

A Method to Facilitate Improved Positioning of a Reverse Prosthesis Stem During Arthroplasty Surgery: The Metaphyseal-centering Technique

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Abstract: Because humeral head offset values vary widely from patient to patient, the final position of the proximal portion of a stemmed humeral prosthesis will sometimes not align well with respect to the center of rotation of the humeral head. This is especially notable when a humeral component with limited modularity is used. To address this problem, a prosthesis-specific method is presented for orienting a reverse shoulder humeral component (AltiVate Reverse, DJO Surgical, Austin, TX). With the metaphyseal-centering technique, priority is given to the positioning of the shell portion of the prosthesis over that of the stemmed portion during bone preparation. To ensure that a centralized shell position is achieved within the proximal humerus bone in patients with extreme posterior and medial offset measurement values, the stem portion of the humeral prosthesis is sometimes purposely undersized and positioned eccentrically within the humeral diaphysis. Bone autograft is used in such cases to improve the fit and fixation of the stem within the humeral canal. The metaphyseal-centering technique facilitates: (1) consistent positioning of the shell portion of the humeral prosthesis relative to the center of rotation of the humeral head, and (2) conversion from a standard to a reverse prosthesis, or vice versa, during revision surgery without the need for stem removal or alteration of the humerus bone. Preliminary outcomes of this surgical technique are encouraging, but formal studies are warranted to validate its clinical utility and longevity of results.

Key Words: metaphyseal, centering, technique, humerus, stem, position, reverse, shoulder, arthroplasty

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The press fit of a humeral stem during shoulder arthroplasty surgery has traditionally been achieved by reaming and broaching with larger and larger instruments until bone hoop

stresses are sufficient for solid fixation of the final component. The final orientation of the implanted stem within the humerus bone that results from this approach is typically along the long axis of the diaphysis. Because the humeral head is not consistently positioned over the long axis of the diaphysis from patient to patient (Fig. 1), this canal-filling technique of press fitting a stemmed prosthesis may result in a well-fixed implant that is eccentrically positioned relative to the ideal center of rotation of the prosthetic head proximally; or, in the case of a reverse shoulder prosthesis, it may result in misalignment of the shell relative to the proximal humerus bone (Fig. 2A).

The phenomenon of humeral head offset variability from patient to patient (Fig. 1) has been well described. The magnitude of the offset has not been shown to be correlated to humeral head size or to any other measured anthropometric parameter of the humerus.^{1–3} Humeral head offset has traditionally been addressed during anatomic shoulder arthroplasty by use of prosthetic humeral heads that attach to the stem with varying degrees of eccentricity. Although such components are readily available for anatomic shoulder arthroplasty, options for compensating for patient offset variability during reverse shoulder arthroplasty are fewer, especially if a reverse prosthesis with an inset shell (Fig. 3) is desired. Currently, there are no commercially available reverse shoulder prostheses featuring an inset-shell design that allow for adjustment of offset through component modularity.

The authors have found that despite limited component modularity acceptable humeral component positioning may be achieved through surgical technique. The metaphyseal-centering technique (MCT) prioritizes the centralized placement of the prosthesis shell within the metaphysis first, and the position of the stem within the diaphysis second, during humeral bone preparation. With the MCT, the stem portion of the reverse humeral prosthesis is sometimes purposely undersized and positioned eccentrically within the diaphysis to accommodate patients with large or small humeral head offset values (Figs. 2B, 4B). In such cases, bone autograft is inserted as needed to improve the fit and fixation of the stem within the metaphysis and diaphysis.

The purpose of this article is to present a surgical technique for orienting a reverse prosthesis humeral implant that has an inset-shell design (AltiVate Reverse, DJO Surgical, Austin, TX). This prosthesis-specific technique allows this implant to be used for both reverse as well as anatomic shoulder arthroplasty surgery in larger patients (Figs. 4B, 5).

SURGICAL TECHNIQUE

The MCT is not intended for proximal humerus fracture cases, for cases where significant proximal humerus bone loss is noted, or for patients in whom the cross-section of the base of the resected head measures <46 mm. Otherwise, the indications, surgical approach, patient positioning, soft tissue releases,

