Use of a Caged, Bone Ingrowth, Glenoid Implant in Anatomic Total Shoulder Arthroplasty
Technique and Early Results

Sean G. Grey, M.D.

Abstract
Shoulder arthroplasty represents one of the fastest growing orthopaedic procedures in the USA. In comparison to hemiarthroplasty, total shoulder arthroplasty has higher patient satisfaction and lower revision rates. Aseptic glenoid loosening remains a concern for longevity of total shoulder arthroplasties. Cement fixation on the glenoid side represents the primary and only mode of fixation in the majority of implants in the USA. Metal backed glenoid designs have demonstrated higher failure rates, primarily due to thinning of the polyethylene bearing surface.

We reviewed our early experience and results with a novel glenoid design. Long-term fixation in this design is provided by a central metallic bone ingrowth cage, without the need for metal backing.

Improved techniques along with an aging patient population have led to a significant increase in the number of total shoulder arthroplasties being performed in the USA. When compared to hemiarthroplasty, total shoulder arthroplasty results in better range of motion, pain relief, and patient satisfaction. While the overall success rate for total shoulder arthroplasty has been quite satisfactory, glenoid-sided loosening remains the most common complication. Radiographic evidence of lucent lines has been reported to range from 22% to 95% in various types of glenoid implants. While radiolucent lines are common, clinical failures, defined as revision surgeries, are much less common in studies evaluating intermediate term follow-up.

Although a variety of glenoid designs exist in the USA at this time, the all-polyethylene cemented peg glenoid design remains the gold standard. In these pegged all-polyethylene glenoid components, radiolucent lines are common, and aseptic glenoid loosening has remained a concern for the long-term survival of the implant. This has led to interest in a variety of metal-backed and bone in-growth devices with the primary goal being to move to either noncemented or limitedly cemented implants with the hope of decreasing the likelihood of aseptic glenoid loosening. A number of metal-backed noncemented designs have been or are currently available in the USA and Europe. In comparison to cemented all-polyethylene glenoids, previous metal-backed designs have shown higher failure rates. Failure of previous metal-backed designs has been primarily related to three mechanisms:

1. Metal backing requires a relatively thin layer of polyethylene in order to avoid overstuffing of the joint. The decreased polyethylene thickness in combination with increased contact pressures lead to higher polyethylene wear rates, osteolysis, and loosening.
2. A number of metal-backed designs have no bone ingrowth surface. Initial fixation was usually obtained with screws. Lack of in-growth led to eventual loosening or fatigue failure of the screws under repetitive loading.
3. Trabecular metal (highly porous metal foam) designs, in which the trabecular substrate is molded to the polyethylene, have shown excellent bone in-growth but have had problems with dissociation of the trabecular metal from the polyethylene. This has been accompanied by higher early revisions for aseptic loosening. Lack of peripheral pegs to control rotational forces between the trabecular metal and polyethylene may be a contributing factor.

Limited cemented, all-polyethylene designs have shown some promise. In this design, early fixation is obtained with a combination of peripheral peg cementation combined

Sean G. Grey, M.D., is at the Orthopaedic Center of the Rockies, Fort Collins, Colorado.
Correspondence: Sean G. Grey, M.D., Orthopaedic Center of the Rockies, 2500 East Prospect Road, Fort Collins, Colorado 80525; sgrey1@msn.com.

with the interference fit of the central peg. Long-term fixation is supplemented with bone in-growth around the flanges of the all-polyethylene central peg. Studies have shown successful bone in-growth around the flanges of the central peg. Some studies, however, have shown radiolucencies around the central peg, and there is concern that the flanges may not represent the best long-term bone in-growth surface.

