Reverse Shoulder Arthroplasty using an Onlay Humeral Prosthesis, Offset Humeral Tray, and Augmented Glenoid Baseplate: Surgical Technique and Review of the Impact of Prosthesis Design on Scapular Fractures following Reverse Shoulder Arthroplasty

Charles Holliday, M.D.¹
Erick M. Marigi, M.D.¹
Ian Marigi, B.A.¹
Thomas R. Duquin, M.D.²
John W. Sperling M.D., MBA¹†

¹ Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA
² Department of Orthopaedics, State University of New York, Buffalo, NY, USA

Short Title: Humeral component Design in RSA
Mayo Clinic institutional review board approved this study (IRB #12-007498).

†Address correspondence to: John W. Sperling, M.D.
Mayo Clinic ; 200 First St SW; Rochester MN 55905
Ph.: 507-284-4896; Fax: 507-266-1803; Sperling.john@mayo.edu

Disclaimers:
Funding: No funding was disclosed by the authors.

Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Given his role as Co-Editor-in-Chief of this publication, Dr. John Sperling had no involvement in the peer-review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to Dr. Ed Craig.
Reverse Shoulder Arthroplasty using an Onlay Humeral Prosthesis, Offset Humeral Tray, and Augmented Glenoid Baseplate: Surgical Technique and Review of the Impact of Prosthesis Design on Scapular Fractures following Reverse Shoulder Arthroplasty

ABSTRACT

Reverse total shoulder arthroplasty (RSA) has become the most utilized form of arthroplasty of the shoulder. Acromial (ASF) and scapular spine (SSF) stress fractures are rare, yet well-recognized complications of RSA with ongoing studies identifying whether patient factors or prosthetic designs serve as risk factors. Specifically, it remains unclear if or how the position of the humeral tray (inlay or onlay) in RSA affects rates of periscapular fractures. The purpose of this article is to describe our technique for RSA using an onlay prosthesis, variable-offset humeral tray, and augmented glenoid baseplate, as well as to review the published results of acromial and scapular spine fractures after RSA based on humeral implant design.

Level of Evidence: Technique Article

Keywords: Reverse shoulder arthroplasty; Acromial stress fracture; Scapular spine fracture; Periscapular spine fracture; Risk factors; Onlay; Inlay

Reverse total shoulder arthroplasty (RSA) is a well-established and increasingly utilized procedure for improving pain relief and function in patients with rotator cuff insufficiency and glenohumeral osteoarthritis. In recent years, periprosthetic scapular spine fractures (SSF) and acromial fractures (AF) have been recognized as a unique complication of RSA.
Biomechanical investigations have suggested etiologies for these fractures to include alterations in deltoid strain\(^{21,41,50}\), glenoid baseplate screws as potential stress risers\(^{20}\), and variations in implant and arm positioning.\(^{21,41,50}\) Reported rates of acromial and scapular stress fractures have been estimated around 0.6\%-5\%.\(^{8,22,27,31,34,41}\), with a recent systematic review reporting an overall incidence of 2.6\% among modern RSA designs.\(^{41}\)

To date, several clinical investigations have identified possible risk factors for acromial and scapular spine fractures (SSF) following RSA. These risk factors include female sex\(^{30}\), poor bone stock\(^{23,30,33,48}\), prior acromioplasty\(^{31}\), rheumatoid arthritis\(^{30,38}\), and rotator cuff tear arthropathy.\(^{30,38}\) Furthermore, recent efforts have been made to identify modifiable procedural and implant related risk factors for scapular fractures, with variable and conflicting results. Proposed risk factors have included superior glenoid baseplate screw placement\(^{4}\), increased deltoid length\(^{9,48}\), glenoid over-lateralization\(^{50}\), and the use of an onlay humeral component design.\(^{3,4,15}\)

