Technical Note

Arthroscopic Single-Row Rotator Cuff Repair Augmentation With Interpositional Demineralized Bone Fiber Implant

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Abstract: Although biomechanical studies show increased load to failure and less gap formation with double-row rotator cuff repair, clinical outcome scores do not necessarily favor double-row rotator cuff repair over single-row repair. Some studies report higher retear rates with single-row repair versus double-row repair, especially with larger tears, but these results do not include orthobiologic augmentation. Single-row repairs with multiple sutures, emphasizing biologic augmentation by venting the proximal humerus, show excellent healing rates and patient satisfaction. Although much of the rotator cuff biologic augmentation literature focuses on scaffolds placed over the cuff, demineralized bone matrix scaffolds at the footprint can promote enhanced healing at the enthesis. This technical note describes a single-row technique that uses demineralized bone fiber scaffolds to augment rotator cuff biologic healing at the enthesis.

Over the past 40 years, rotator cuff repair (RCR) techniques have evolved from open repair to minimally invasive arthroscopic techniques. More recently, these techniques have increasingly used orthobiologics to augment and improve patient outcomes.[1] Rotator cuff pathology continues to plague the population, with reported rates of rotator cuff disease ranging from less than 10% in patients younger than 20 years to over 65% in patients older than 70 years.[2]

Advances in suture anchors, repair configurations, and biologic augmentation have improved surgical and clinical outcomes. An emphasis on restoration of the patient's anatomy with successful repair shows improved outcomes, lower pain scores, and better strength, particularly when the integrity of the rotator cuff remains intact at follow-up.[3,4] Whereas some studies indicate higher retear rates with single-row RCR versus double-row RCR, others report no difference.[5-7] Similarly, studies have revealed mixed results regarding patient-reported outcomes between single- and double-row repair techniques.[6,8] Moreover, studies have shown improved healing of RCR using a double-row technique on follow-up imaging but failed to show differences in clinical outcomes.[9] Jost et al.[10] showed that suture number, rather than anchor number or number of rows, determines the strength of RCR. In addition, Barber et al.[11,12] revealed that triple-loaded anchors resist gap formation.

Orthobiologics continue to gain increasing interest in RCR, especially in patients at higher risk of rotator cuff failure after surgery. Kwon et al.[13] found that patients older than 70 years and those with larger and retracted tears had higher rates of failure. Biologic augmentation ranges from using patients' biology (microfracture is utilizing the patients own biology by releasing bone marrow to aid in healing) via microfracture techniques to using platelet-rich plasma, stem cells, bone marrow aspirate concentrate, extracellular matrix patches, bovine collagen implants, scaffolds, and demineralized bone fiber.[1,14,15] A study by Arroyo et al.[16] found that the single-row repair technique with microfracture of the greater tuberosity at the time of repair had comparable biomechanical strength, excellent healing rates, and

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excellent patient-reported outcomes when compared with double-row repair.

Despite the large body of recent literature reporting the use of scaffolds placed in an onlay fashion during cuff repair, biologic repair has not emphasized healing at the enthesis or tendon-bone interface.[17-20] Villarreal-Espinosa et al.[21] published a technique using a demineralized bone fiber scaffold at the enthesis using a double-row repair method to promote healing and improve clinical outcomes. Similarly, we present a single-row repair technique using a trough to vent the proximal humerus with interpositional demineralized bone fiber augmentation (Video 1). This technique provides additional osteoinductive capacity at the enthesis, and our inlay technique promotes tendon-bone healing.

Surgical Technique

Patient Positioning

The anesthetist performs a regional block in the preoperative holding area. After administration of general anesthesia in the operating room, the patient is placed in the lateral decubitus position with a beanbag and axillary roll in place. We acknowledge that patient positioning is entirely the choice of the operating surgeon. The patient is then prepared and draped in the usual sterile fashion. The arm is positioned using an articulated arm holder (SPIDER 2 Limb Positioner; Smith & Nephew, Andover, MA) to apply additional traction if needed during the procedure.

