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Hybrid fixation in anatomic shoulder arthroplasty: surgical technique and review of the literature

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Hybrid constructs have been used as a primary fixation technique in primary anatomic total shoulder arthroplasty for more than a decade. A highly porous metal central peg, metal cage, or coatings attached to the surface of cemented polyethylene glenoid component have been used with the concept of providing an additional adjunct in promoting osseointegration, preventing glenoid component loosening, and promoting longer-term success. The purpose of this article is to analyze the published results, complications, as well as rate of revision using this form of glenoid fixation. In addition, key aspects of the surgical technique that may be considered to facilitate optimal results when hybrid fixation is considered in total shoulder arthroplasty are also reviewed.

Anatomic total shoulder arthroplasty (TSA) is a well-established procedure in providing pain relief and improved function for patients with glenohumeral osteoarthritis.[3,13] However, aseptic glenoid component loosening remains a primary mode of failure serving as the most common cause of revision TSA.[4,16] Starting in the early 1990s, porous metal-backed glenoid components were commonly used; however, follow-up studies demonstrated elevated rates of complications with unacceptable rates of failure.[5,15,18] As a result of the complications associated with metal backed glenoid components, cemented all-polyethylene designs became the fixation method of choice for anatomic glenoid components. Although glenoid component loosening and revision rates have improved, radiolucent lines in the glenoid-cement interface are still common across both pegged and keeled components with rates ranging from 22% to 95% in the first few years after surgery[4,7,19] and even 50% to 60% grade 2 lucency or higher at 7-8 years of follow-up.[12] Furthermore, glenoid component loosening still remains the most common long-term complication after TSA with reported loosening rates of up to 1.2% per year.[15]

Over the past decade as investigations have questioned the long-term survivability of cemented all-polyethylene components, modern hybrid glenoid components have been designed.[7] Hybrid fixation is based on the ideal characteristics of cement for excellent initial stability and biologic fixation to provide long-term survival. These components consist of a highly porous metal central peg, a metal cage, or coatings attached to a cemented polyethylene surface on the face of the glenoid. Biomechanical investigations have reported high initial stability with excellent promise for osseointegration and the ability to withstand high cycle loading at elevated magnitudes without fracture or disassociation.[6,17] Early clinical studies established equivalent clinical and radiographic outcomes between hybrid glenoid and pegged implants.[9] Subsequently additional investigations demonstrated hybrid glenoid components with a central porous titanium post or cages demonstrated lower rates of radiolucent lines and failures in comparison to all-polyethylene glenoid components up to 5 years.[7,14] Recently, Malahias et al [11] performed a systematic review demonstrating a high pool implant survivorship of 97% with low rates of glenoid component-related complications of 2.8% at short midterm follow-up. This article describes an anatomic TSA using hybrid cemented fixation of the glenoid component in which technical difficulties are addressed as well as a report on preliminary data from an ongoing multicenter study.

Patient selection

A standard comprehensive workup of patients with shoulder pain is obtained. This begins with a complete history and physical

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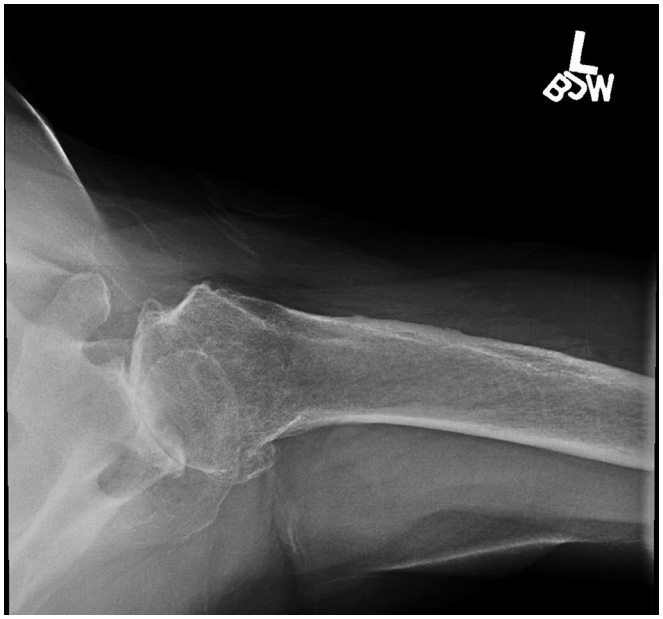

Figure 1 Preoperative axillary view radiograph of the left shoulder demonstrating posterocentral glenoid wear.

examination outlining the course of the patient's pathology, current functional limitations, and clinical status of the rotator cuff.