Modifications to humeral component design have evolved over the years, with efforts focused on reducing rates of scapular notching and addressing range-of-motion (ROM) deficits that were common with traditional Grammont style inlay prostheses.\(^{40}\) Early biomechanical studies by Virani et al\(^{46}\) suggested that ROM deficits and impingement seen with the Grammont style prosthesis were primarily related to implant positioning, with humeral implant design (inset vs. onset) having little impact.\(^{46}\) These findings led Dr. Frankle and their group to modify the principles of reverse shoulder arthroplasty in order optimize soft tissue tension and range of motion. This was achieved, in part, by utilizing a thicker glenosphere and a more vertical 135 degree opening angle humeral component.\(^{40}\) These concepts have carried over into the contemporary prostheses in use today.\(^{40}\)
Contemporary humeral component designs can be broadly categorized as either inlay or onlay, with onlay prostheses offering the benefit of bone preservation\textsuperscript{40}, improved ROM\textsuperscript{3,6,12,14,25,26,35}, lower rates of scapular notching\textsuperscript{12}, and easier conversion from anatomic total shoulder arthroplasty (aTSA).\textsuperscript{40} Alternatively, inlay prostheses have also demonstrated improvement in shoulder pain, ROM, and function, with the added theoretical benefit of increased bone-implant interface when compared to onlay prostheses.\textsuperscript{39} However, specific analyses of humeral component design and it’s relationship to acromial and scapular spine fractures have yielded conflicting results.\textsuperscript{3,4,12,15,32,35,51}

Recently, offset humeral trays have been introduced, however there is little information available on the technique of implantation and impact on soft tissue tensioning with reverse arthroplasty. Notably, offset humeral trays are unique to onlay prosthesis designs, conferring one additional potential benefit. This article presents key technical aspects of RSA implantation and tensioning, using an onlay humeral prosthesis with offset humeral tray and augmented glenoid baseplate of one specific commercially available implant system.

**Clinical Evaluation and Surgical Technique**

Patients presenting with shoulder pain undergo a standard comprehensive workup including complete history and physical exam, with special attention to the course of their shoulder pathology and clinic status of the deltoid and rotator cuff. Standard imaging includes antero-posterior and axillary radiographs to characterize glenohumeral joint pathology, joint space narrowing, and variations in glenohumeral morphology. Computed tomography is frequently obtained to further characterize the glenoid version and bone loss, in addition to obtaining radiographic data for patient specific instrumentation.
The most common indication for RSA is glenohumeral arthritis in the setting of rotator cuff deficiency and an intact deltoid with persistent symptoms despite a comprehensive course of nonoperative management. Additional common indications are listed below. Patients presenting with failure of previous shoulder surgery undergo further assessment, including evaluation of the prior implant type and expected bone loss in addition to examination of the rotator cuff and deltoid function.

**Indications:**
- Rotator cuff arthropathy
- Glenohumeral arthritis with deficient rotator cuff
- Unreconstructable proximal humerus fractures particularly in the elderly
- Massive irreparable rotator cuff tears in the elderly
- Rotator cuff deficiency, bone loss, deformity, or instability not conducive to aTSA
- Patients who have failed prior shoulder arthroplasty with rotator cuff failure and/or instability

**Contraindications**
- Axillary nerve damage or a non-functioning deltoid muscle
- Excessive glenoid vault deficiency not amenable to baseplate fixation
- Active infection.

**Surgical Technique**

Successful RSA implantation requires surgeon expertise in shoulder anatomy, kinematics, implant design, and operative technique, among others. Here we describe one
Humeral component Design in RSA

surgeon’s preferred technique using an onlay, variable-offset humeral component with augmented glenosphere baseplate, highlighting the key technical aspects as they relate to soft tissue tensioning and mitigating scapular and acromial strains.

Patient positioning

The patient is induced under general anesthesia with or without the use of an interscalene block. Afterward, the patient is positioned in the standard supine beach-chair position, with the medial border of the scapula positioned at the edge of the bed. A rolled-up towel is selectively placed posteriorly between the scapulae to support and stabilize the ipsilateral scapula during glenoid implantation.

Approach and initial exposure

One of the most challenging parts of RSA implantation is glenoid exposure. Glenoid exposure is facilitated through four key steps including an appropriate humeral head cut, humeral osteophyte removal, capsule release and deltoid mobilization. All of these steps occur on the humeral side. Therefore, the key to glenoid exposure is on the humeral rather than the glenoid side.

A deltopectoral approach is carried out in standard fashion, ensuring excellent exposure of the glenoid and proximal humerus. A 10 cm skin incision is created just lateral to the coracoid, beginning proximally at the level of the anterior clavicle. Distally, the incision lies just medial to the midpoint of the arm. The deltopectoral interval is identified just inferior to the level of the coracoid and is developed further distally. According to surgeon preference, the cephalic vein is preserved and retracted medially. Access to the subdeltoid space is achieved just proximal to the deltoid insertion, and a plane is developed between the deltoid and lateral humerus. The subacromial space is then developed bluntly, at which point a Darrach elevator may be used to
gently free subacromial adhesions as needed. The arm is adducted and externally rotated, at which point a plane is developed between the conjoint tendon and the subscapularis. Next, the anterior humeral circumflex artery and veins are identified and ligated.