Portal Placement

We perform standard portal placement typical of RCR, with a posterior viewing portal placed in the soft spot roughly 2 cm inferior to the posterior corner of the acromion (Fig 1). By use of a spinal needle under direct visualization, an anterior portal is established through the rotator interval. The spinal needle is placed through the center of a triangle created by the acromioclavicular joint, coracoid process, and lesser tuberosity of the humerus as described by Johnson et al.[22] After anterior cannula placement, diagnostic arthroscopy is performed and any intra-articular pathology is addressed.

Assessment of Subacromial Space, RCR, and Bone Fiber Scaffold Placement

After the intra-articular portion of the procedure, the subacromial space is entered through the already established posterior portal. A lateral portal is made roughly 3 to 4 cm off the edge of the acromion. A subacromial bursectomy is performed to facilitate the subsequent steps of the procedure and, if necessary, to allow decompression. Releasing the coracoacromial ligament often makes shuttling sutures out anteriorly easier. At this point, the surgeon identifies the rotator cuff tear (Fig 2), assesses its size, and determines the number of sutures required for proper repair. Using an arthroscopic burr, the surgeon creates a trough medially, where the tendon will lie on the repair, using the articular surface medially and the anterior and posterior edges of the tear as landmarks (Fig 3). The ideal location for the trough is at the footprint of the torn tendon at its insertion on the greater tuberosity, allowing interposition of the demineralized bone matrix (DBM) fiber implant between the cuff and the decorticated bony surface. The sutures are passed in a mattress configuration and sequentially shuttled anteriorly to optimize visualization and future passing of sutures.

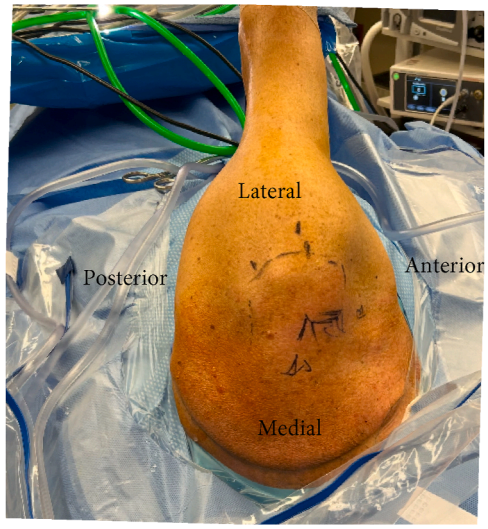

Fig 1. The patient is placed in the lateral decubitus position. A left shoulder is shown. A beanbag is used for positioning, and the arm is placed into balanced suspension.

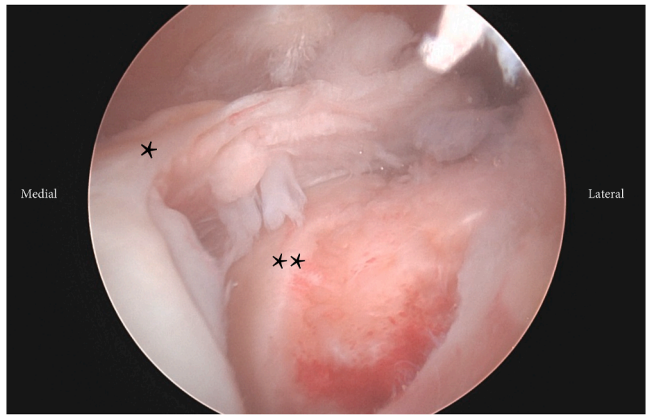

Fig 2. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. The rotator cuff tear is identified by viewing from posterior in the subacromial space. The rotator cuff tear (single asterisk) can be seen medially, and the articular margin (double asterisks) and enthesis are seen lateral to the rotator cuff tear. Visualization is performed with a 30° arthroscope.

After suture placement, a spinal needle is used to direct the placement of a fourth portal just lateral to the lateral acromion. This facilitates the placement of anchors and demineralized bone fiber implants (Tetrous, Sherman Oaks, CA). Placement of these implants includes introducing the appropriate tap into the subacromial space through the portal just created. The tap is advanced until the circular cutout meets the decorticated bone, and a twisting motion is used to carve a 2-mm-deep circle into the underlying bone (Fig 4). The surgeon will often see bone marrow elements released from the proximal humerus at this point (Fig 5). Excess bone is removed using a shaver. The bone fiber implant is placed into the circle created, and the implant is gently tapped into place. The implant is freed from its inserter using a gentle twisting motion. Depending on the tear size, 1 or 2 demineralized bone fiber implants are placed (Figs 6 and 7).