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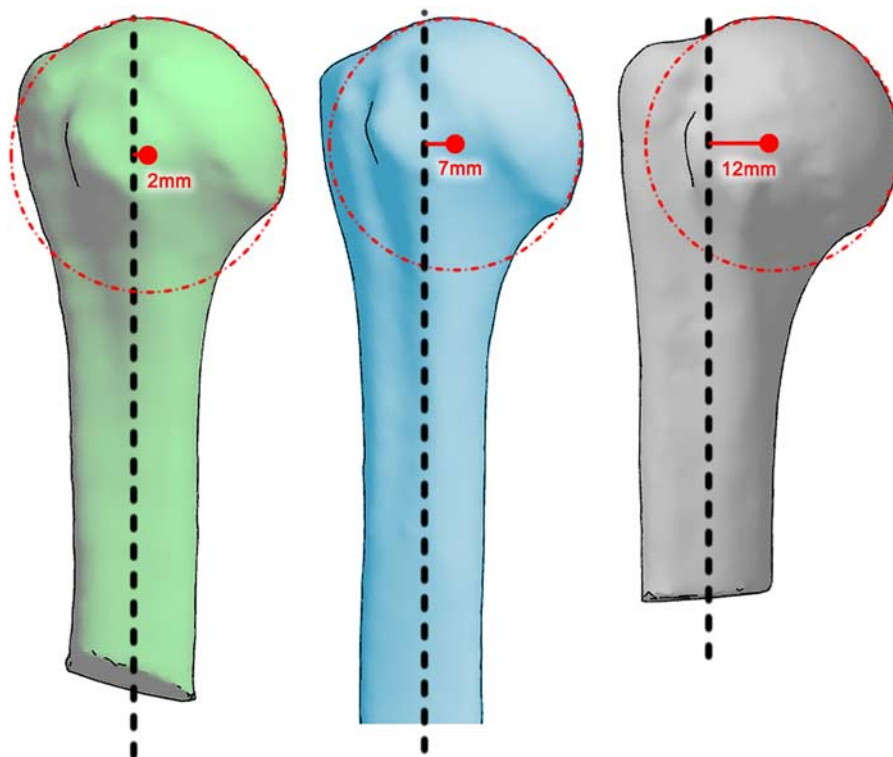


FIGURE 1. Examples of 3 humeri with small (2 mm), medium (7 mm), and large (12 mm) humeral head offset measurement values are shown. The amount of offset from patient to patient is highly variable, and its magnitude is not correlated with humeral head size or any other known parameter.¹⁻³ If the goal during arthroplasty surgery is to replicate a patient's normal anatomy, offset must be addressed either through component modularity or by surgical technique.

and preparation of the glenoid bone are no different for this technique than they are for a typical standard or reverse total shoulder arthroplasty procedure. As such, the focus of what is presented regarding the surgical technique will be purely on describing the preparation of the humerus bone. The main surgical steps described below are illustrated in Figure 6, and shown in the accompanying video (Supplemental Digital Content 1, <http://links.lww.com/TSES/A29>).

Once the humerus has been exposed, a cutting guide is used to create a resection of the humeral head at the anatomic neck at 135 degrees of inclination. Cutting at 30 degrees of retroversion is typical, but the exact amount of retroversion may be adjusted to conform to the patient's individual anatomy. The head is removed and saved as a source of bone autograft, which may be needed for the purpose of augmenting the press fit of the humeral component in some cases (Figs. 2B, 4B). Removing a thin layer of subchondral bone at the superior periphery of the humeral head (Fig. 6A) will facilitate subsequent bone graft preparation, as it is easier to morselize the cancellous bone beneath with a rongeur after this hard subchondral bone has been removed.

Once the head has been removed, the glenoid is exposed, and a standard polyethylene glenoid or a glenosphere component is placed as needed for standard or reverse total shoulder reconstruction.

After completion of the glenoid reconstruction, the humerus is again dislocated anteriorly. The center of the face of the cut bone at the anatomic neck is marked. Next, an osteotome is used to remove bone from the center of the cut face in a circular pattern with a diameter of roughly 30 mm and a depth of about 20 mm. This step is important; the purpose of it is:

(1) to obtain additional bone autograft, and (2) to create a large, centered pilot hole into which the reamers may be countersunk. Our experience has been that it is much more difficult to control the reamers that are used in subsequent steps unless this step has been completed. The pilot hole should be centralized within the anatomic neck bone cut, and it should be large enough that the distal aspect of the reamer just fits within it (Figs. 6C, D).

A small, shell-shaped reamer is used first. A larger shell-shaped reamer that is appropriately sized for press fitting of the prosthesis shell is used next for the final reaming of the proximal humerus bone. During the reaming steps, it is important that the surgeon focus on keeping the reamers steady and centered—much as one would do while reaming an acetabulum during hip surgery—to achieve a centralized shell position.

Now that the proximal metaphyseal bone has been prepared to accept the prosthetic shell, larger and larger canal reamers are used to sound, but not ream, the humeral canal. Aggressive diaphyseal reaming is not recommended. The reamers simply serve to allow the surgeon to know the largest possible prosthesis size that may be used. Use of a larger broach or prosthesis size may cause fracture of the diaphysis.

Next, the broaches are assembled with the trial shells attached so that they function as trial prostheses. The surgeon should concentrate on centering the shell as each trial prosthesis/broach is advanced deeper and deeper into the bone. Larger and larger trial prostheses are used until stability is achieved. Stability of the trial prosthesis is often realized with a trial stem size that is smaller than the size of the largest reamer that was used to sound the humeral canal in the previous step.