Deep exposure and Subscapularis release

The long head of the biceps is tenodesed to the tendinous insertion of the pectoralis major tendon using two #2 non-absorbable sutures. In revision cases, or in cases with difficult exposure, the proximal 1 cm of pectoralis major tendon may be released to improve visualization. While subscapularis tenotomy, peel, and lesser tuberosity osteotomy are all validated options for subscapularis management, our preferences is to perform a subscapularis tenotomy or peel. Subsequently, a retention stitch placed in the superolateral corner and lateral midportion of the subscapularis tendon. Subsequently, the joint capsule is released from the humerus, first ensuring complete release of lateral humeral attachments and then along the inferomedial humeral neck to the mid-sagittal line of the humerus.

Humeral preparation

The humerus is dislocated using gentle adduction, extension, and external rotation. The bursal and articular aspects of the rotator cuff are carefully evaluated to verify the expected rotator cuff pathology. The medullary canal of the humerus is opened using a 5-mm round burr, starting at the superior apex of the humeral head (Figure 1). An ice pick is used to define the path of the intramedullary canal. Circular reamers are then sequentially introduced until firm resistance is encountered. At this point, the intramedullary humeral cutting guide is attached, and the humeral resection is completed in 30° of retroversion approximately 1 mm superior to the rotator cuff insertion (Figure 2). If there are any proximal humeral defects or deficiencies, cancellous autograft from the resected humeral head is acquired, using a rongeur, to later bone
Humeral component Design in RSA

139 graft the area in question. Sequential broaching of the humeral canal is then performed, ensuring appropriate depth and rotational stability of the final trial size (Figure 3). Throughout humeral canal instrumentation both reaming and broaching are performed to promote a neutral stem position and avoid varus or valgus alignment. Humeral preparation is then completed using a rongeur to remove any residual humeral osteophytes (Figure 4). Any remaining posterior capsule is then released off the posterior calcar up to the teres minor insertion.

142 Glenoid Preparation

Attention is then directed toward the glenoid, at which point the patient may be placed in additional reverse Trendelenburg so that the longitudinal axis of the glenoid is positioned vertically. To improve glenoid exposure, the arm is placed in 70-90° of abduction and slight forward flexion. A Fukuda or glenoid access retractor is then placed on the postero-inferior glenoid rim to retract the humerus posteriorly and a double-pronged glenoid retractor is placed between the subscapularis and the anterior capsule on the anterior glenoid. It is helpful to have a posterior retractor that has an opening or window that facilitates access to a circular reamer. Electrocautery is used to circumferentially remove the glenoid labrum in a subperiosteal plane. The anterior capsule is then divided, starting superiorly, and carried along the anterior rim and postero-inferiorly to approximately the 8 o’clock position (right shoulder). The anterior double-pronged glenoid retractor is then repositioned directly onto the glenoid bone anteriorly. Careful attention is paid to ensure the true inferior glenoid rim is exposed.

Once adequate exposure is obtained, glenoid wear, version, and inclination are evaluated and correlated with preoperative imaging. In select cases, patient specific guides are printed to provide a detailed understanding of the glenoid pathology (Figure 5). In our practice, we aim to position the glenosphere with 10 degrees of inferior tilt, which has been demonstrated to improve
stability and reduce the risk of atraumatic dislocation.³⁶,⁴⁴ Boileau et al⁷ have shown that there is on average 21° of superior tilt on the inferior aspect of the glenoid where the glenoid baseplate is placed. Therefore, on average 31° of tilt must be corrected in all cases (21° of superior tilt and the desired 10° of inferior tilt). There are three ways for the surgeon to correct the superior tilt: bone grafting, eccentric reaming, and use of an augmented baseplate. Recent literature from Rothmann Institute and Mayo Clinic have reported high rates of bone graft resorption and failure in the primary and revision setting.¹⁸,⁴⁷ Eccentric reaming removes a large amount of bone and the best quality cortical bone. There has been recent supportive literature of bone preservation with use of augmented baseplates, as such our practice has migrated to using augmented baseplates in nearly all reverse cases (Figure 6).¹