Standard imaging includes shoulder antero-posterior and axillary radiographs of the shoulder to assess for humeral head or glenoid deformity, glenohumeral joint space narrowing, and associated osteophytes (Fig. 1). Advanced imaging through computed tomography is often acquired to characterize the glenoid bone wear and version.

An anatomic TSA using hybrid fixation is then offered to patients with glenohumeral arthritis, an intact rotator cuff, and recalcitrant symptoms despite a comprehensive course of nonoperative therapies. In patients with previous arthroplasty, additional detail is focused on the type of implant used, status of the glenoid, anticipated bone loss, and rotator cuff status. For a majority of these cases, a reverse shoulder arthroplasty is often indicated.

Indications

The indications are as follows:

- Patients with symptomatic end-stage glenohumeral arthrosis with an intact rotator cuff and sufficient bone stock.
- Pain and disability despite comprehensive non-operative therapies (including nonsteroidal anti-inflammatory drugs, glenohumeral joint injections, and physical therapy).

Contraindications

The contraindications are as follows:

- Full thickness rotator cuff tear not amenable to fixation
- Rotator cuff arthropathy
- Substantial glenoid bone loss
- Insufficient humeral bone stock
- Glenoid retroversion >25 degrees
- Active Infection

Surgical technique

Patient positioning

The procedure begins with induction under general anesthesia with or without interscalene block. Afterward, the patient is positioned in the standard supine beach-chair position with the medial border of the scapula on the edge of the bed. A rolled-up towel may then be placed in between the scapulae further stabilizing the scapula for glenoid implantation.

Approach and initial exposure

A standard deltopectoral approach is used for shoulder exposure and should be adequate enough to provide excellent exposure to visualize the entire glenoid and proximal humerus. Key landmarks consisting of the anterior clavicle, coracoid process, and midpoint of the arm at the level of the armpit are identified. The vertical incision is made starting on the lateral aspect of the coracoid process extending 10 cm to a point just medial to the midaspect of the arm. The deltopectoral interval is identified proximally and developed further distally. As per the surgeon preference, the cephalic vein is preserved and retracted medially. The subdeltoid space is accessed above the deltoid insertion and carried proximally releasing adhesions between the deltoid and lateral humerus up to the subacromial space. The arm is then adducted and externally rotated followed by development of the plane between the conjoint tendon and subscapularis. At this point, the anterior circumflex humeral artery and accompanying two veins are isolated and ligated.

Subscapularis release

The long head of the biceps tendon is then tenodesed to the pectoralis major tendon using two #2 nonabsorbable sutures. A subscapularis tenotomy is performed with a retention stitch placed in the superolateral corner and another in the lateral midportion of the subscapularis tendon. Alternatively, the subscapularis can be managed with a peel technique or lesser tuberosity osteotomy. The capsule is directly released off the humerus, ensuring exposure up until the inferomedial neck of the humerus.

Humeral preparation

Preparation of the humerus begins with complete exposure and dislocation of the humeral head into the wound with gentle adduction, extension, and external rotation. The bursal and articular sides of the rotator cuff are carefully inspected to ensure no major tears. Any irreparable supraspinatus or infraspinatus tendon tears would then result in conversion to reverse shoulder arthroplasty. Small tears that are amenable to fixation may be repaired given an appropriate clinical rotator cuff on physical exam. An intramedullary guide is used as the humeral resection guide. First, the medullary canal is opened up with a 5-mm round bur, followed by an ice pick to define the canal. Circular reamers are then progressed in the humeral canal until firm resistance is encountered. The humeral resection guide is then placed with a cutting block 1 mm superior to the rotator cuff insertion and the cut is performed in 30° of retroversion. The humeral canal is then broached up to the final trial size, given the appropriate height and rotational stability. Residual humeral osteophytes are then removed with a rongeur.

