Technical Note

Techniques to Address Humeral Bone Insufficiency During Total Shoulder Arthroplasty With a Nonspherical Humeral Head and Inlay Glenoid

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Abstract: Total shoulder arthroplasty with a humeral head resurfacing (HHR) component and an inlay glenoid (OVOMotion; Arthrosurface) is a successful treatment option for patients with advanced glenohumeral arthritis, an intact rotator cuff, and adequate proximal humeral bone stock. In patients with poor proximal humeral bone, historically stemmed humeral components have been used instead of HHR. However, strategies can be used to successfully optimize HHR implant fixation in suboptimal bone without converting to stemmed implants or in surgical centers where stemmed prostheses are not available. This Technical Note describes 3 techniques—upsizing the humeral taper post, using humeral autograft, and cementation—to improve humeral implant fixation in patients with suboptimal bone stock when using the Arthrosurface OVOMotion implant.

There has been exponential growth in total shoulder arthroplasty (TSA) procedures, with increased interest in bone-conserving options such as humeral head resurfacing (HHR) component with an inlay glenoid and stemless anatomic TSA.[1-7] Advantages of HHR with an inlay glenoid and stemless TSA include shorter operative and anesthesia time, less intraoperative blood loss, a lower risk of periprosthetic fracture, and more bone-stock preservation.[5,8-12] In addition, studies have demonstrated excellent clinical outcomes and few postoperative complications following use of TSA with HHR and an inlay glenoid.[9,13-17]

In patients with known poor proximal bone, stemmed TSA implants have traditionally been used.[5,18] However, strategies can be implemented to optimize stability of HHR implants without needing to intraoperatively convert to stemmed prosthesis. In this Technical Note, 3 techniques are described to successfully maximize HHR implant stability in the setting of suboptimal proximal bone stock when using the Arthosurface OVOMotion TSA implant (OVOMotion/Inlay Glenoid Total Shoulder System; Arthrosurface, Franklin, MA). The first technique is to upsize the humeral taper post from the standard 12.0-mm size to an alternative 15.6-mm size available from the femoral head resurfacing set (HemiCAP, Femoral Head Resurfacing System; Arthrosurface).The second technique is to use autograft bone and impact that into the humerus before post insertion. The third and last line technique is to cement the humeral component. These techniques may have significant utility as back-up options when suboptimal bone is unexpectedly encountered, and stemmed prosthesis are not readily available.

Surgical Technique (With Video Illustration)

Diagnosis of glenohumeral arthritis with intact rotator cuff and adequate-appearing proximal bone stock is made. Patients receive either regional alone or regional and general anesthesia and are placed in the beach-chair position. The primary steps of the following surgical procedure are summarized in Table 1 and demonstrated in Video 1. A standard deltopectoral approach with a subscapularis tenotomy is performed. Osteophytes are removed, and sizing guides are used to determine the superoinferior (SI) and anteroposterior (AP) dimensions of the humeral head. For the ovoid

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Table 1. Operative Technique

Patient positioning	Patients receive either regional alone or regional and general anesthesia and are placed in the beach-chair position.
Superficial dissection	A standard deltopectoral approach is used.
Deep dissection	A subscapularis tenotomy is performed, the capsule is dissected, and the humeral head is exposed. Osteophytes surrounding the humeral head are removed to identify the true border of the humeral head.
HH sizing	Sizing guides are used to determine the superoinferior (SI) and anteroposterior (AP) dimensions of the HH. Component sizes range from 46 mm (SI) × 42 mm (AP) to 58 mm (SI) × 54 mm (AP). The undersurface of the implant however is spherical, allowing for spherical reaming.
HH preparation	After sizing, the surface reamer is used as a guide to insert the guide pin into the HH. The centering shaft is advanced over the guide pin until the set stop is at the level of the humeral surface. The surface reamer and the subsequent flat access reamers are each advanced over the centering shaft until the set stop is reached. Bony debris from these previous steps is removed. After removing the flat access reamer, a pillar of healthy bone, approximately 1 × 1 cm remains around the centering pin
Autograft harvest	The centering shaft is withdrawn several millimeters, and an osteotome is used to remove the pillar of bone, which is saved for later potential use as autograft
Glenoid implant Placement	The glenoid is exposed and prepared. The all-polyethylene inlay glenoid component is inserted using third-generation cement technique ensuring that component sits flush with the surrounding native glenoid surface.
Humeral bone assessment and standard postinsertion	Humerus bone quality is reassessed. If bone stock is adequate, the preparation trial and guide handle are placed and the centering guide pin is placed through them back into the existing pilot hole. The pilot drill is inserted through the guide handle and advanced until the indicated laser mark. The standard 12.0-mm tapered post is loaded onto the distal end of the guide handle, which is advanced over the centering guide wire until the preparation trail is reached. The hex driver is then placed through the guide handle to advance the taper post into the humerus to the proper depth. All insertion devices are removed and the final HH surface component is impacted onto the post in the correct AP-SI orientation engaging the Morse taper.
Determination of bone quality	Before inserting the taper post, inadequate bone stock can be readdressed by using option A, B, or C, described to follow.
Option B: upsizing the taper post	The standard post associated with this implant system (Arthrosurface) is a 12.0-mm tapered post. However, a larger 15.6-mm tapered post from the femoral head resurfacing system (Arthrosurface) can be made available by industry product representatives. It is compatible with the standard HH surface components, as both components use the same morse taper. The 15.6-mm post can be loaded onto the standard guide hand and inserted in place of the 12.0-mm post without any additional humeral preparation and with the same insertional tools. After placement, the HHR component is impacted onto the taper post.
Option B: autograft bone placement	Autograft is available from the earlier HH preparation. This pillar of healthy metaphyseal bone is placed on the back table. An osteotome is used to make a single cut in the ring, allowing it to be flexible enough to fit into the impaction site while still retaining structural integrity. Additional humeral preparation is required before inserting the autograft. All tools required are available in the standard OVOMotion tray (Arthrosurface). The guide handle with preparation trial are placed on the humerus and secured with 3 short guide pins. The centering pin is placed and the guide handle is removed. The pilot drill is placed over the centering pin and the step drill is advanced over the pilot drill 0.5 to 1 cm into the humerus. All instruments are removed except for the centering pin. The cut autograft ring is advanced over the centering pin into the humeral. The standard size tapered post is loaded onto the guide hand and is then inserted over the guide pin into the humerus with the same insertional technique described above. As the taper post is inserted, the autograft ring is circumferentially impacting into the surrounding metaphysis. After placement, the HHR component is impacted onto the taper post.