First, a placement guide and Steinmann pins are placed into the glenoid vault at the desired version and inclination. This is typically centered over the inferior glenoid with 5 - 10° of inferior tilt. The high side (less deficient) of the glenoid is reamed so that 50% of the articular surface is prepared (Figure 7). Within this system, patient specific instrumentation (PSI) in the form of reaming guides can be generated to provide more precise glenoid preparation. This is typically acquired in cases of advanced glenoid wear or glenoid dysplasia. Next, augmented sizing guides are used to determine the appropriate augmented glenoid baseplate size and orientation. An augmented reamer guide is placed, and an augment reamer is used to ream the low side (more deficient) of the glenoid (Figure 8). Having the ability to precisely prepare and then place the augmented baseplate in the identical rotation is critical. It has been shown that five degrees of malrotation of the baseplate can result in a loss of greater than 50% contact with the underlying native bone.⁴⁰ The augmented baseplate is impacted into position and is secured to the glenoid (Figure 9). Typically, all 4 screws are utilized paying close attention to insert a
screw into the superior glenoid at the base of the coracoid, and the inferior glenoid aiming into
the scapular pillar. The anterior and posterior screws are generally shorter screws providing
additional support with lengths ranging from 14-16 mm. As needed a trial glenosphere is placed
and dialed to the appropriate offset so that the inferior aspect of the glenosphere extends $1 - 2$
mm below the inferior rim of the glenoid. Inferior offset of the glenosphere below the glenoid
rim is effective in preventing scapular notching.$^{13,43}$ However, it has been suggested that that one
does not need to maximize the amount of the glenosphere offset below the bottom part of the
glenoid to prevent notching, as maximizing overhang can result in excessive deltoid tension and
compromised glenoid fixation.$^{13,43}$ Additionally, the less the glenosphere is dialed inferiorly, the
less humeral bone that needs to be resected to obtain the optimal soft tissue tensioning.$^{13}$ The
final glenosphere is then dialed to match the desired offset and impacted into position. (Figure 10)

**Humeral Component Placement**

Attention is returned to the humerus for component trialing and implantation. Standard
and offset humeral trays are attached to the trial broach, selecting the tray that is positioned most
centrally over the resected surface, minimizing any overhang of the components, as well as
optimizing soft tissue tension (Figure 11). The desired trial humeral bearing is then attached, and
the shoulder is reduced to assess soft tissue tensioning, range of motion, and implant stability
(Figure 12). Special attention is placed on the combined lateralization generated from the
implant configuration to create the desired amount of tension on the deltoid and rotator cuff.
Specifically, the baseplate, glenosphere, humeral tray, and humeral bearing thickness as well as
humeral tray offset can be varied to achieve optimal tensioning and positioning. In most cases,
we utilize a lateralized baseplate with a standard thickness glenosphere and adjust the modular humeral components to ensure that we are promoting impingement free ROM while balancing the soft tissue tension.

One key technologic development is the use of offset humeral trays. The use of a lateral offset humeral tray results in medialization and distalization of the implant. This is helpful in the setting of lateralized RSA designs that may lead to a lateralized center of rotation. The offset trays can decrease acromial-humeral impingement as well as making the construct less tight. This allows the surgeon to adjust the tension on the humeral side (Figure 13).

Once satisfied with humeral component trialing, the trial broach is removed. At this point, if the surgeon determines that there are proximal humeral deficiencies preventing adequate stem fit, crushed humeral cancellous autograft may be manually impacted with finger pressure along the deficient areas prior to final implant placement. Finally, the final humeral stem is impacted into position with the desired height and retroversion (Figure 14 and 15). There is evidence noting that there is nine times less wear with vitamin E impregnated polyethylene, therefore, while not all manufactures offer Vit-E polyethylene components, our preference is to use this on all reverse arthroplasty cases.² The final humeral tray and bearing are then implanted, the shoulder is reduced, and the shoulder is irrigated with pulse lavage (Figure 16).

Closure and rehabilitation

The subscapularis is repaired to its tendinous insertion on the lesser tuberosity using multiple interrupted braided non-absorbable sutures. Of note, use of an offset tray with slight medialization also facilitates closure of the subscapularis tendon (Figure 17). The deltopectoral interval is then approximated with braided absorbable suture and the remaining subcutaneous tissue and skin are closed in layers (Figure 18). Postoperatively, the shoulder is placed in a
Humeral component Design in RSA

shoulder immobilizer for 6 weeks. Passive ROM exercises are initiated on postoperative day 1 and active assisted ROM exercise is introduced at 6 weeks postoperatively. Active ROM exercises are initiated once full active-assisted ROM is achieved. By week 8, strengthening is initiated, first with isometric strengthening exercises, followed by elastic band exercises at week 12. After week 12, patients are encouraged to return to all previous activities.

