Humeral windows and longitudinal splits for component removal in revision shoulder arthroplasty

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Background: Removal of a humeral component during revision shoulder arthroplasty can be difficult. If the component cannot be extracted from above, an alternative approach may compromise bone integrity. Two potential solutions are a humeral window and a longitudinal split. This review was performed to determine complications and outcomes associated with these osteotomies during revision arthroplasty.

Methods: We reviewed records of 427 patients undergoing revision shoulder arthroplasty, identifying those requiring a window or longitudinal split. Outcomes were intraoperative and postoperative complications, rate of healing, and security of implant fixation.

Results: Twenty-six patients underwent creation of a window. Six intraoperative fractures were documented: 5 in greater tuberosity and 1 in humeral shaft. At radiographic follow-up, 23 of 26 windows healed; 2 patients had limited follow-up, and 1 did not have follow-up at our institution. Nineteen patients underwent longitudinal osteotomy. One had intraoperative fracture in greater tuberosity. At radiographic follow-up, 17 of 19 longitudinal splits healed; 1 had limited radiographic follow-up, and 1 did not have follow-up at our institution. Three patients underwent formation of both window and longitudinal osteotomy. At radiographic follow-up, all shoulders healed, and there were no intraoperative or postoperative fractures or malunions.

Conclusions: In both groups, there were no cases of malunion or clinical loosening. These data suggest that windows and longitudinal splits facilitate controlled removal of well-fixed components with high rate of union and low rate of intraoperative or postoperative sequelae.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Revision shoulder arthroplasty; humeral window; longitudinal split

Increase in the frequency of primary shoulder arthroplasty has also led to an increase in failures and revision surgery.²,⁶,¹² Day et al⁵ reported an increase of 6% to 13% annually in procedure volume and rates from 1993 to 2007; furthermore, the revision burden during that time increased from 4.5% to 7%. Whereas revision of the glenoid component is required more frequently, there are instances in which revision of a humeral component is necessary.¹,¹⁷,¹⁸ Removal of a well-fixed humeral component during revision shoulder arthroplasty presents a difficult problem. Common reasons for removal are component malposition or loosening, for glenoid exposure, infection, and component fracture. The most significant factor leading to revision or removal of the humeral component after hemiarthroplasty is the development of painful arthritis of the glenoid, with or without rotator cuff tearing.⁴

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Conversely, a problem with the glenoid component (glenoid loosening or glenoid polyethylene wear, creating osteolysis) or the need to gain access to the glenoid component is the most influential factor leading to revision or removal of a humeral component in total shoulder arthroplasty.4

If the humeral component cannot be extracted easily from above, an alternative approach must be taken that may compromise bone architecture to remove the device. Two potential solutions to this problem that allow removal of a well-fixed prosthesis are creation of a humeral window and creation of a longitudinal split (vertical humeral osteotomy) in the humerus. Anterior and medial cortical humeral windows have been reported to facilitate removal of well-fixed humeral components with a high rate of union.13 The second technique, a longitudinal split, has been an effective tool for the removal of humeral prostheses with or without perioperative complications, postoperative fractures.8,15,16 Similarly, an equivalent technique has seen success in revision hip surgery.3,10,11 Currently, there are no data in the literature comparing these techniques and only a few reports assessing them individually. In this study, we identified patients requiring creation of a humeral window, longitudinal split, or both while undergoing revision shoulder arthroplasty. Outcomes studied from this population include intraoperative complications, postoperative complications, rate of healing, and security of new implant fixation.

Methods and materials

Four hundred twenty-seven patients underwent revision shoulder arthroplasty at our institution between January 1, 1994, and December 31, 2010. Of these patients, 329 patients underwent removal of the primary humeral stem. Among these 329 patients, 26 had a humeral window created during the revision shoulder arthroplasty to remove a well-fixed humeral component. Conversely, 19 had a longitudinal osteotomy made to remove a well-fixed humeral component during the course of revision. Three patients underwent both a humeral window and a longitudinal split for successful removal of the component.

Of the 26 patients who had a cortical humeral window, 18 were women and 8 were men. The mean age of the patients at the time of surgery was 68.6 years. There were 19 total shoulder arthroplasties and 7 hemiarthroplasties. Of these, there were 18 cemented humeral components and 8 textured, press-fitted humeral implants. The reasons for revision surgery were glenoid arthritis (7), shoulder instability (7), infection (5), glenoid component loosening associated with instability (3), glenoid component loosening (3), and fractured humeral component (1).