(*continued*)

Table 1. Continued

Option C: cementation of humeral component	The same type of cement used for previous glenoid component implantation is also used. The humerus is prepared with pulsatile lavage, the cement is vacuum-mixed and pressurized into the humerus. On the back table, the HH surface component is impacted onto the tapered post and cement is placed on the backside of the taper post. Cement is not placed on the titanium plasma spray undercoating of the HHR component. The cement backed prosthesis is impacted into the humerus and held in place until the cement is hardened.
Wound closure	After placement of the final HHR component, the shoulder is irrigated, the subscapularis is repaired, and standard closure is performed.
Postoperative care	Postoperatively, the patients are placed into a sling. There are no modifications to the standard postoperative protocol when the 15.6-mm post, autograft, or cement are used.

AP, anteroposterior; HH, humeral head; HHR, humeral head resurfacing; SI, superoinferior.

HHR component, the SI dimension is 4 mm larger than the AP dimension, with varying radiuses of curvature. After sizing, a guide pin is placed through the sizing guide and the centering shaft is advanced over the guide pin to the level of the humeral head (Fig 1). The surface reamer and subsequent flat access reamers are each advanced over the centering shaft until the set stop is reached (Fig 2). The spherical and flat top reaming mobilizes periarticular osteophytes in addition to subchondral and metaphyseal bone, which should be discarded due to their pathologic nature. After removing the flat access reamer, a pillar of metaphyseal bone, approximately 1 × 1-cm remains around the centering shaft (Fig 3A). The centering shaft is withdrawn several millimeters, and an osteotome is used to remove that bone, which is saved for later potential use as autograft (Fig 3 B-D).

The glenoid is exposed and the all-polyethylene inlay glenoid component is inserted using third-generation cement technique ensuring that component sits flush with the surrounding native glenoid surface. Attention is then turned back to the humerus and bone quality can be addressed if needed. If bone stock is adequate, the preparation trial and guide handle are placed and the centering guide pin is placed through them back into the existing pilot hole. The pilot drill is inserted through the guide handle and advanced until the indicated laser mark (Fig 4A). The standard 12.0-mm tapered post is loaded onto the distal end of the guide handle (Fig 4B), which is advanced over the centering guide wire until the preparation trial is reached. The hex driver is then placed through the guide handle to advance the taper post into the humerus to the proper depth. All-insertion devices are removed and the final

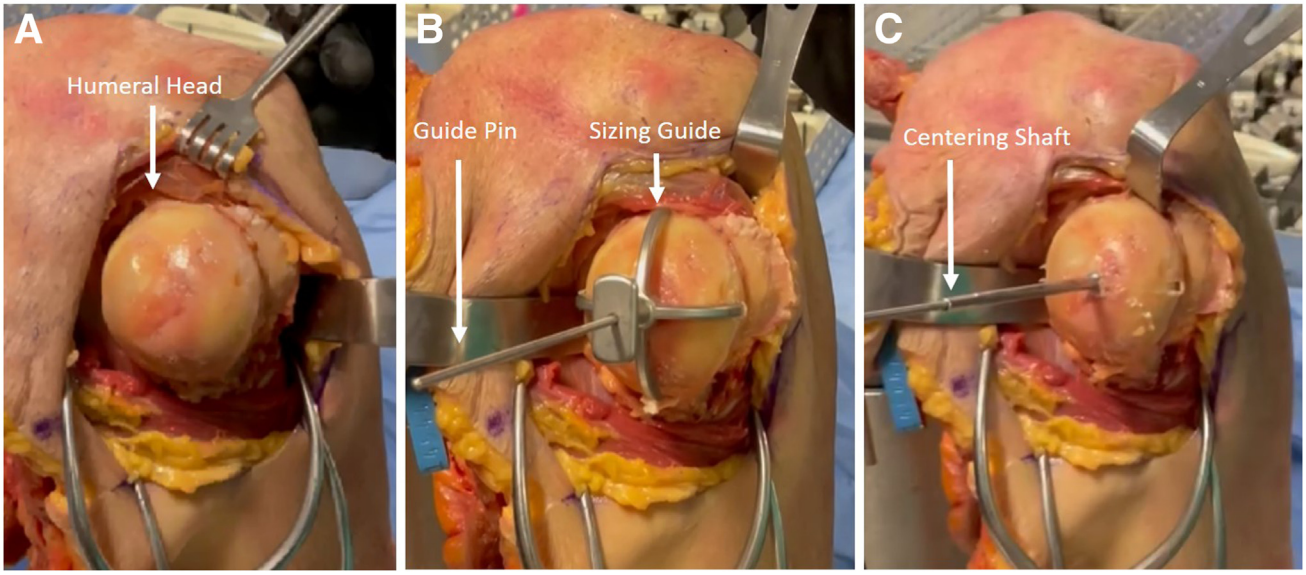

Fig 1. Left shoulder in beach-chair position: a standard deltopectoral approach is performed and the humeral head is delivered (A). After sizing, a guide pin is placed through the sizing guide (B) and the centering shaft is advanced over the guide pin to the level of the humeral head (C).