DISCUSSION

Acr
amial and scapular spine fractures following RSA and are associated with adverse clinical outcomes. Specifically, patients have demonstrated worse pain, ROM, and functional outcome scores. Various studies have identified possible risk factors for acromial and scapular spine fractures following RSA, with conflicting results when specifically evaluating for onlay and inlay humeral stem designs.

In a non-randomized retrospective review of 100 patients undergoing RSA with onlay humeral prosthesis, Ascione et al reported a 5% rate of scapular fractures. In a subsequent publication, Ascione et al reported an updated series of 485 RSA with onlay humeral stems with a 4.3% scapular fracture rate. In this series, they found that most fractures occurred in the scapular spine, with 57% of fractures occurring at the tip of the superior glenoid baseplate screw. In 2020, Haidamous et al published a multicenter retrospective review of scapular spine fractures following RSA. In this investigation, they reported an 11.9% incidence of scapular fracture among 84 RSA onlay prostheses, and a 4.7% incidence of acromial stress fractures in 342 RSA inlay prostheses ($P = .043$). While the difference in fracture rate was statistically significant in this study, their conclusions were limited by short follow-up of just one year, a small number of onlay prostheses implanted, and 37% of patients being lost to follow-up.
Contrary to these findings, several publications have failed to identify a significant difference in scapular fracture rates between onlay and inlay prosthesis designs.\textsuperscript{5,32,41,51} Merolla et al\textsuperscript{32} conducted a review comparing outcomes following 36 inlay and 38 onlay RSA prostheses. Though limited by a small sample size, they reported no difference in scapular fracture rates between groups and significantly higher rates of scapular notching among the inlay group. Similarly, Zmistowski et al\textsuperscript{51} published a review of 958 RSA with no differences in the rates of acromial or scapular spine fractures between onlay and inlay prostheses. With respect to systematic analyses, Jackson et al\textsuperscript{19} demonstrated no differences between AF or SSF among onlay and inlay humeral designs after a systematic review of 306 shoulders. Additionally, while not a comparative study, Routman et al\textsuperscript{38} published an acromial and scapular fracture rate of 1.77\% among 4125 reverse arthroplasties utilizing an onlay design, much lower than the rates reported in aforementioned studies.

Of note, it has been suggested that categorizing humeral prosthesis into onlay and inlay groups may be an oversimplification when attempting to understand the relationship between prosthesis design and scapular fractures.\textsuperscript{40} This may explain the variability in reported fracture rates among primary investigations, as simply comparing onlay versus inlay humeral prosthesis fails to account for variations in implant positioning and surgical techniques, which alter deltoid and scapular strains. Ultimately, stresses experienced by the acromion and scapular spine following RSA are dependent on the complex interaction of variables including glenoid and humeral implant design, size, and positioning, patient anatomy, and patient activity.\textsuperscript{40} There is significant variation in glenoid and humeral component positioning achieved with the various implants in use today, with overlap existing between onlay and inlay designs.\textsuperscript{49} For example, a large “inlay” prosthesis may not always be fully accommodated by the humeral metaphysis,
resulting in final position that is more comparable to onlay prostheses.\textsuperscript{40} Alternatively, with a larger humeral head resection, an “onlay” humeral component may be positioned so that the bearing surface rests below the original anatomic neck, as would be expected with inlay prostheses.\textsuperscript{40}

Considering these limitations, investigations focusing on measures of glenoid and humeral positioning may offer better insight into the effects of component implantation on scapular fractures. Recent studies have used the RSA component classification described by Routman et al\textsuperscript{37} which classifies components as having a medialized glenoid (MG), lateralized glenoid (LG), medialized humerus (MH), or lateralized humerus (LH). Some studies have proposed that MH configurations may be a risk factor for scapular fractures.\textsuperscript{8,16,21} Kerrigan et al\textsuperscript{21} reported decreased acromial strain with LH designs in a cadaveric model. Alternatively, Hamilton et al\textsuperscript{16} used digital bone models to demonstrate improved deltoid efficiency with LH designs. These findings are supported by a systematic review by Cho et al\textsuperscript{8} found an 8.4% fracture rate among MG/MH designs, compared to 4.0% for LG/MH designs and 2.8% for MGLH designs. However, the systematic review by Shah et al\textsuperscript{42} evaluating postoperative complications of over 14,000 shoulders reported no differences in AF or SSF between various implant designs, with rates of 2.8%, 2.5%, and 2.2% in LG/MH, MG/MH, and MG/LH designs, respectively.