As increasingly larger trial prostheses are used, a point may be reached where the trial stem could be advanced further

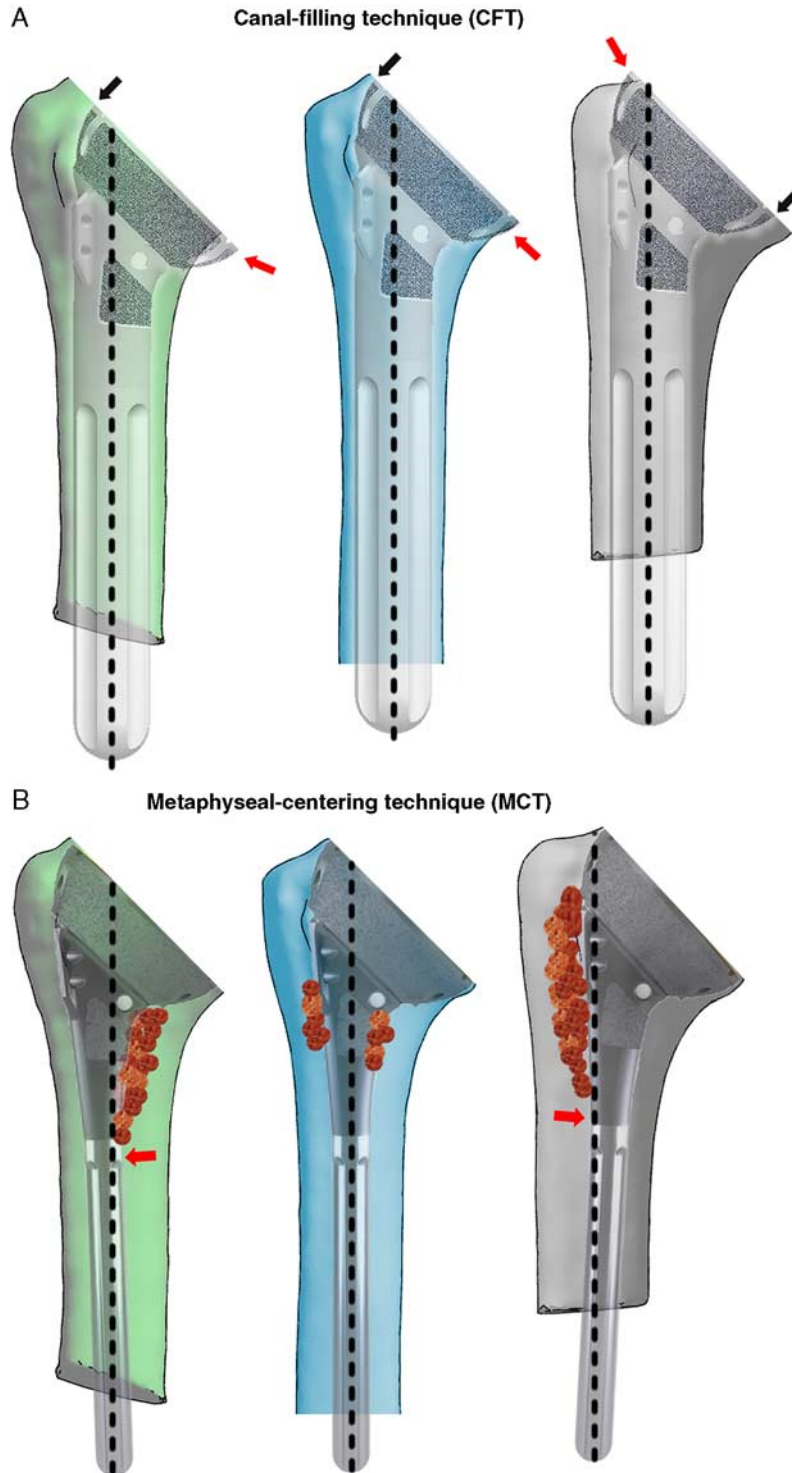


FIGURE 2. The final humeral component positions resulting from the CFT versus the MCT for reverse shoulder arthroplasty are illustrated. Note that when moving from a smaller to a larger prosthesis the size of the stem portion of the prosthesis changes, but the size of the shell portion remains the same. A, With the CFT, a relatively thick stem fills the diaphyseal canal, leading to alignment of the stem portion of the prosthesis with the long axis of the bone (dashed black line). The resultant shell position will sometimes be outside of the confinements of the cortical bone (red arrows). The breach of the proximal cortical bone is more severe in patients with the little humeral head offset (green humerus) or in those with excessive humeral head offset (gray humerus). B, A slightly undersized stem is used with the MCT. The shell of the prosthesis is positioned centrally within the bone, and the proximal cortical bone is never breached, regardless of humeral head offset magnitude. The stem portion of the prosthesis will end up in a slightly valgus position in a low-offset humerus, and in a slightly varus position in a high-offset humerus (red arrows). When using an undersized stem, bone autograft may be used to improve the fit and fixation of the undersized prosthesis within the canal. CFT indicates canal-filling technique; MCT, metaphyseal-centering technique.