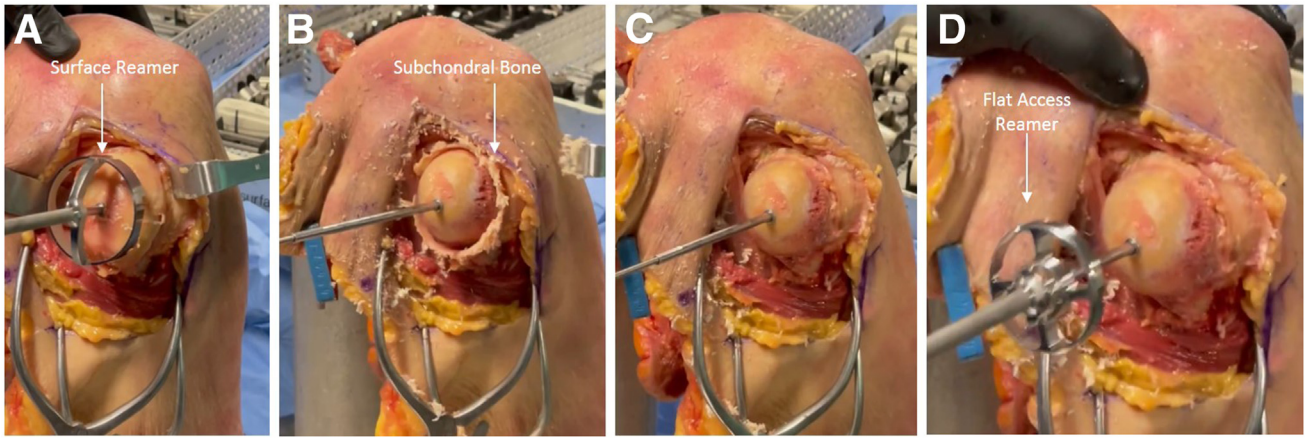

Fig 2. Left shoulder in beach-chair position: The surface reamer (A) is advanced over the centering shaft until the step stop is reached. Mobilized subchondral and metaphyseal bone is discarded (B-C). The flat access reamers is then also advanced over the centering shaft until the set stop is reached (D).

HHR component is impacted onto the post in the correct AP-SI orientation engaging the morse taper.

However, before inserting the taper post, inadequate bone stock can be readdressed by using Option A, Option B, or Option C, described to follow.

Option A: Upsize the Taper Post

The standard post associated with this implant system (OVOMotion Shoulder Arthroplasty System; Arthrosurface) is a 12.0-mm tapered post. However, a larger 15.6-mm tapered post, which originates from the femoral head resurfacing system (HemiCAP, Femoral Head Resurfacing System; Arthrosurface) can be made available by industry product representatives. Comparison of the specification of the 2 posts is presented in Figure 5 A and B, and Table 2. It is compatible with the standard humeral head surface components, as both components use the same morse taper. The 15.6-mm post can be loaded onto the standard guide hand and inserted in place of the 12.0-mm post without any additional humeral preparation and with the same insertional tools (Fig 5C). The 15.6-mm post has a larger thread to core diameter ratio than the standard 12.0-mm post, which enables superior bony fixation. After placement, the HHR component is impacted onto the taper post.

Option B: Autograft Bone Placement

Autograft is available from the earlier humeral head preparation. This pillar of healthy metaphyseal bone is placed on the back table. An osteotome is used to make a single cut in the ring, allowing it to expand into the impaction site during screw insertion (Fig 6).