Glenoid preparation

Attention is then turned to the glenoid. The patient may be placed in additional reverse trendelenburg until the longitudinal

Figure 2 Off-axis eccentric reaming of the glenoid.

axis of the glenoid is positioned directly vertical and the arm is positioned in 70-90 degrees of abduction and slight flexion to enhance the exposure of the glenoid. A Fukuda retractor is placed on the posterior-inferior glenoid rim retracting the humerus posteriorly. A double-pronged glenoid retractor is preliminarily placed on the anterior glenoid. Using electrocautery, the glenoid labrum is then circumferentially excised around the glenoid in the periosteal plane followed by a release of the anterior capsule from the glenoid rim starting superiorly to approximately the 8 o'clock (right shoulder) position. The anterior glenoid retractor is then repositioned directly on bone. At this point, it is important to identify the true inferior aspect of the glenoid and junction of the glenoid face and neck. If need be, a handheld retractor and cautery may be used to ensure appropriate visualization of this area.

Preoperative imaging is then reviewed and correlated with the clinical pattern of glenoid wear, version, and inclination. The anatomic center of the glenoid is marked and the glenoid is appropriately sized. A centering pin is then placed through the center of the desired sizing guide and then checked clinically altering the location as necessary. Meticulous and sequential reaming is performed and adjusted depending on the pattern of bone loss to restore native version to neutral while minimizing bone removal. The addition of both off-axis and augmented glenoid components allow for eccentric reaming and minimal bone resection, relying on the glenoid component to fill in areas of need (Fig. 2). Augmented glenoid components are preferred to maximize equal bony apposition in cases where bone loss persists in a specific quadrant after appropriate eccentric reaming has been performed. The glenoid is then prepared to accept the central and peripheral component pegs, with excess bone subsequently cleared from the holes. The trial glenoid is placed ensuring the implant is in contact with all four quadrants of the glenoid and does not rock in any direction.

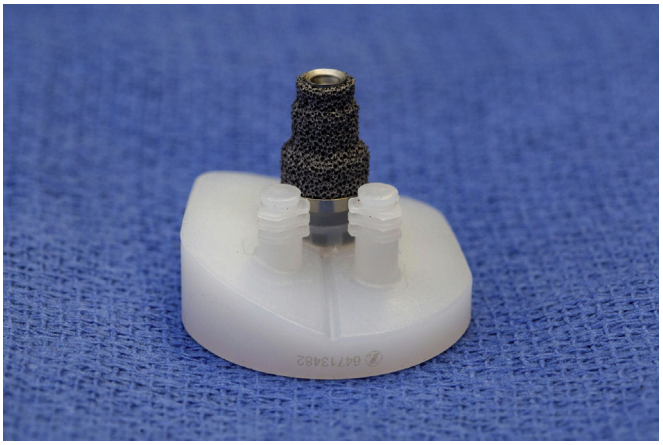

Figure 3 Hybrid modular glenoid component with a posterior augment composed of an all-polyethylene convex-backed base with a porous coated central post and three peripheral pegs.

The real glenoid component is selected and later cemented using third-generation technique (Fig. 3). The wound is irrigated with pulsatile lavage followed by continued drying with sponges around and inside the peg holes. Bone cement in the form of high-viscosity polymethymethacrylate is prepared using vacuum mixing. Once at the appropriate consistency, it is then individually pressurized one time into the small peg holes using a syringe with an outlet slightly larger than the drill holes. The glenoid component is aligned and then impacted into the cement bed with direct longitudinal pressure held by the component impactor. Extravagated cement is then removed, and the component stability is checked (Fig. 4).

Final component placement

Attention is returned to the humerus, where the trial stem is removed and the humeral component is inserted in the same fashion until the desired height and rotation. An eccentric trial humeral head is selected to match the diameter of the resected humeral head discounting osteophytes and also based on capsular and rotator cuff laxity. Final trialing is performed where attention is placed on the position of the humeral head and soft tissue balancing. In general, the humeral head should completely cover the osteotomy, face opposite the glenoid with the arm in the neutral position, and not impinge on the deep surface of the rotator cuff. The shoulder is then ranged to check for soft tissue tension and stability. In the neutral position, a posterior stress should lead to translation of the humeral head on the glenoid ideally less than 50% of the diameter with spontaneous reduction back to a centered position. With the arm elevated 30 degrees in the scapular plane, posterior translation of approximately one third is expected. Once the proper size and orientation of the humeral head is established, multiple interrupted sutures are placed in the rotator interval with the arm in external rotation, and then the final humeral head is impacted into place. The shoulder is reduced and irrigated for a final time.

