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Glenoid cement mantle characterization using micro–computed tomography of three cement application techniques

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Background: Numerous studies have documented the concern for progressive radiolucent lines, signifying debonding and subsequent aseptic loosening of the glenoid component. In this study, we compared 3 cementation methods to secure a central peg in 15 cadaveric glenoids.
Methods: Cement application techniques consisted of (1) compression of multiple applications of cement using manual pressure over gauze with an Adson clamp, (2) compression of multiple applications of cement using a pressurizer device, and (3) no compression of a single application of cement. Each glenoid was then imaged with high-resolution micro–computed tomography and further processed by creating 3-dimensional computerized models of implant, bone, and cement geometry. Cement morphology characteristics were then analyzed in each of the models.
Results: There were no significant differences detected between the 2 types of compression techniques; however, there was a significant difference between compression methods and use of no compression at all. All morphologic characteristics of a larger cement mantle were significantly correlated with greater cortical contact.
Conclusions: We demonstrate that compression techniques create a larger cement mantle. Increased size of the cement mantle is associated with increased contact with cortical bone at the glenoid vault. This method for characterizing the cement mantle by micro–computed tomography scanning techniques and 3-dimensional analysis may also be useful in future finite element analysis studies.
Level of evidence: Basic Science Study, Surgical Technique, Imaging.

Keywords: Total shoulder arthroplasty; cementing technique; glenoid component; micro-CT; cement mantle

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Total shoulder arthroplasty (TSA) has been proven to be a reliable treatment for end-stage osteoarthritis of the glenohumeral joint. Patients can expect longevity of the component for 8 to10 years, with 89% survival at 10 years.[27] The most common cause of failure in TSA is the loss of fixation of the glenoid component.[3] Numerous

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studies have documented the concern for progressive radiolucent lines, signifying debonding and subsequent aseptic loosening of the glenoid component.[4,24,33,37]

Failure of fixation may occur at the cement-component and cement-bone interfaces. Loosening between the polyethylene component and the cement has been demonstrated in biomechanical studies.[1,13,31] Despite this, in vivo studies have shown that failure occurs most often at the bone-cement interface as evidenced by radiolucent lines in radiographic studies and in retrieval of loose components.[21,33,35] Yian et al[38] discovered that of 47 glenoid components that developed symptomatic loosening, 2 required revision and were found to have loss of fixation at the bone-cement interface. In vivo studies demonstrate that fibrosis, necrosis of bone, and resorption of bone can occur, which lead to debonding at the bone-cement interface over time.[20]

There is no current consensus on how to optimally apply cement to the glenoid.[40] Raiss et al[29,30] hypothesized that greater cement penetration would lead to greater bonding at the bone-cement interface and reduction of radiolucent lines. Pressurization has been shown to create a larger cement mantle that is more uniform within the glenoid.[2,6,23,30] One novel pressurization method included creation of a weep hole, which was demonstrated to have decreased radiolucent lines and a greater cement mantle by reducing intraosseous pressure.[14,15] Despite these findings, there is concern that the creation of an osteotomy may weaken the periarticular bone. Preparation of the glenoid bone before implantation was examined by Edwards et al,[10] who compared 3 methods of drying the cancellous surface to reduce radiolucent lines. They discovered that there was no difference in the amount of radiolucent lines postoperatively in glenoids dried with thrombin-saturated gel, compressed air, or saline irrigation than in those dried with gauze.

In our study, we compared several cementation techniques that are practical to implement in the operating room. Cement application techniques in our study consisted of (1) compression of the cement using manual pressure over gauze with a straight Adson clamp, (2) compression of the cement using a pressurizer device, and (3) no compression of cement. We hypothesized that compression of the cement with a straight Adson clamp and gauze would yield greater cement penetration and volume than compression with a plunger or no compression technique. We also hypothesized that pressurization techniques would lead to greater depth of penetration and contact with the deep cortical bone at the base of the glenoid.

Materials and methods

Specimen preparation

Fifteen fresh frozen cadaveric shoulders of unknown age or gender were thawed for 24 hours at room temperature. Each of the scapulae and their respective glenoid lacked any gross anatomic defects or changes consistent with osteoarthritis. The cartilaginous surface was intact without degenerative change, and there was no evidence of glenoid retroversion in any of the specimens. No imaging was performed before implantation. The humerus was disarticulated from the glenoid. Soft tissues were removed from the scapula.

The scapulae were evaluated by dual-energy x-ray absorptiometry before assignment to a cementing method. The 15 scapulae were separated into 3 bone density groups: low, medium, and high. There were 5 scapulae in each bone density group. Scapulae among each bone density category were then randomly assigned to a cementation group to evenly distribute bone density among the 3 cementation methods. Mean bone density was not significantly different among the 3 implantation groups using dual-energy x-ray absorptiometry or trabecular bone density as described here (Table I).

The following 3 implantation methods were used on 5 cadaveric glenoids each ($n = 5$):

1. compression of the cement with Raytec gauze in the jaws of a straight Adson clamp;
2. compression of the cement using a pressurizer device; and
3. no compression of cement before component insertion.

Glenoid component simulation

A peg was machined from polyoxymethylene (Delrin; DuPont, Wilmington, DE, USA) to simulate the central peg of a 3-inline pegged glenoid. The mock peg had a diameter of 5 mm and a length of 15 mm. The peg was a smooth cylinder and lacked any threaded macrostructure to improve generalizability of the findings to multiple glenoid implant types. A pressurizer (tamp) was machined with the same dimensions from aluminum (Fig. 1).

Glenoid component implantation

The central peg implantation was performed by 1 experienced orthopedic surgeon (senior author, A.D.A.) by drilling a hole in the approximate center of the glenoid, perpendicular to the tangential plane of the curvature of the glenoid. This technique was found by Lewis et al[18] to reliably place the central peg within the deepest aspect of the glenoid vault in morphologically normal glenoids. The intact cartilaginous surface of the glenoid was not reamed before implantation to avoid altering the macrostructure of the glenoid for drilling or analysis purposes. Holes were drilled to a depth of 15 mm by the use of a 5-mm bit. After drilling, the holes were thoroughly irrigated and dried with gauze. Stryker Simplex P radiopaque polymethyl methacrylate (PMMA) cement (Stryker, Mahwah, NJ, USA) was