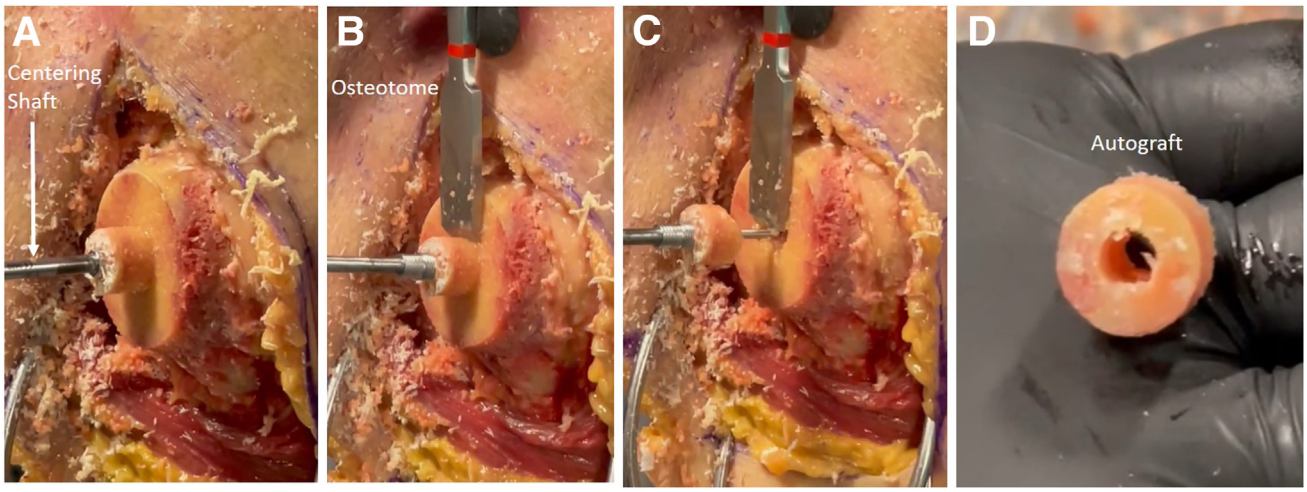

Fig 3. Left shoulder in beach-chair position: After removing the flat access reamer, a pillar of metaphyseal bone, approximately 1 × 1 cm remains around the centering shaft (A). The centering shaft is withdrawn several millimeters, and an osteotome is used to remove that bone (B-C), which is saved for later potential use as autograft (D).

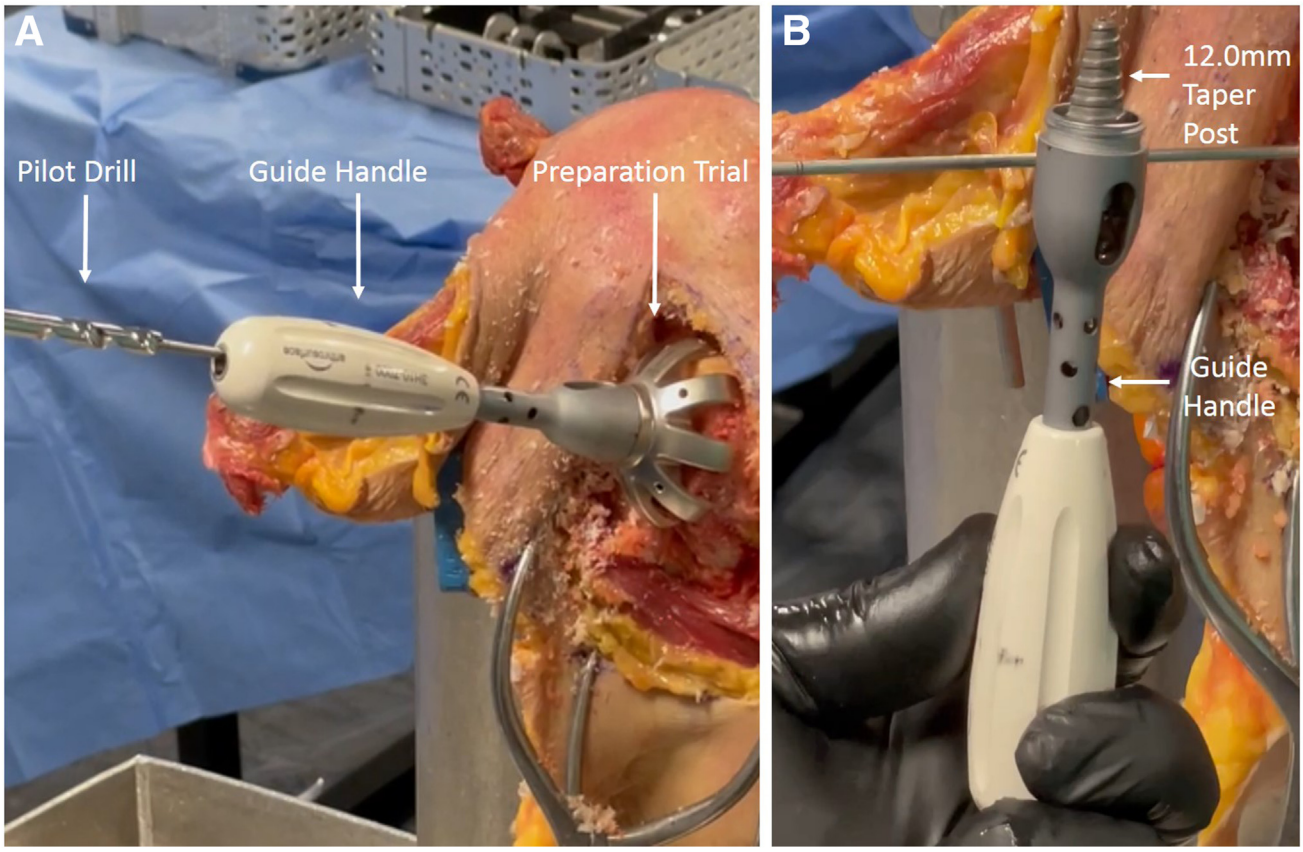

Fig 4. Left shoulder in beach-chair position: The preparation trial and guide handle are placed and the centering guide pin is placed through them back into the existing pilot hole. The pilot drill is inserted through the guide handle and advanced until the indicated laser mark (A). The standard 12.0-mm tapered post is loaded onto the distal end of the guide handle (B). This is then advanced over the centering guidewire until the preparation trail is reached. The hex driver is then placed through the guide handle to advance the taper post into the humerus to the proper depth

Additional humeral preparation is required before inserting the autograft. All tools required are available in the standard OVOMotion tray (Arthrosurface). The guide handle with preparation trial are placed on the humerus and secured with 3 short guide pins. The centering pin is placed and the guide handle is