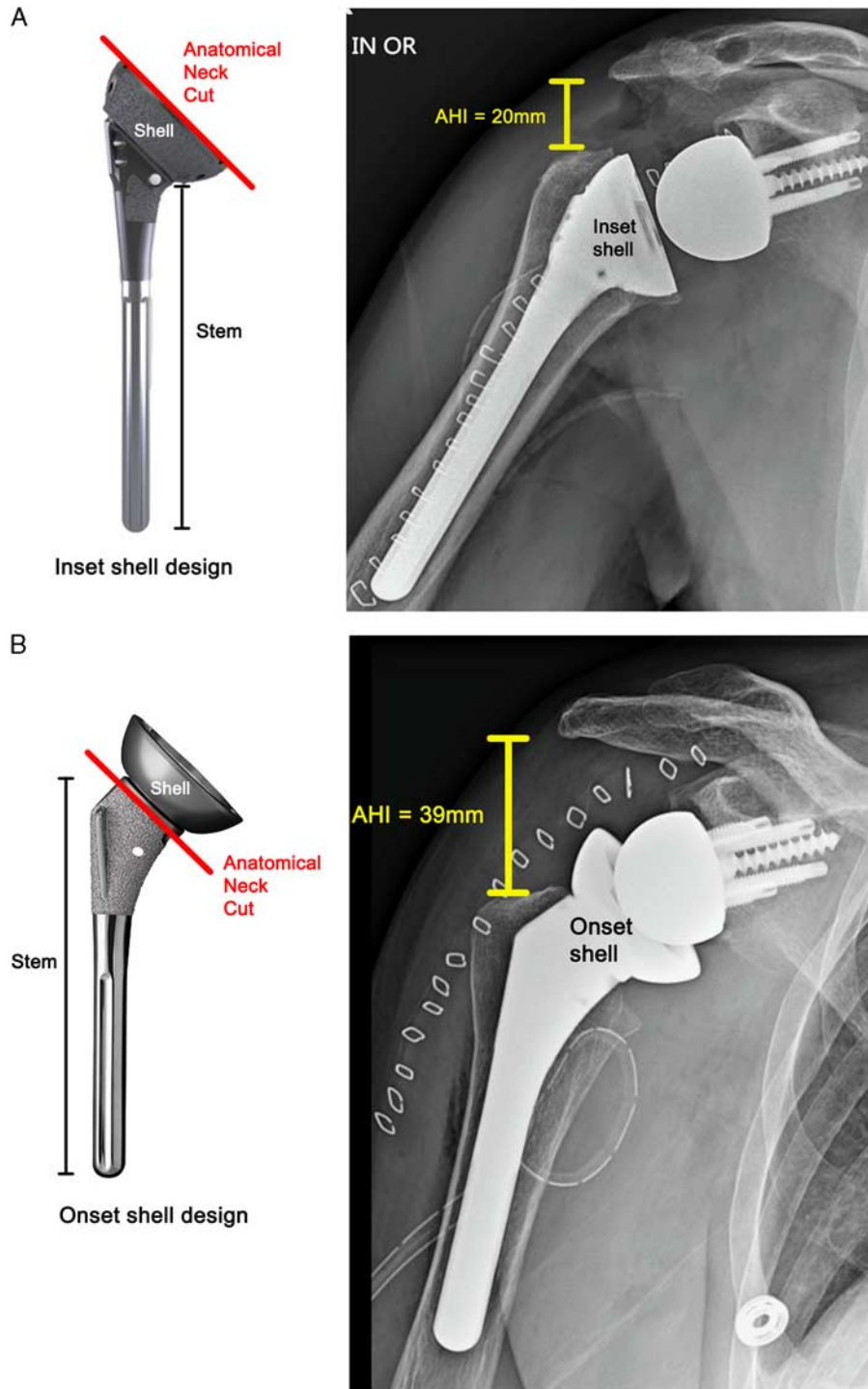


FIGURE 3. Reverse prostheses with an inset-shell design (A) versus an onset-shell design (B) are shown. The humerus is distalized more relative to the acromion with the onset-shell design when compared with the inset-shell design. This is demonstrated by the larger AHI value that is seen with the onset-shell design. The MCT is only applicable to a prosthesis with an inset-shell design. AHI indicates acromiohumeral interval; MCT, metaphyseal-centering technique.

into the bone, but doing so would cause misalignment of the shell portion of the trial prosthesis proximally (Figs. 2A, 4A). If shell misalignment occurs, simply reduce the stem size to the largest size that will still allow proper alignment of the shell within the proximal bone. Augmentation of fit and fill of the

prosthesis within the humeral canal with bone autograft is recommended for such incidences (Figs. 2B, 4B).