Single-row knotless RCR is then completed. Depending on the number of sutures placed, double- or single-loaded anchors are used lateral to the created trough and the demineralized bone fiber implant(s) (Fig 8). Figure 9 demonstrates the final repair construct with the enthesis re-created and Figure 10 is a diagram demonstrating the final construct. The surgeon can also consider triple-loaded knotless anchors to more closely re-create a knotless-type Southern California Orthopaedic Institute row repair.[5] These anchors reduce the tendon to the trough and/or bone fiber implants, completing the repair. The technique allows the tendon to re-create the enthesis with contact on decorticated bone both inferior and lateral to the tendon edge (Figs 8-10). Table 1 presents advantages and disadvantages of our technique, and Table 2 lists pearls and pitfalls.

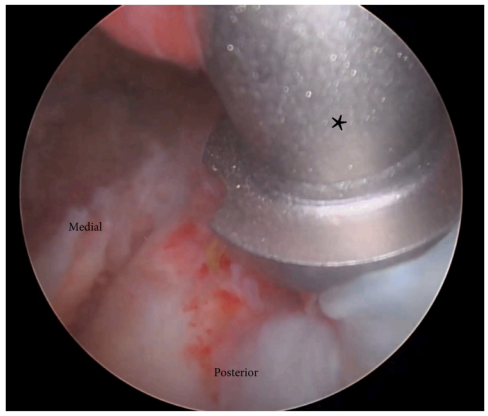

Fig 4. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. As viewed from the posterior portal, a cutting awl (asterisk) with a circular blade is brought into the subacromial space from the superior portal and is used to penetrate the bone and create the appropriate depth of 2 mm for the implant. In addition to preparing a hole for the implant, this awl vents the proximal humerus, allowing egress of marrow elements. Visualization is performed with a 30° arthroscope.

Rehabilitation Protocol

The patient wears an abduction sling with a pillow for 6 weeks after the procedure. The patient can begin gentle pendulum exercises immediately; however, formal physical therapy typically starts after the first postoperative visit, 7 to 10 days after the procedure. Gentle passive motion starts at 3 weeks, with gentle active-assisted motion (e.g., wall walks) between weeks 4 and 5. Active range of motion begins at 6 weeks if the patient is able to proceed without significant limitations

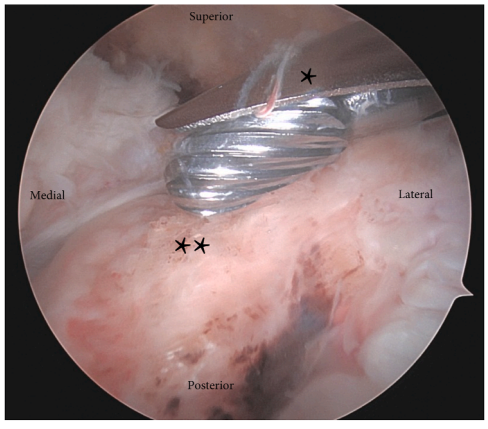

Fig 3. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. A high-speed burr (single asterisk) is introduced through the lateral portal and used to create a trough (double asterisks) just lateral to the articular margin. The burr is visualized in the subacromial space from posterior, and creation of the trough is shown. Visualization is performed with a 30° arthroscope from the posterior portal.

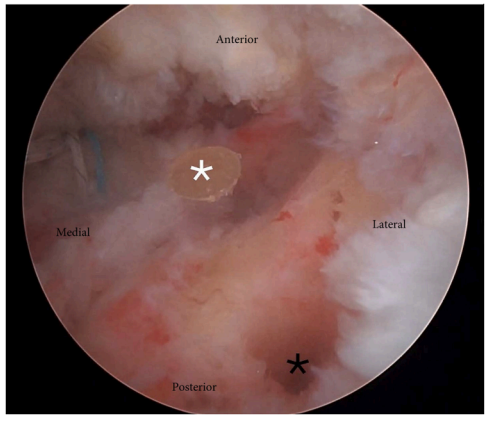

Fig 5. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. As viewed from the posterior portal, the 2 prepared holes for the demineralized bone matrix are shown. The white asterisk indicates escaping marrow elements from the more anterior of the 2 prepared holes. The black asterisk indicates the more posterior of the 2 prepared holes for implant placement. Visualization is performed with a 30° arthroscope.