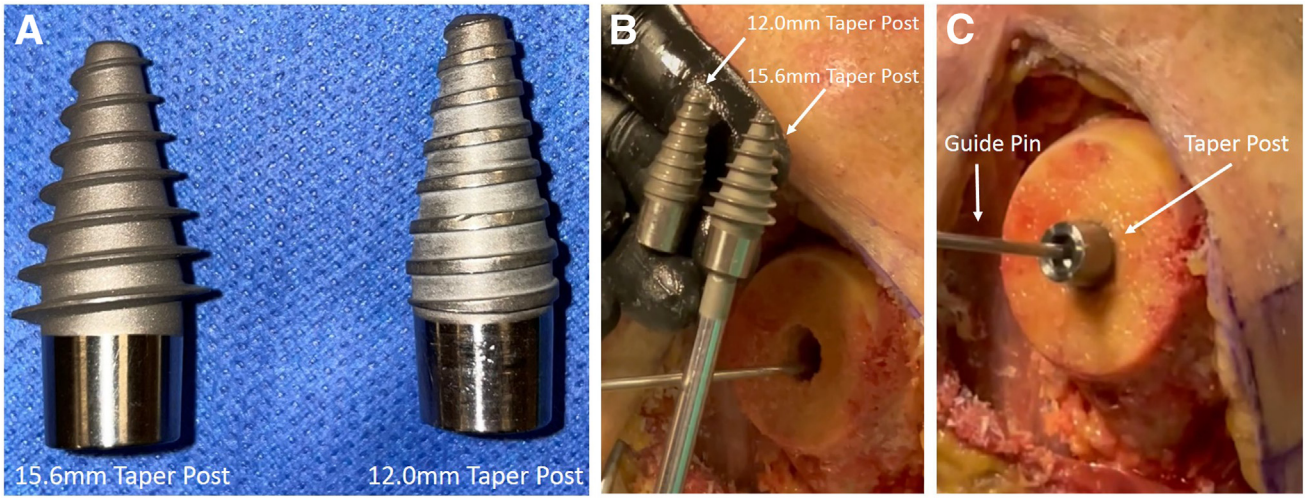

Fig 5. Comparison of the size of the standard 12.0-mm and 15.6-mm taper posts on the back table (A) and in situ (B). Both post of the same morse taper which is compatible with the standard humeral head surface components (C).

Table 2. Comparison of Taper Post/Screw Sizes

Criteria	Standard 12.0-mm taper post	Alternative 15.6-mm taper post
Catalog number (implant system)	8165-0032 (OVO/ OVOMotion Shoulder)	H156-0032 (HemiCAP Femoral Head Resurfacing)
Length, mm	32.0	32.0
Guidewire diameter, mm	2.5	2.5
Outer thread diameter (maximum), mm	11.8	15.6
Inner core diameter (maximum), mm	11.0	11.0
Thread depth (maximum), mm	0.8	4.6
Thread to core diameter ratio	1.07	1.42
Pitch (constant), mm	4.0	4.0

removed. The pilot drill is placed over the centering pin and the step drill is advanced over the pilot drill 0.5 to 1 cm into the humerus (Fig 7). All instruments are removed except for the centering pin. The cut autograft ring is advanced over the centering pin into the humerus (Fig 8 A and B). The standard size tapered post is loaded onto the guide hand and is then inserted over the guide pin into the humerus with the same insertional technique described above (Fig 8C). As the taper post is inserted, the autograft ring is circumferentially impacting into the surrounding metaphysis. This additional autograft assists in providing biological and mechanical support improving component stability. After placement, the HHR component is impacted onto the taper post.

Option C: Cement the Humeral Taper Post

The final option is to cement the humeral component. In this setting, the same type of cement used for previous glenoid component implantation is also used. The humerus is prepared with pulsatile lavage, the cement is vacuum-mixed and pressurized into the humerus. On the back table, the HHR surface component is impacted onto the tapered post and cement is placed on the backside of the taper post (Fig 9). Cement is not

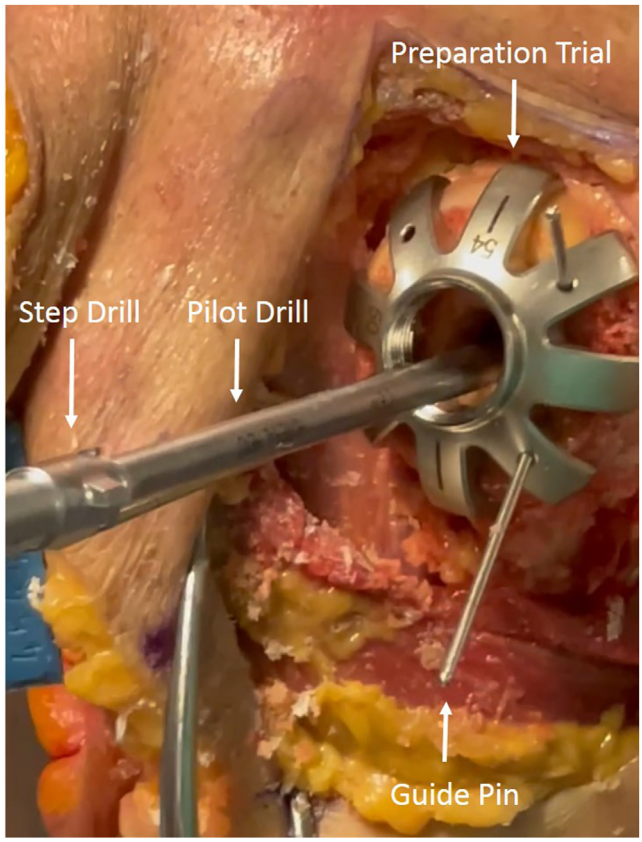

Fig 7. Left shoulder in beach-chair position: The guide handle with preparation trial are placed on the humerus and secured with 3 short guide pins. The centering pin is placed and the guide handle is removed. The pilot drill is placed over the centering pin and the step drill is advanced over the pilot drill 0.5 to 1 cm into the humerus

Fig 6. Autograft preparation: the pillar of healthy metaphyseal bone previously saved is placed on the back table (A). An osteotome is used to make a single cut in the ring (B-C).