In such cases, bone autograft is inserted into the bone graft window of the humeral prosthesis to enhance fixation. Purposeful protrusion of bone autograft from the bone graft

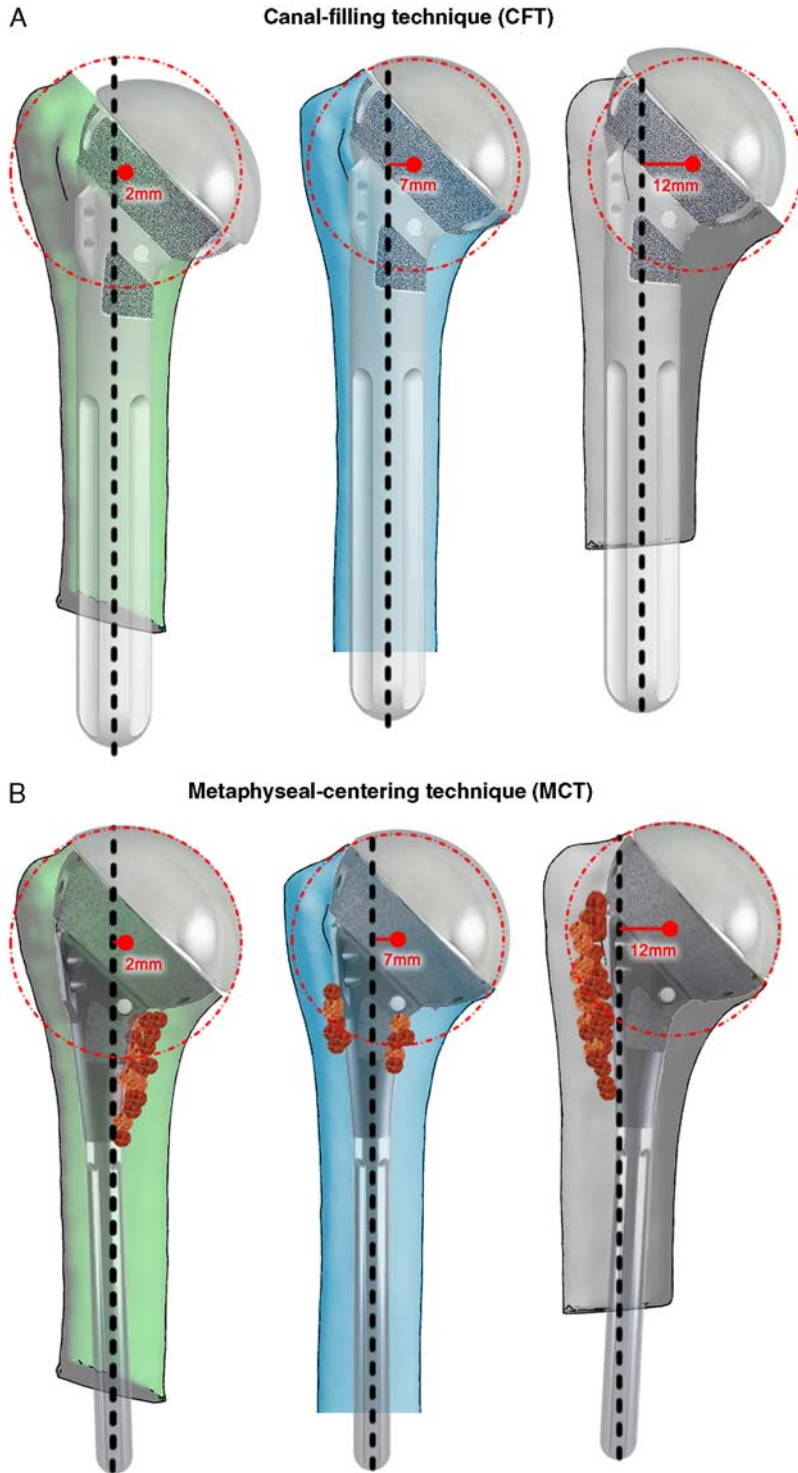


FIGURE 4. The utility of DJO AltıVate Reverse prosthesis for anatomic shoulder reconstruction is dependent upon surgical technique. A, When a thick-stemmed prosthesis that fills the humeral canal is used (CFT), the resultant shell position may preclude acceptable anatomic replication in patients with extreme humeral head offset values (green and gray humeri). B, With the MCT, priority is given to positioning of the shell over that of the stem during preparation of the humerus bone. This results in more consistent positioning of the shell relative to the center of rotation of the humeral head, and allows acceptable anatomic replication even in cases of extreme humeral head offset (green and gray humeri). CFT indicates canal-filling technique; MCT, metaphyseal-centering technique.