This article presents a technique for RSA utilizing an onlay humeral component design with variable-offset humeral tray and augmented glenoid baseplate, highlighting technical pearls that optimize soft tissue tension and help to mitigate scapular and acromial strains. Technical pearls to consider include an appropriate correlation of preoperative advanced imaging, clinical glenoid wear pattern, restoring the appropriate soft tissue tension to avoid impingement, and
avoiding undue stress on the acromion and scapular spine. This is accomplished with utilization of offset humeral trays to titrate the soft tissue tension on the deltoid and scapular musculature. Additionally, this ability to modify the humeral components allows for appropriate positioning of the humeral tray over the anatomic humeral neck cut, which can help limit the extent of strain across the scapula.

CONCLUSION

Acromial stress and scapular spine fractures remain a relevant complication in modern RSA. Conflicting results exist regarding an onlay vs. inlay humeral stem design as it relates to fractures, with recent investigations suggesting no differences. As such there remains no clear consensus regarding implant design and positioning, and cases should likely be evaluated based on individual patient characteristics. This article presents our preferred technique for RSA implantation with the use of a modern onlay humeral stem design with variable-offset humeral tray and augmented glenoid baseplate, highlighting technical pearls that optimize soft tissue tension and help to mitigate scapular and acromial strains.

REFERENCES


21. Kerrigan AM, Reeves JM, Langohr GDG, Johnson JA, Athwal GS. The influence of reverse arthroplasty humeral component design features on scapular spine strain. *Journal*
Humeral component Design in RSA of Shoulder and Elbow Surgery. 2021;30(3):572-579
doi:https://doi.org/10.1016/j.jse.2020.06.011.


Humeral component Design in RSA

Analysis. *Journal of Shoulder and Elbow Arthroplasty*. 2018;2:2471549218777628

49. Werthel JD, Walch G, Vegehan E, Deransart P, Sanchez-Sotelo J, Valenti P.
Lateralization in reverse shoulder arthroplasty: a descriptive analysis of different implants
3.

50. Wong MT, Langohr GDG, Athwal GS, Johnson JA. Implant positioning in reverse
shoulder arthroplasty has an impact on acromial stresses. *Journal of Shoulder and Elbow

51. Zmistowski B, Gutman M, Horvath Y, Abboud JA, Williams GR, Jr., Namdari S.
Acromial stress fracture following reverse total shoulder arthroplasty: incidence and
**LEGENDS**

**Figure 1:** 5-mm round burr to create the entry hole at the superior apex of the humeral head.

**Figure 2:** Humeral resection utilizing an intramedullary humeral cutting guide.

**Figure 3:** Sequential broaching of the humeral canal.

**Figure 4:** Heart shaped metaphyseal surface after osteophyte removal.

**Figure 5:** Patient specific guide with depth control

**Figure 6:** Schematic demonstrating the preservation of bone with use of the augmented glenoid reaming system.

**Figure 7:** High side glenoid reaming with the patient specific guide.

**Figure 8:** Low side glenoid reaming with the augmented reamer guide.

**Figure 9:** Insertion of the augmented baseplate

**Figure 10:** Glenosphere is dialed to the appropriate offset prior to implantation to titrate the soft tissue tension.

**Figure 11:** Humeral tray offset options.

**Figure 12:** Humeral tray with +6 offset on humerus selected to optimize central position on the resected surface.

**Figure 13:** Postoperative radiographs of different offset tray configurations to demonstrating the ability to tension each shoulder as desired.

**Figure 14:** Humeral stem inserted into the prepared canal in neutral alignment.

**Figure 15:** Humeral stem positioned centrally in the prepared canal.

**Figure 16:** Final construct with offset humeral tray minimizing medial overhang.

**Figure 17:** Subscapularis closure after placement of final components.

**Figure 18:** Preoperative and postoperative anterior-posterior radiograph of an arthritic shoulder treated with a RSA with an offset humeral tray and augmented baseplate.
50% less bone removal