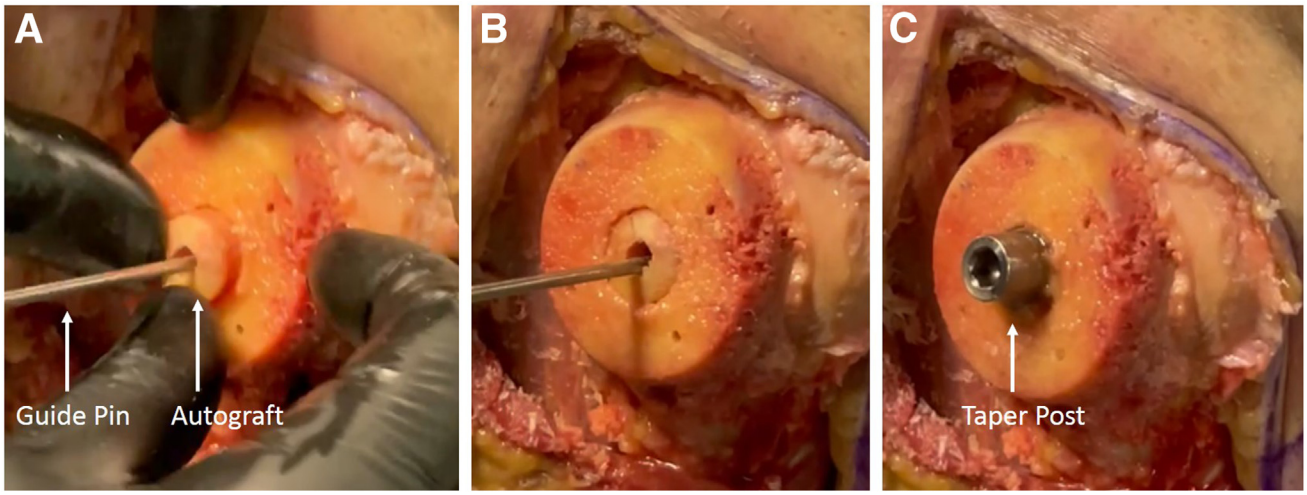

Fig 8. Left shoulder in beach-chair position: The cut autograft ring is advanced over the centering pin into the humerus (A-B). The standard size tapered post is loaded onto the guide hand and is then inserted into the humerus with the same insertional technique described previously (C). As the taper post is inserted, the autograft ring is circumferentially impacting into the surrounding metaphysis.

placed on the titanium plasma spray undercoating of the HHR component, which is designed to allow bony ongrowth. The cement backed prosthesis is impacted into the humerus and held in place until the cement is hardened (Fig 10).

After completion of each of the techniques, final HHR surface component is confirmed to be secure. The shoulder is irrigated, the subscapularis is repaired, and standard closure is performed. There are no modifications to the standard postoperative protocol when the 15.6-mm post, autograft, or cement is used. The advantages and disadvantages of these techniques are summarized Table 3. Preoperative and postoperative radiographs are presented in Figure 11.

Discussion

This Technical Note describes 3 methods—upsizing the humeral taper post, using humeral autograft, and cementing—to successfully maximize humeral implant fixation in patients with suboptimal humeral bone stock when using the Arthrosurface OVOMotion implant. These techniques may have significant utility when poor bone is unexpectedly encountered intraoperatively and in surgical settings when stemmed prosthesis are not readily available.

Each technique has unique advantages and disadvantages. Upsizing the taper post can be easily completed without requiring additional bone preparation or insertional tools however requires availability of the implant. The 15.6-mm post, when compared