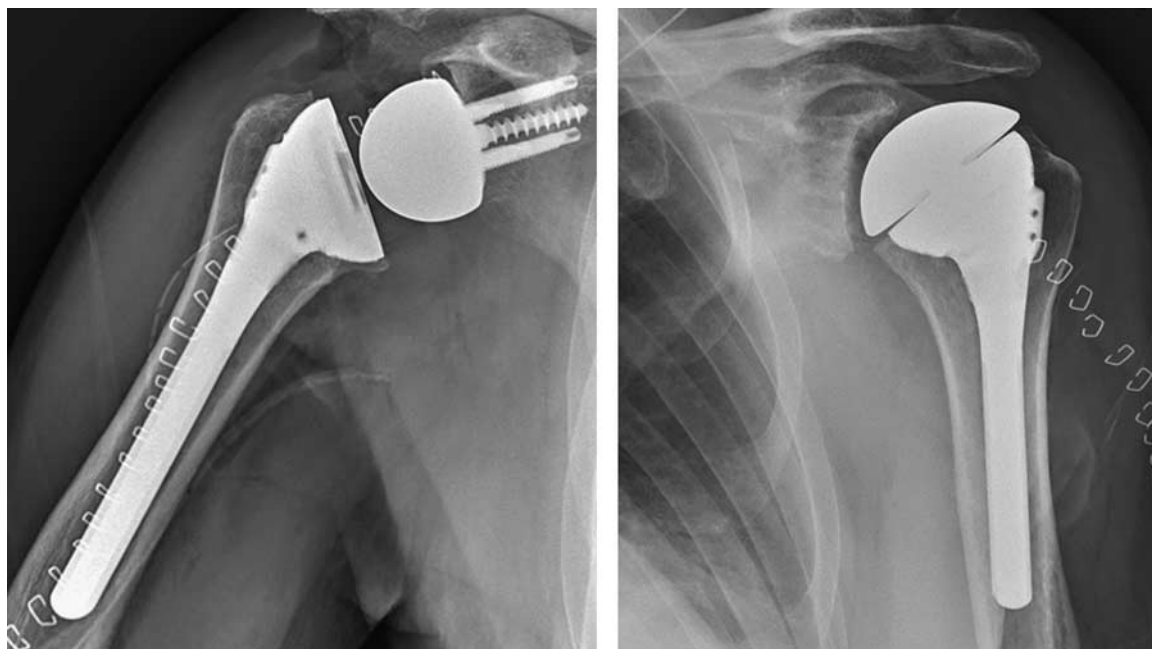


FIGURE 5. Radiographs demonstrate that when the metaphyseal-centering technique is used in conjunction with the AltıVate Reverse prosthesis the final position of the humeral implant is exactly the same for both anatomic and reverse shoulder reconstruction—the only difference being whether it is a prosthetic humeral head versus a polyethylene cup that is coupled to the humeral prosthesis.

window of the prosthesis will increase the interference fit. If component stability is still insufficient, and/or if a prosthesis with no bone graft window is being used, the bone autograft may be added around the prosthesis stem at the metaphyseal-diaphyseal junction, deep to the region of proximal bone that was prepared for the shell. Partial insertion of the prosthesis into the humerus bone before adding the bone graft material serves the purpose of preventing the bone autograft pieces from falling down the canal. With the final prosthesis partially inserted, bone graft may be added, removed, or rearranged as needed to achieve optimal stability and ideal positioning of the component. The final prosthesis is then impacted into place. Bone cement may be used in the rare case where it is not possible to achieve a stable humeral construct after impaction bone grafting.

A metallic head with adapter or a polyethylene cup are then attached to the reverse prosthesis stem as indicated for anatomic or reverse shoulder arthroplasty.

DISCUSSION

Experience with the MCT is limited to the authors' use of it with the DJO AltıVate Reverse shoulder prosthesis. However, it is the authors' hope that, despite the fact that the technique as presented here is prosthesis-design specific, the main principles described here might be adapted to optimize implant positioning for other shoulder prosthesis systems as well. Regardless of the implant manufacturer, better clinical results will potentially be realized through thoughtful consideration of how to best prepare the humerus bone to optimize the final positioning of any humeral implant.

When the MCT is used in conjunction with the AltıVate Reverse prosthesis the final position of the humeral implant is exactly the same for both anatomic and reverse shoulder reconstruction—the only difference being whether it is a prosthetic humeral head versus a polyethylene cup that is coupled to the humeral prosthesis (Fig. 5). A potential

advantage of this approach during revision arthroplasty surgery is easy conversion from a standard to a reverse humeral prosthesis, or vice versa, without the need for removal of a well-fixed stem or alteration of the humerus bone in any way.