Closure and rehabilitation

Closure begins with tying the previously placed rotator interval sutures with the arm in the preferred degree of maximum external rotation to avoid over tightening the rotator interval. For a tenotomy, the subscapularis is repaired tendon-to-tendon using multiple interrupted sutures. The deltopectoral interval is then closed with

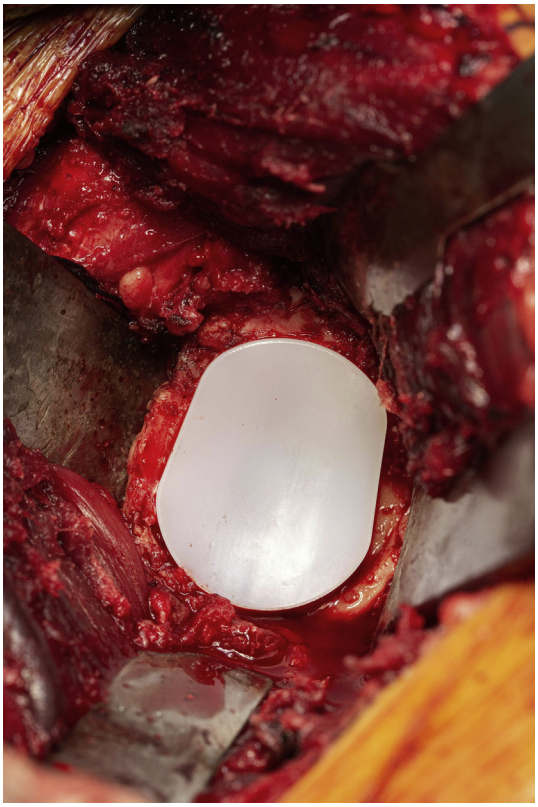

Figure 4 Final cemented hybrid glenoid component.

number-2 vicryl suture. The subcutaneous tissue and skin are closed in layers to provide a watertight closure.

Postoperatively, patients are placed in a shoulder immobilizer with abduction pillow immediately. On postoperative day 1, passive range of motion (ROM) exercises are initiated. By week 6, active assisted range of motion exercises are introduced, with active range of motion initiated once full active assisted range of motion is reached. By week 8, isometric strengthening may begin, followed by elastic band strengthening by week 12 at which point patients are generally ready to return to all activities.

Discussion

Aseptic glenoid loosening remains a frequently encountered problem in shoulder arthroplasty, with ongoing implant developments aiming to prevent glenoid component failure and complications. Previous literature has suggested equivalent or improved outcomes with hybrid fixation as compared to cemented all-polyethylene glenoid components. However, we present a reproducible technique on hybrid fixation of the glenoid component that may offer several advantages in the long term compared with previously described methods. These technical points include achieving adequate glenoid exposure, utilization off-axis instrumentation in cases of difficult exposure, and augmented glenoid components which help maximize bony contact in cases with glenoid bone loss.

To date, there exist 5 primary investigations and 1 systematic review evaluating TSA with hybrid fixation of glenoid components. Budge et al[6] first descried their series of a monoblock hybrid glenoid component (Trabecular Metal Glenoid; Zimmer, Warsaw, IN) composed of a polyethylene glenoid face that is compression molded to a porous tantalum keel in 2013. Although porous tantalum coating initially showed biomechanical promise for good bone ingrowth, their series unfortunately revealed a 21% glenoid component failure rate specifically owing to fatigue fractures at the keel-glenoid junction.[1,6] This led to early implant design revisions to reduce the risk of failure. Later in 2018, Nelson et al[14] reported their experience of 45 patients using a hybrid glenoid component (Comprehensive Shoulder System, Biomet, Warsaw, IN, USA) with a central porous titanium post. In contrast to previous tantalum-coated components, they reported a low rate of glenoid component failure at 2.2%. In addition, they reported comparable improvement in clinical outcomes and progressive radiolucent lines to reported series of all polyethylene components.[2,14]

In direct comparison to cemented all-polyethylene glenoid components, three retrospective, nonrandomized cohort investigations compared outcomes of hybrid glenoid component fixation to cemented all-polyethylene glenoid components. In 2015, Gullota et al[9] compared 43 patients treated with a hybrid glenoid component (Regenerex Hybrid Glenoid; Biomet Inc., Warsaw, IN, USA) with 40 patients who received a cemented all-polyethylene pegged glenoid component at an average of 38 months of follow-up. In general, they identified no differences among groups with respect to radiolucent line scoring (1.0% vs. 1.6%) adapted from the Lazarus et al,[10] postoperative change in VAS pain (1.2 vs. 1.5), change in ASES (33.7 vs. 35.5), or complications (2.3% vs. 7.5%) at the final follow-up.