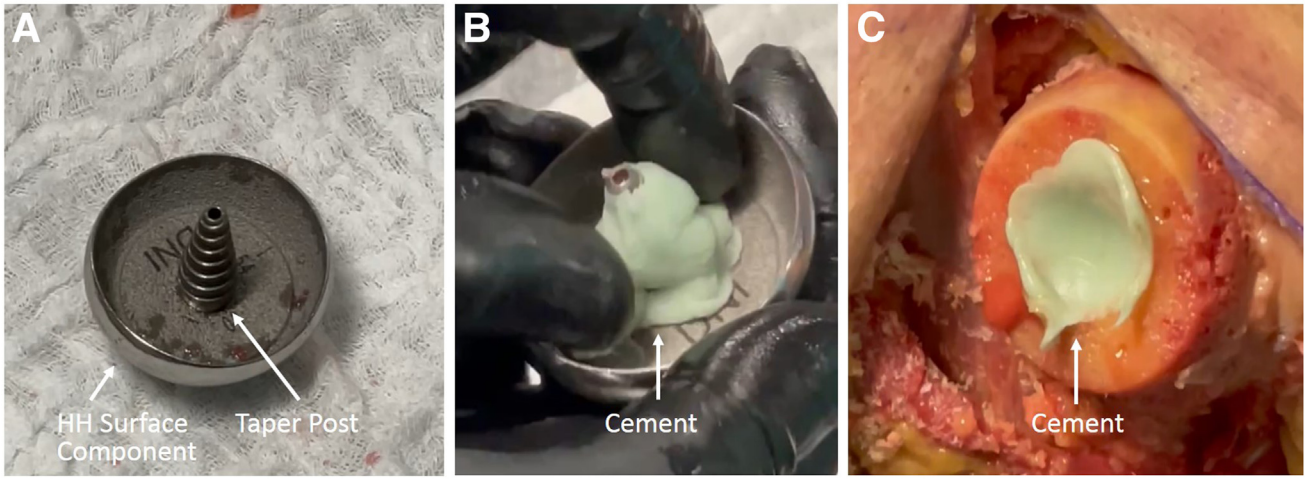

Fig 9. Left shoulder in beach-chair position: On the back table, the humeral head (HH) surface component is impacted onto the tapered post (A). Cement is placed into the backside of the taper post (B) and into the humerus (C). Cement is not placed on the titanium plasma spray undercoating of the HHR component. (HHR, humeral head resurfacing.)

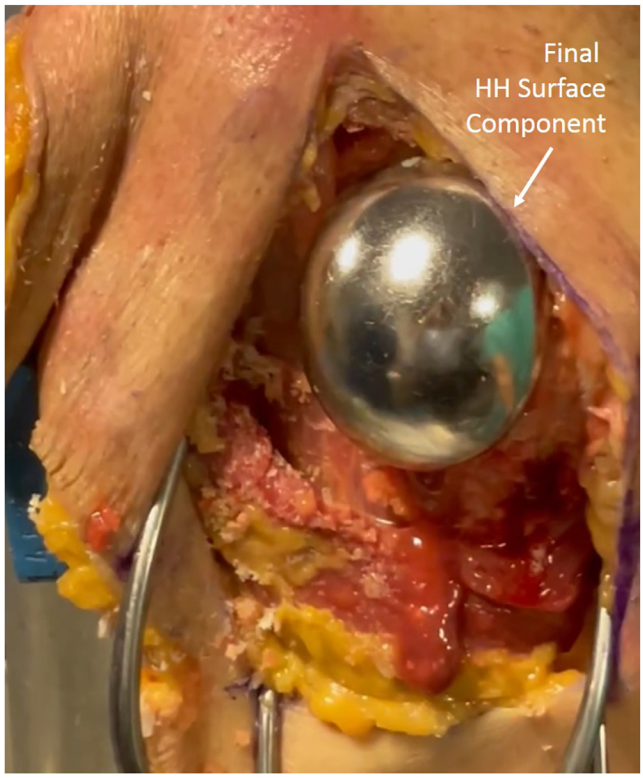

Fig 10. Left shoulder in beach-chair position: The final humeral head (HH) surface component impacted into place onto the humerus

with the standard 12.0-mm post, has a larger outer thread diameter, thread depth, and thread to core diameter ratio. Screw pullout strength is proportional to the surface area of thread that is in contact with bone, which is increased by a larger outer thread to inner core diameter ratio.[19] Use of the 15.6-mm post with its larger thread depth enables stronger fixation in the humeral metaphysis when compared with the standard post. Both posts share the same length, inner core diameter, morse taper, and insertional screw driver which allows for identical humeral preparation, post insertion, and compatibility with HHR components. One limitation is that the 15.6-mm taper post may not be readily available in all operative settings; availability should be discussed with implant representatives preoperatively. However, stocking of the single larger taper post as a back-up may be significantly less burdensome and expensive than stocking all implants, instrumentation, and trays required for an alternative stemmed implant system.[20] This may have particular utility in the ambulatory surgical center setting, where implant supply stores and costs may pose limitations.

Autograft bone placement can be reproducibly obtained in all cases and can be used with the standard 12.0-mm post. Only the bone that remains after use of the flat access reamer should be used for autograft; bony debris from periarticular osteophytes, surfacing

Table 3. Pearls and Pitfalls

Criteria	Pearls	Pitfalls
Patient selection	Indicated in patients with glenohumeral arthritis with intact rotator cuff and adequate bone stock	TSA with humeral head resurfacing and in inlay glenoid is contraindicated in patients with rotator cuff arthropathy or poor proximal bone stock
Remove osteophytes surrounding the humeral head	Allows identification of the true superoinferior and anteroposterior dimensions of the humeral head for placement of the nonspherical HHR component	If humeral head is between 2 sizes, it is recommended to use the smaller size reamer/implant, as to maximize bony contact and minimize implant overhang
Autograft selection	Use the pillar of metaphyseal bone that remains around the centering shaft after using the flat top reamer	Bony debris from periarticular osteophyte removal, surfacing reaming, and flat access reaming is pathologic and should not be included as autograft
Autograft harvest	Withdrawal the centering shaft several millimeters, and use an osteotome to remove the autograft	Removing the centering shaft entirely destabilizes the autograft, and may result in the graft splintering during harvest
Taper post selection	The 15.6-mm post can be used in place of the standard 12.0-mm post to maximize fixation. No additional humeral preparation or insertional tools are required	In patients who may have suboptimal bone, communicate with industry product representative preoperatively to ensure availability of 15.6-mm taper implant
Autograft bone placement	Cut the autograft on the back table and inserted it over the guideline into the humerus	Additional humeral preparation is required otherwise the autograft will not fit into the humeral head

(*continued*)

Table 3. Continued

Criteria	Pearls	Pitfalls
Cement the humeral component	Impacted the HHR surface component onto the tapered post before cementing. Place cement on the backside of the taper post only	Avoid placing cement on the titanium plasma spray undercoating of the HHR component, which is designed to allow bony ongrowth.
Patient tolerance	There are no modifications to the postoperative protocol when 15.6-mm post, autograft, or cementation are used	Appropriate subscapular repair remains essential

HHR, humeral head resurfacing; TSA, total shoulder arthroplasty.