Of the 19 patients who underwent formation of a longitudinal osteotomy, 10 were women and 9 were men. The mean age of the patients at the time of surgery was 62.3 years. There were 11 hemiarthroplasties and 8 total shoulder arthroplasties. Of these, there were 13 cemented humeral components and 6 textured, press-fitted humeral components. The reasons for revision surgery were shoulder instability (5), infection (4), glenoid arthritis (4), instability associated with a rotator cuff tear (3), and glenoid component loosening with or without rotator cuff tearing (3).

There were 3 patients who underwent formation of both a humeral window and a longitudinal split. All 3 of these patients were women, the mean age at time of surgery was 67 years, and all had hemiarthroplasties with cemented humeral components in place. The reasons for revision surgery were glenoid arthritis (2) and instability (1).

Radiographic follow-up was done at an average of 2.9 years (range, 7-80 months), 1.9 years (range, 6-66 months), and 3.2 years (range, 7-79 months) after revision surgery in patients with a humeral window, a longitudinal split, or both techniques, respectively.

Operative technique

Planning
Preoperative planning is critical. Know the make and model of the humeral implant and have humeral heads and the specific extractor available. Also have a generic extractor and large bone impactors plus a heavy hammer available. Allograft corticocancellous chips and a strut should be accessible. A Micro sagittal saw and a burr with router and spherical tips are essential. Similarly, a number of different sizes of thin, straight and curved osteotomes are needed.

Window
In creation of a cortical humeral window, the deltopectoral approach was used in 18 patients. An anteromedial exposure was used in 8 shoulders to aid in dissection of the scarred soft tissues beneath the deltoid muscle and to decrease the forces required to position the humerus.7 In this exposure, in addition to developing the deltopectoral interval, the anterior aspect of the deltoid origin is incised from the clavicle, acromioclavicular joint, and anterior acromion. At closure, the deltoid is repositioned with its origin sutured to the bone of the acromion, the acromioclavicular joint capsule, the trapezius fascia, and through burred holes in the clavicle. The size of the humeral window varied and was dependent on several factors: cement distribution, regions of bone deficiency, and anticipated length of the revision stem. Typically, the anterior window is made beginning 3 cm distal to the humeral osteotomy site with a Micro sagittal saw. This is done to preserve strength of the tuberosities, including the attachment site for the subscapularis. The two vertical osteotomies for the window are approximately 1 cm apart, allowing access to the anterior, medial, and lateral aspects of the prosthetic humeral stem. These vertical osteotomies are extended distally to 1 cm beyond the end of the component being removed. The superior and inferior aspects of the pectoralis major insertion are detached from bone. The central portion of the pectoralis major is left attached to the window, with the saw or osteotome cut in the bone performed beneath the central portion of the pectoralis major tendon as it is elevated. The anterior aspect of the deltidoid insertion is also elevated. In repair of the window, it is held in place with No. 5 circumferential sutures, wires, or cables. The upper portion of the pectoralis major is fixed to the humerus with two burr holes slightly medial to the window, and the lower aspect of the pectoralis major is sutured to the elevated portion of the distal aspect of the deltoid muscle.

Twenty shoulders had an anterior window (Fig. 1, A). Of these, 16 windows were repaired with heavy suture and 4 were repaired with wire or cable. Five patients with a cortical window
had a medial window (Fig. 1, B), and all of these were bone grafted. The remaining patient had anterior and medial windows created, which were bone grafted and subsequently fixed with cables (Fig. 2, A and B).

Split
A deltopectoral approach was used in all 19 shoulders that underwent a longitudinal split. The longitudinal split is extended by an oscillating saw from the humeral head osteotomy just lateral to the bicipital groove to 1 cm beyond the distal end of the implant (Figs. 1, C, and 3, A and B). The depth of the split extends through bone or bone and cement down to the metal stem. With use of narrow osteotomes, the split is slowly spread to disrupt the implant cement or implant-bone interface. After removal of the implant, the split is repaired with circumferential wires or cables.

Among the 19 splits, 15 were repaired with cable or wire and 4 were repaired with heavy suture.

Combination
All 3 shoulders requiring both a humeral window and a longitudinal split were accessed by a deltopectoral approach. Two patients in this group underwent creation of an anterior window first, followed by a split; one patient initially had a split, followed by an anterior window. Two of the shoulders were repaired with wire or cable and allograft bone grafting; 1 of the shoulders was repaired with suture as well as allograft bone grafting.