The genesis of the current cage glenoid design developed from the success of the Equinoxe (Exactech, Inc., Gainesville, Florida) reverse shoulder arthroplasty’s baseplate, which utilizes a central peg. With its release in March 2007, the glenoid baseplate showed minimal aseptic loosening on early and intermediate follow-up. In addition, early retrieval studies have shown excellent bone in-growth in as little as 6 months. Additional intraoperative observation demonstrated stable fixation of the baseplate with interference fit of the central peg alone, prior to screw placement in most bone densities. These concepts were incorporated into a cemented nonmetal-backed glenoid implant with an interference-fit plasma coated cage peg and titanium peripheral pegs (Fig. 1). The potential advantages of this implant are as follows:

1. This novel glenoid design provides the possibility of bone in-growth without any metal backing.
2. By maintaining a monolithic 4 mm thick polyethylene bearing surface without a metal backing, concerns of polyethylene failure due to insufficient thickness, backside wear, and joint overstuffing are all mitigated.
3. Initial intraoperative fixation is obtained with interference fit of the oversized cage peg in the central hole, eliminating the need for stabilizing the implant until the cement sets. Not only does this decrease operative time, but the secure immediate fixation prevents the micromotion that is often seen when stabilizing the implant manually during cement curing.

Early short-term fixation is obtained by a combination of central peg interference fit and peripheral peg cementation. The addition of the peripheral pegs allows for better control of rotational forces. Long-term fixation is achieved with a combination of peripheral peg cementation and bone in-growth through the central cage. When compared to an all-polyethylene center peg with flanges, the central titanium cage is considered a superior bone in-growth surface. Grit-blasted peripheral pegs may allow for fully uncemented technique in the future; however, at the time of this writing, the device is only cleared by the Food and Drug Administration for cemented use.

The glenoid bone preparation is identical for the cage design and the all-polyethylene peg design, and this allows the surgeon to choose between either implant, based upon bone quality or other factors, prior to opening the component to be implanted. Finally, even in the face of adequate bone in-growth, the system is designed to be revision friendly. The central cage and peg can be removed with little damage or loss to underlying glenoid bone.

**Technique**

The overall surgical technique for the cage glenoid varies little from the standard anatomical total shoulder arthroplasty technique. The primary distinction of the cage glenoid technique is that it requires “straight line” glenoid insertion. Unlike a standard all-polyethylene implant, in which the prosthesis can be rolled into the glenoid, the cage implant must be inserted directly perpendicular to the face of the glenoid from the time the central cage peg engages the drilled glenoid bone holes until it is fully seated. This straight line insertion requires better surgical glenoid exposure, and caution should be carried out in patients with difficult exposure or significant glenoid deformity.

Exposure is obtained through a standard deltopectoral approach. Care should be taken to release an appropriate amount of pectoralis major tendon to allow for relaxation and posterior translation of the humerus during glenoid preparation. Humeral capsular releases should be performed past the six o’clock position and distally on the neck to the superior border of the latissimus dorsi tendon. I prefer a slight increase in humeral head retroversion (cutting into the bare area). This is generally well tolerated on the humeral side with use of the replicator plate. In addition, the removal of an additional 5 mm to 7 mm of posterior humeral bone results in significantly better glenoid exposure.

After preparation of the humerus, attention is turned to glenoid exposure. Capsular releases should be performed circumferentially on the glenoid. Labrum and all soft tissue debris should be removed from the glenoid face (Fig. 2). As mentioned previously, glenoid preparation is identical for the all-polyethylene peg system and the cage design. Two orthogonal lines are drawn, dividing the anterior-posterior and superior-inferior halves of the glenoid face (Fig. 3). The proper position of the central peg hole is consistently just anterior to the intersection of these two lines. The position is confirmed with the glenoid drill guide. The central hole can be drilled either through the guide or in a freehand method. Sequential reaming is carried out to the appropriate size.
Care is taken to remove minimal subchondral bone. The peripheral peg drill guide is placed in the central hole, and the peripheral three peg holes are drilled (Figs. 4 and 5).

Attention is then turned toward trialing. The option of either an all-polyethylene component or cage glenoid component still exists. After identifying the appropriate sized trial glenoid, the trial and the glenoid insertion tool are used. If straight line insertion is possible and bone density is adequate, a cage glenoid component is selected; however, if straight line insertion is not possible, either further releases are performed, or the all-polyethylene pegged implant is selected. A depth gauge is available to ascertain if the drilled holes are of sufficient depth to permit for full insertion of the pegs. The central hole may require repeat drilling, especially if additional reaming was performed.