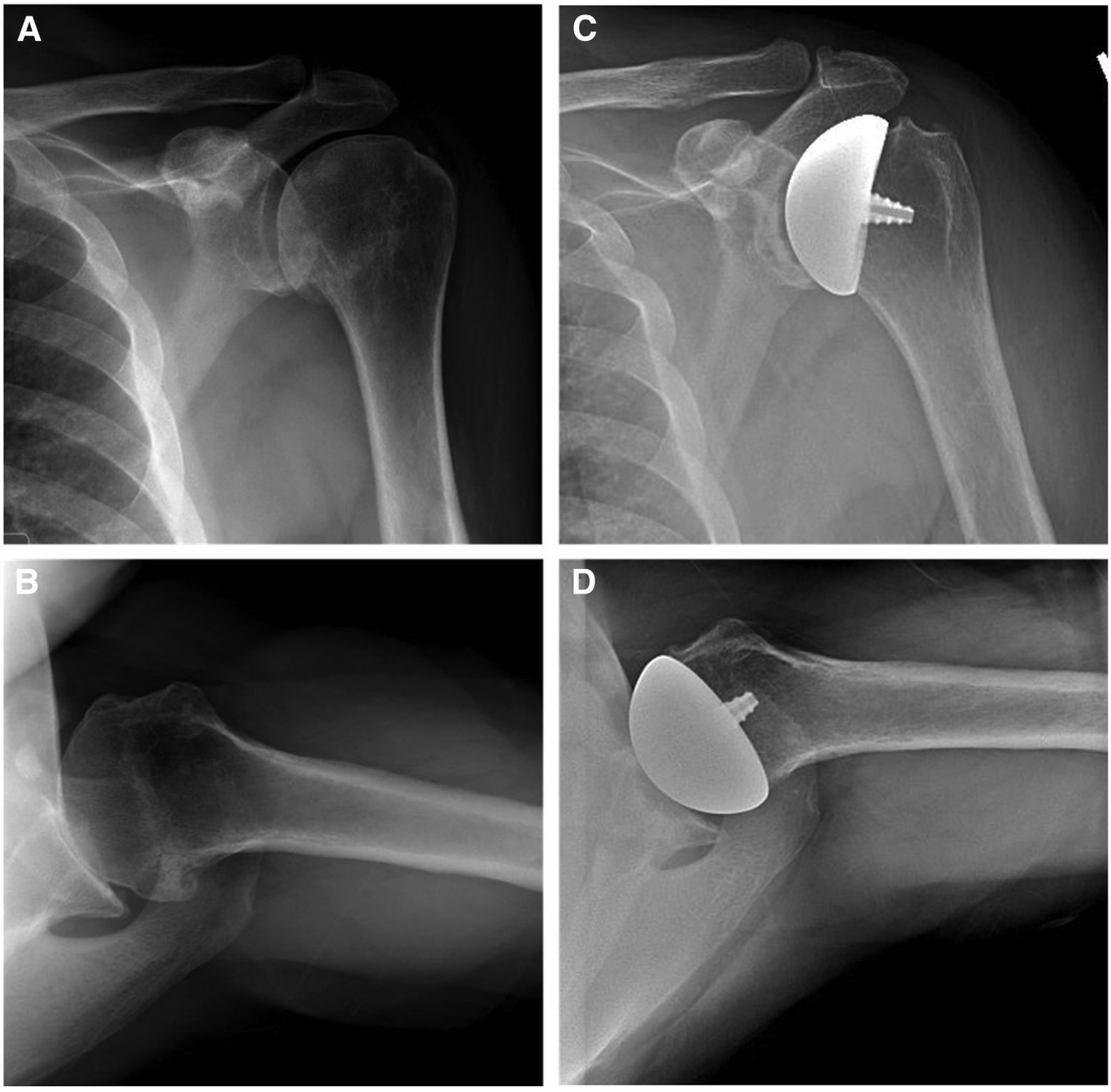

Fig 11. (A-D) Preoperative and postoperative anteroposterior and axillary radiographs are presented in a left shoulder, after insertion of the humeral head (HH) surface component, standard 12.0 taper post, and inlay glenoid component

reaming, and flat access reaming is pathologic and should be discarded. One disadvantage is that additional humeral preparation is required; however, this is minimal, and all instruments are available in the standard OVOMotion tray.

Cement can provide immediate strong fixation in patients with poor bone or a bone/prosthesis mismatch.[21] Cementation can be easily completed, as cement is already available for glenoid fixation. The literature demonstrates that cemented stemmed components have low rates of revision and aseptic loosening.[22,23] Cementing, however, can increase difficulty of future revision surgery, and thus the decision to cement must be made on a patient-specific basis. In the case of revising a cemented OVOMotion humeral component, all cement would likely be resected when making a humeral head neck cut if converting to a stemmed implant.

In patients with critical proximal humeral bone loss, transitioning to a stemmed humeral component if available may be considered. However, the techniques described can be used as intraoperative back-up tactics if poor bone is unexpectedly encountered and stemmed components are not available. Long-term follow-up studies are needed to compare clinical and radiographic outcomes following use of these techniques versus standard HHR implants or transitioning to stemmed components.

Disclosures

The authors report the following potential conflicts of interest or sources of funding: J.P.Z. reports a relationship with Arthrosurface that includes: speaking and lecture fees. All other authors (A.D.P., J.D.C., M.C.K., J.M.P.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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