Reverse shoulder arthroplasty systems vary widely in terms of humeral component modularity, inclination angle, the amount of lateralization that the stem provides, and the position of the shell relative to the anatomic neck of the humerus (inset versus onset; Fig. 3).⁴ Additional component modularity at the shell/stem interface might facilitate achievement of anatomically accurate shoulder reconstruction with less attention to bone-preparation detail. There are tradeoffs, though, that come with increasing prosthesis component modularity, including the increased potential for failure or dissociation of the components over time at the modular interfaces.^{5–8}

The MCT and its application for either reverse or anatomic shoulder reconstruction presumes the use of a prosthesis with no component modularity between the stem and the shell, a fixed offset length, an inset-shell design, and a 135-degree inclination angle. It is the 135-degree inclination angle coupled with the bone-preparation technique at the level of the anatomic neck of the humerus that allows this inset-shell reverse humeral implant to also be used effectively for anatomic shoulder reconstruction. Anthropometric studies have documented that ~80% of people have a humeral head inclination angle that falls between 130 and 140 degrees,^{1,9} and our experience confirms that acceptable anatomic replication is possible most of the time when coupling a prosthetic humeral head with this prosthesis.

When the shell is purposefully centered within the proximal bone cut it is inevitable that the stem portioned of the prosthesis may end up positioned in a slightly valgus or varus orientation in patients with either very low or very high humeral head offset values (Figs. 2B, 4B). Use of impaction bone grafting with a slightly undersized stem is often required in such patients to achieve a solid press fit while maintaining the centralized position of the shell at the anatomic neck level.