Implant and cement removal
It is important to free any fins or any other irregularities of the upper end of the proximal humerus from bone and cement, approaching this from the top of the humerus. A Micro sagittal router or burr and narrow osteotomes are used. An accessory medial window is sometimes necessary to completely free the upper end of the humeral implant. When a longitudinal split through bone or bone and bone cement is made, on spreading of the split (in the presence of a low-textured implant), a “pop” is often felt, indicating that the bond to the implant has been broken. With use of an extractor for that specific implant or large impactor under the collar of the prosthesis, the implant is then driven free from the bone. When an anterior window is made to free a textured implant, the window is elevated with a narrow, curved osteotome, maintaining the window in one piece. By use of a burr with a router tip, longitudinal grooves are created in the cement, and a narrow osteotome removes the strips of cement. Medial and lateral to the window, a spherical burr or router is used to remove the cement before driving the component free from the humerus.

After implant removal and in the absence of infection, the remaining bone and cement of the humeral canal are roughened before the new implant is secured in place. When infection is present, efforts are made to remove all remaining bone cement.

Implant reinsertion
The length of the new humeral stem is selected so it will extend past the window or split for 4 to 5 cm. When bone cement was previously used, a cement-within-cement technique is used. The surface of the old cement is roughened. The new narrower, longer humeral stem is selected. The window is repositioned and held in place or the split is closed. New cement is injected into the humeral canal, and the new implant is placed. The cement oozing through the bone, including any between the edges of the
osteotomy, is removed with a scalpel. After curing of the cement, small corticocancellous chips are often impacted into the narrow osteotomy gap.

On occasion, when the earlier prosthesis was press-fitted, it is possible to press-fit a slightly wider humeral component, but cement fixation is typically used.

In the presence of infection, efforts are made to remove most if not all of the old cement. At the time of implant reinsertion, as either a primary or delayed exchange, antibiotics are placed in the new bone cement.

**Results**

**Window**

Of the 26 shoulders that underwent creation of a window during revision shoulder arthroplasty, 20 patients had placement of cemented humeral stems and 6 patients had placement of uncemented stems (Fig. 2, A and B). Among the patients with a window, there were a total of 5 intraoperative fractures. There were 3 greater tuberosity fractures, 1 humeral shaft fracture, and 1 patient with a humeral shaft and greater tuberosity fracture. All greater tuberosity fractures in this group were repaired with heavy suture. Both patients who sustained humeral shaft fractures underwent revision surgery for symptoms of instability and were fixed with long-stem press-fit humeral components followed by cable fixation.

At most recent radiographic follow-up at a mean of 2.9 years (range, 7-80 months), 23 of the 26 patients had windows that healed. Of the remaining 3 patients, 2 had limited radiographic follow-up (1 and 2 months) and 1 did not have radiographic follow-up at our institution. There were 3 cases with 1 mm of incomplete periprosthetic lucency and 3 cases with 1.5 mm of incomplete periprosthetic lucency. There were no cases of window malunion, and no postoperative fractures occurred.

**Split**

Of the 19 patients who underwent revision shoulder arthroplasty with creation of a longitudinal split, 18 had placement of a new cemented humeral component (Fig. 3, A and B). There was 1 patient with an intraoperative fracture of the humeral shaft and greater tuberosity. Fixation of the humeral shaft was performed with a long-stem press-fit prosthesis and cerclage wiring. This was also supplemented with bone grafting. The greater tuberosity fracture was reduced and fixed with heavy suture. At most recent radiographic follow-up at a mean of 1.9 years (range, 6-66 months), 17 of the 19 patients had splits that healed. One patient had limited radiographic follow-up (1 month), and 1 patient did not have radiographic follow-up at our institution. There were 2 cases with 1 mm of incomplete periprosthetic lucency. There were no cases of malunion, and no postoperative fractures occurred.

**Combination**

There were 3 patients who underwent creation of a cortical window and longitudinal split during the same revision
operation to remove a well-fixed humeral stem. Two patients in this group underwent creation of an anterior window followed by a split; one patient had a split followed by an anterior window. All 3 patients had placement of a new humeral component, and all were cemented.

At most recent radiographic follow-up at a mean of 3.2 years (range, 7-79 months), all osteotomies had healed. In this patient group, there were no intraoperative fractures, postoperative fractures, or instances of malunion.

