joint center of rotation to maximize the function of the deltoid and minimize stress on the glenoid component [23]. The effects of altered joint compression and shear forces upon loosening and stress shielding of the humeral component of the reverse prosthesis are not completely known [15]. A systematic review by Phadnis of 41 clinical studies including 1455 cemented and 329 uncemented reverse total shoulder arthroplasty humeral components demonstrated equivalent clinical outcomes and no difference in rates of loosening or revision [24]. Uncemented stems (Fig. 6) did have higher rates of non-progressive radiolucent lines and stem migration, while cemented stems had higher rates of acromial fracture, infection, nerve injury, and thromboembolism. A systematic review and meta-analysis by Grey comprised of 65 studies including 1,660 cemented and 805 uncemented reverse total shoulder arthroplasty humeral components revealed no difference in rates of aseptic loosening or revision between the two groups [25].

7. Comparing cemented and uncemented humeral stems

While outcomes of anatomic and reverse arthroplasty with both cemented and noncemented humeral components are generally comparable, there exist distinct advantages and disadvantages to selecting a cemented technique. Cementation of the humeral component during shoulder arthroplasty has the advantage of providing immediate fixation with minimal broaching or reaming in patients with poor bone quality. Cement can fill gaps between bone and the humeral component when proximal humeral morphology or bone loss create a bone/prosthesis mismatch [2,8]. A good cement mantle may also prevent osteolysis by excluding glenoid wear debris from the humeral canal [13]. Cement can also serve as a carrier for antibiotics. The use of cement for initial fixation does have disadvantages. It increases operative time and complexity. In the revision setting, cemented stems can be difficult to revise [26]. Retained cement at the time of revision surgery for infection may serve as a nidus for subsequent relapse and treatment failure. The decision to use cement should be based on
8. Conclusions

Immediate solid, durable fixation of the humeral component in total shoulder arthroplasty is key to the long term success. Using standard length stems, both cemented and uncemented stems of a very low rate of aseptic loosening and revision. Osteolysis may occur in response to stress shielding proximal to cemented or large diameter press-fit humeral components, but glenoid wear likely plays a role in bone resorption as well. Short stem and stemless components have theoretical advantages, but long-term data is limited and early reports suggest high rates of loosening and radiographic changes with some implants. Data on reverse total shoulder arthroplasty suggests that cemented and uncemented humeral components both perform well. Surgeons should recognize the relative indications and contraindications for the use of a cemented humeral component and allow individual case characteristics to guide clinical decision making.

Disclosures

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**BIBLIOGRAPHY**


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Figure 6 – Press-fit reverse humeral stem. Press-fit reverse shoulder arthroplasty humeral stem with metaphyseal ingrowth and diaphyseal fill.