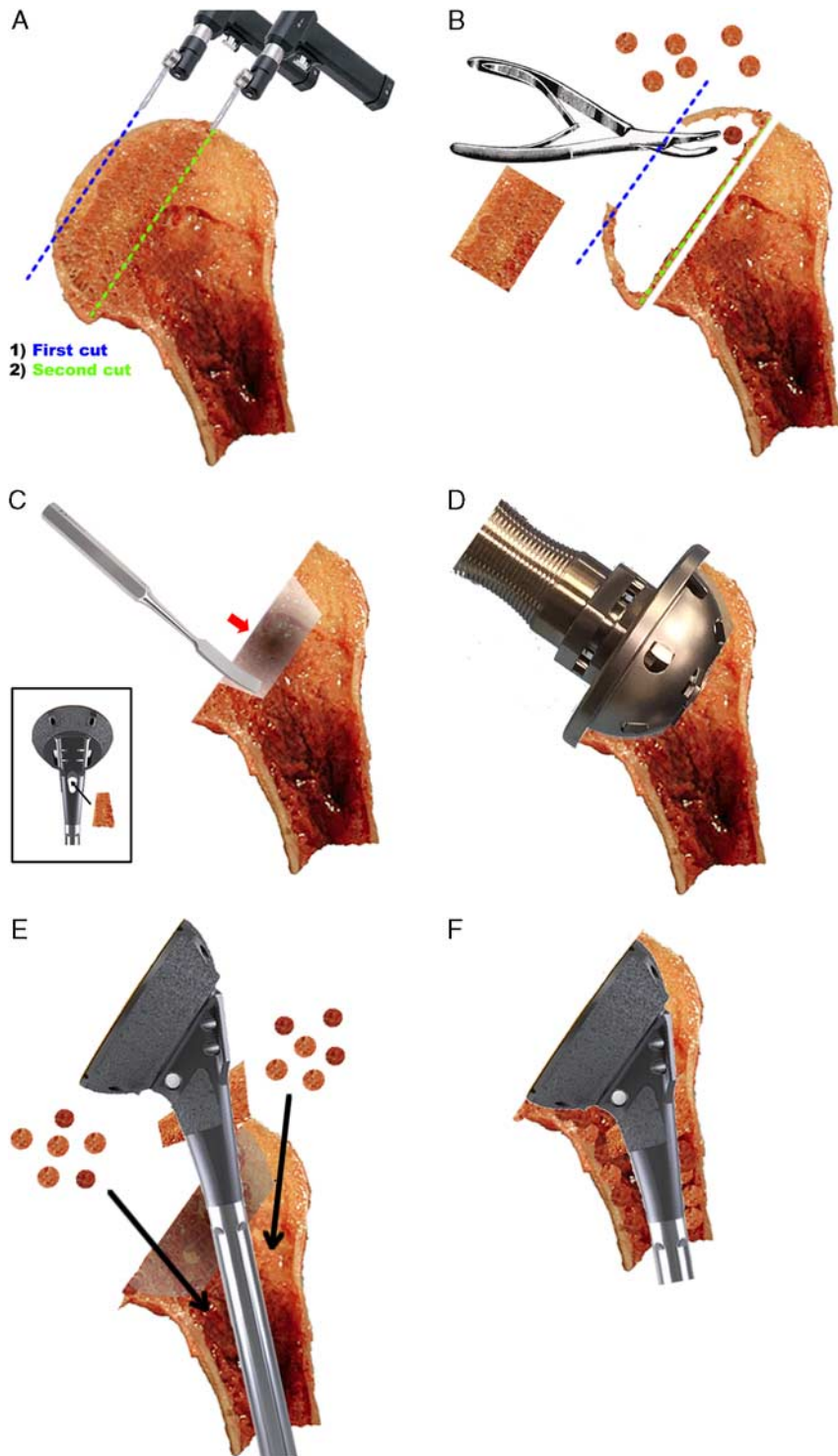


FIGURE 6. A, The humeral head is resected. B, The superficial cut (dashed blue line) facilitates bone graft preparation with a rongeur. C, After head resection, an osteotome is used to harvest additional bone graft. Bone in this region is removed leaving a circular hole with a roughly 30 mm diameter. The void that is left will serve as a central pilot hole to help guide the reamers. Bone autograft may be inserted into the bone graft window of the prosthesis with purposeful protrusion to enhance press fit fixation if needed. D, A small reamer is first used, followed by a larger reamer that is appropriately sized to achieve a press fit of the shell. Great care should be taken to keep the reamers centered within the proximal bone. E, After proper prosthesis size has been determined through reaming and broaching, the final prosthesis is inserted partially. Additional bone autograft may be applied around the stem of the prosthesis to enhance component stability and press fit fixation as needed before final impaction. F, The prosthesis has been seated.

In such cases, use of bone autograft harvested from the humeral head and proximal humerus is recommended (Figs. 2B, 4B, 6). Others have described a similar impaction bone grafting technique that is based around an anatomic as opposed to a reverse humeral prosthesis.¹⁰⁻¹² Although impaction bone grafting has been shown to provide a secure and durable means of humeral component fixation when used with a specific anatomic stem,¹² it is unknown at this time whether or not similarly successful long-term results will be seen when impaction grafting is used with the AltiVate Reverse prosthesis.

Indications for use of the AltiVate Reverse prosthesis as an anatomic shoulder implant are currently limited due to humeral component size constraints. The authors have successfully employed the MCT for anatomic reconstruction in patients where the diameter of the base of the humeral head is ≥ 46 mm, but a word of caution is warranted if use of this technique is being contemplated for anatomic arthroplasty in smaller patients. The diameter of the most proximal portion of shell of the AltiVate Reverse prostheses used in our series measures 42 mm, which makes it too large to use for anatomic reconstruction in some small patients. In these patients, the preparatory reaming with the shell reamer may lead to destruction of the proximal humerus bone at the site of the insertion of the rotator cuff. Although this might not be of critical importance during a reverse arthroplasty procedure for cuff tear arthropathy, it would certainly compromise the results of anatomic shoulder arthroplasty. It is strongly advised, therefore, that this technique not be used for anatomic arthroplasty in patients where the diameter of the base of the resected humeral head measures <46 mm. Because the MCT is more forgiving in larger patients, surgeons who are in the learning stage are encouraged to first apply this technique to patients where the base of the humeral head measures ≥ 50 mm. This size restriction might potentially be eliminated in the future if smaller implant shell sizes become available. This size limitation does not apply to reverse arthroplasty surgery.

The preliminary clinical and radiographic results of the primary author's (C.S.H.) first 53 patients are encouraging (follow-up time, 2 to 12 mo). There have been no complications related to humerus component fixation such as loosening, osteolysis, or intraoperative or postoperative periprosthetic humerus fractures. One 70-year-old male patient who was treated initially with anatomic arthroplasty went on to tear his supraspinatus tendon 9 months after that procedure. Revision surgery was performed to convert from a standard to a reverse prosthesis. The humeral prosthesis was noted to be well fixed at the time of revision surgery, and it was retained for the conversion. All patients in this series were satisfied and stated that they would have the procedure performed again under similar circumstances. At this time, formal studies using accepted medical metric measurement tools are underway to validate the clinical utility and the longevity of results of this surgical technique.

In summary, the MCT is a surgical technique for orienting an inset-shell reverse shoulder arthroplasty humeral component

that facilitates reliable, centralized positioning of the proximal portion of the humeral component within the bone. The MCT may be used for reverse shoulder arthroplasty, as well as for anatomic reconstruction in patients with larger humeral heads. The technique facilitates conversion from a standard to a reverse prosthesis, or vice versa, during revision surgery without the need for stem removal or alteration of the humerus bone. The technique is not appropriate in the setting of significant proximal bone loss, for proximal humerus fracture cases, or for some small patients during anatomic shoulder arthroplasty. Preliminary outcomes are encouraging, but formal studies are warranted to validate the clinical utility and longevity of results of this surgical technique.

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