The glenoid is cemented in place by placing cement in the peripheral holes. The peripheral holes are irrigated free of blood and debris. A provisional peg is placed in the central drilled hole to prevent cement from entering. In a doughy state, cement is pressurized into the peripheral holes using the instruments. The cage glenoid is then impacted until seated with one of a variety of supplied insertion tools. Straight line insertion is paramount, as off-line insertion may lead to damage to the locking mechanism that fixes the
metal pegs to the polyethylene articular body (Fig. 6). Care should be taken to assess full seating of the entire glenoid (Fig. 7). Attention can then be turned to completion of the arthroplasty, as the central cage peg will prevent micromotion as the cement cures in the peripheral holes.

Results
At the time of this writing, the investigator has performed 127 total shoulder arthroplasties with the cage glenoid technique since December 2011. It has become the preferred implant for anatomic total shoulder arthroplasty in patients without significant bone deformity. In the presence of large glenoid deformity (greater than 12° of posterior erosion), typically we use a posterior augmented glenoid design. In the majority of osteoarthritis patients, bone quality has not been an issue for central peg fixation. We remain more cautious in patients with inflammatory and crystalline arthropathies; however, many of these patients also have adequate bone density for cage glenoid placement.

At the time of this writing, we have not undertaken a formal review of the patients. This will be done when greater than 2-years follow-up is available. However, at this point we have made the following observations:

1. Operative time has been significantly reduced relative to total shoulder arthroplasty cases using an all-polyethylene cemented glenoid, as 5 to 13 minutes are eliminated by removing the need to hold the implant while the cement sets.

2. Given that all four pegs have a metallic component, postoperative radiographs allow for more critical review of multi-planar glenoid position. We feel this has improved our overall glenoid placement, as recent studies have suggested that small changes in glenoid position have implications on long-term survival of the implant.

Short-term clinical results in terms of range of motion, function, and pain relief do not appear to vary significantly from our anatomic total shoulder arthroplasties using all-polyethylene glenoids. A short-term review of our 6 and 12 month x-rays have shown good position of the implants, signs of early bone in-growth, and no obvious signs of progressive lucency in all but three patients (discussed below). We have not altered our postoperative care or changed our short- and long-term activity restrictions based on the bone in-growth implant.

We have observed radiographic evidence of loosening in three patients, two of which required revision. The first patient had the initial design of the implant (no longer available) in which the central cage had a thicker plasma coating and was more oversized in relationship to the drilled center peg hole in the glenoid. This thicker peg resulted in greater interference and more difficult insertion/impaction into dense bone. Complete seating may have been the issue with this patient. This resulted in damage to the mechanism connecting the polyethylene to the central peg, which was identified on the first postoperative x-ray. The patient subsequently developed pain and went on to have a revision approximately 10 months after the index procedure. She was converted to an all-polyethylene pegged implant with good results. The implant has since been modified. Decreasing the thickness of the plasma spray coating on the cage peg has improved the ease of insertion into dense bone. With this thinner coating, we have found that the vast majority of patients get excellent initial interference fixation with the bone cage into the central hole on the glenoid.

A second patient developed postoperative subscapularis insufficiency. Loosening of the central peg locking mechanism was observed between 3 and 6 months postoperatively. She was revised to a reverse shoulder arthroplasty without complication.

In both of the above patients, at the time of revision surgery, the central peg was found to have excellent bone ingrowth. Despite this ingrowth, the revision was uncomplicated, and the cage could be removed with minimal glenoid bone loss. In each revision, the polyethylene articular surface was separated from the underlying cage with an osteotome. When the cage was noted to be well fixed, a 3.2 mm drill bit was used to remove bone from the central cage. A slap hammer extraction device was then threaded into the central cage, and with slight rotational force, the implant was removed without difficulty.

Summary
Early experience with a novel cage glenoid implant design appears to hold promise for a minimally cemented, bone in-growth implant, with a potential to decrease long-term aseptic glenoid loosening. Longer term follow-up is necessary to confirm these promising early results.

Disclosure Statement
Sean G. Grey, M.D., is a consultant for Exactech, Inc., Gainesville, Florida, and receives royalties on products related to this article.

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