In addition, in 2015, Grey et al[8] analyzed 46 patients treated with a hybrid cage-glenoid construct (Equinoxe cage glenoid; Exactech Inc., Gainesville, FL, USA) to 46 patients treated with cemented all-polyethylene pegged glenoid components at a mean of 25 months of follow-up. They observed a significantly lower rate of radiolucent lines (13.5% vs. 27.6%) with a lower score (0.22 vs. 0.57) graded according to Lazarus et al [10] and mean blood loss (252 mL vs. 337mL) in hybrid fixation compared to cemented all-polyethylene glenoid components, with similar rates of complications (6.3% vs. 6.3%). Interestingly, the authors concluded that blood loss was likely owing to a decreased operative time from the immediate interference fit of the cage peg and not needing to wait for cement curing.

In 2019, Friedman et al[7] reported their institutional experience analyzing a matched cohort study of 316 patients treated with a hybrid cage-glenoid construct (Equinoxe cage glenoid; Exactech Inc., Gainesville, FL, USA) as compared with patients treated with cemented all-polyethylene pegged glenoid components at 50 months of follow-up. They reported a lower rate of radiolucent glenoid lines (9.0% vs. 37.6%) graded according to Lazarus et al,[10] aseptic glenoid loosening (1.3% vs. 3.8%), and revision rate (2.5% vs. 6.9%) with the hybrid fixation cohort. Overall, the data regarding hybrid glenoid components remain limited. A systematic review by Malahias et al[11] summarizes and provides additional insight into the literature to date reporting pool data for hybrid glenoid component fixation with rates of postoperative radiolucent lines at a mean rate of 17.3% (range; 5% to 64.4%), complications at 7.4%, and revisions at 2.6%. In additional, more recent data from a retrospective multi-center investigation on 1555 patients treated starting in 2012 with hybrid glenoid component fixation from Mayo Clinic, Campbell Clinic, and the University of Buffalo, (Comprehensive; Zimmer Inc., Warsaw, IN, USA) demonstrated aseptic glenoid component loosening in 5 patients (0.3%) with a minimum of 2-year follow-up.

Technical pearls to consider include an appropriate correlation of preoperative advanced imaging and clinical glenoid wear pattern to correctly identify the glenoid center, eccentrically ream appropriately, and place the augments in the desired position. With glenoid reaming, the present technique calls for reaming to be fully reamed to allow the components to sit flush with maximal bony contact on the glenoid face. In the authors' experience, this often

starts with appropriately identifying the glenoid center. In cases with uneven glenoid erosion, particularly advanced posterior wear this may result in subchondral bone penetration. Violation of the subchondral plate has been descried as a risk factor for subsidence in cemented all-polyethylene keeled glenoid components[20]; however, the authors experience with the ingrowth nature of the hybrid component appears to limit this complication.[14] Furthermore, these also serve as indications for the use of augmented glenoid components aimed at areas with eccentric wear in order to once again maximize bony contact and limit maximal reaming. Potential difficulties with the technique include inability to acquire complete exposure of the glenoid given the need to ensure straight-line impaction of the glenoid component on-axis with the central peg. Using the pearls outlined previously for glenoid exposure and use of an off axis reamer in difficult cases may help limit this difficulty for surgeons.

Conclusion

Hybrid glenoid fixation of anatomic TSA is becoming an increasingly used glenoid fixation strategy. This article presents a review of the known literature and our preferred technique for hybrid glenoid component fixation with the use of a polyethylene base and highly porous metal central peg. Future investigations should continue to research the long-term clinical and radiographic outcomes of this fixation method.

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Conflicts of interest

John Sperling reports that he has received royalties from Zimmer-Biomet.

Dr Thomas Throckmorton reports that he has received royalties from Exactech.

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