Discussion

Removal of a well-fixed humeral component presents a unique challenge. If the stem cannot be freed enough to extract it from the bone, 2 methods to facilitate removal are use of a cortical window and a longitudinal split osteotomy. Either of these methods gives the surgeons increased access to on-growth or in-growth areas of the stem, allowing more distal separation of the interface between the cement mantle or bone and the humeral stem.

Sperling and Cofield first described use of anterior or medial windows to facilitate removal of a well-fixed humeral prosthesis. Anterior windows are preferred when distal fixation predominates and there is a need to visualize the canal. Conversely, a medial window should be used to separate areas of a proximally cemented or textured implant as it allows better visualization of the cement mantle. When published, 17 of 20 patients in the study had achieved union of the window, and the remaining 3 had limited radiographic follow-up. However, they reported 4 intraoperative fractures (20%) that occurred during removal of the prosthesis. An added potential concern of the humeral window includes detachment of most if not all soft tissue structures to completely remove the window, potentially leading to nonunion or malunion. Whereas this particular concern has not been a problem in the literature, it is a theoretical risk not undertaken in using the split osteotomy. Further concerns include creation of a stress riser with this cortical defect, leading to early or later fracturing. In our study, all patients had successful removal of the humeral component. Furthermore, there were no instances of postoperative fracture or malunion. However, the cortical window group did have 5 patients who had intraoperative fractures. The fractures all occurred during disimpaction of the humeral component on attempted removal. We have learned two things to avoid these fractures. First, to avoid fractures through osteopenic or otherwise compromised tuberosities, firmly hold the humerus distally with slight traction and minimal torsional forces on the arm. Second, to avoid more distal humeral fractures, fully release the glenohumeral joint capsule contractures to allow the proximal humerus to move forward with minimal force. At the time of disimpaction, maintain straight distal traction on the arm, again without a torsional component to the applied traction.

In 2011, Van Thiel et al described a vertical humeral osteotomy technique for removal of well-fixed humeral components, similar to the extended trochanteric osteotomy described in hip surgery. In their study, they showed no iatrogenic fractures, perioperative or postoperative, in the 23 of 27 patients available for follow-up at an average of 41 months after operation. In 2012, Johnston et al described 13 patients who underwent a longitudinal
osteotomy to facilitate removal of a well-fixed component. This study also showed no fractures, and radiographic follow-up at a mean of 30 months demonstrated no evidence of humeral loosening or nonunion. This technique has been questioned as there is concern of distal propagation of the split. Some proponents advocate placing a 2.5-mm drill hole at the distal end of the osteotomy, lessening the ability of the split to extend farther distally. A second concern is nonunion of the split. This has been addressed by previous authors by circumferential wire fixation before the use of cement. An additional concern is potential damage to the radial nerve with the use of circumferential suture or cable needed to stabilize the split. Among patients in the longitudinal osteotomy group of this study, 1 patient suffered from intraoperative fractures with a humeral shaft fracture as well as a greater tuberosity fracture. The fracture occurred during cement removal just before disimpaction of the previously implanted stem. All patients in this group had successful removal of the humeral component, and there were no cases of postoperative fracture or malunion or nonunion.

Creation of a window or a split facilitates controlled removal of humeral stems in revision shoulder arthroplasty with a high rate of union. In considering removal of a nonpolished, low-textured implant, with or without cement, if the implant cannot be removed by disrupting the proximal bonding of the implant to bone or cement and driving it free with a designated stem holder, generic slap impactor, or impactor placed beneath the collar of the implant, it would be appropriate to consider a longitudinal osteotomy. The split allows complete detachment between a smoother prosthesis and the bone or cement interface as there is little interdigitation between the two. Conversely, if a fully textured prosthesis is to be removed, with or without cement, it is likely appropriate to consider a humeral window. The window grants more access to the humeral stem, thus exposing a greater surface area for the surgeon, and will allow direct detachment of the interface between the humeral stem and the native bone or cement. In considering a humeral window, it is necessary to create a window with an optimal location and extent. A medial metaphyseal window exposes the cement mantle and porous on-growth or in-growth portion of a proximally textured or cemented implant. This is preferred when direct access proximally is needed. Alternatively, an anterior cortical window is preferred when the fixation is more distal and direct visualization of the canal is needed to effectively remove cement or disrupt the interface between a textured component and the bone.

Conclusion

All humeral stems could be removed and new stems securely placed by the window or split technique. There were no cases of malunion or clinical loosening. Further research and experience with these techniques may result in lower rates of intraoperative fractures, although the majority observed in this study occurred in the greater tuberosity and not in the humeral shaft.

Disclaimer

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