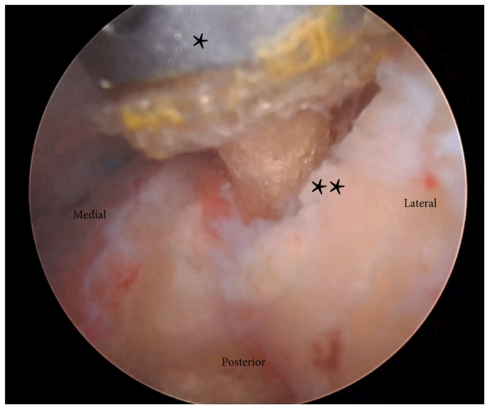

Fig 6. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. A demineralized bone fiber implant with its insertion handle is viewed from the posterior portal. The implant (2 asterisks) is inserted using its insertion handle (1 asterisk) into the previously prepared hole. The implant is gently tapped into its final position. Visualization is performed with a 30° arthroscope.

or pain. If the RCR includes several side-to-side stitches or margin convergence, the formal protocol begins at 4 to 6 weeks postoperatively.

Discussion

Rotator cuff tears that fail to respond to nonoperative management may burden patients, limiting their function and decreasing their quality of life. Despite a litany of techniques and innovations in the field of RCR surgery, retears occur, making it crucial for surgeons to continue to seek the most optimal ways to treat rotator cuff disease.[17]

Recent advances and an increased understanding of how DBM can increase healing have led to interest in optimizing the biologic healing capacity directly at the enthesis. DBM used at the enthesis enhances healing at the bone-tendon interface.[14,23] Most of the data available in the literature regarding DBM used as a scaffold in RCR are derived from animal studies. These studies

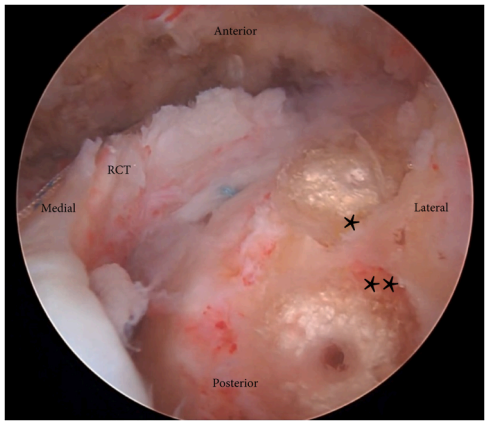

Fig 7. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. Via the posterior portal in the subacromial space, the rotator cuff is visualized medially. The prepared trough, with 2 demineralized bone fiber implants, is seen laterally. The anterior of the 2 implants is denoted with a single asterisk. The posterior of the 2 implants is demarcated with double asterisks. Visualization is performed with a 30° arthroscope. (RCT, rotator cuff tear.)

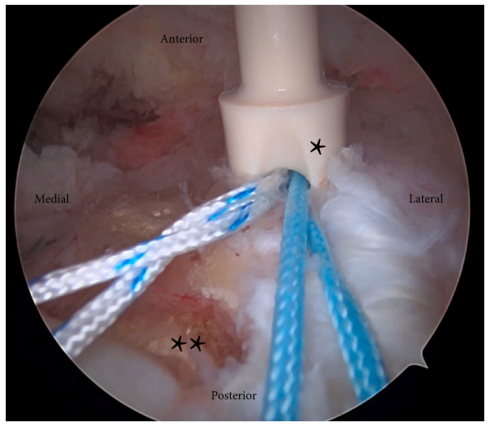

Fig 8. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. As viewed from the posterior portal, a double-loaded suture anchor (single asterisk) is placed just lateral to the previously placed demineralized bone fiber implants. The demineralized bone fiber implants are visualized medial to the anchor. The double asterisks indicate the more posterior of the 2 previously placed demineralized bone fiber implants. Visualization is performed with a 30° arthroscope.

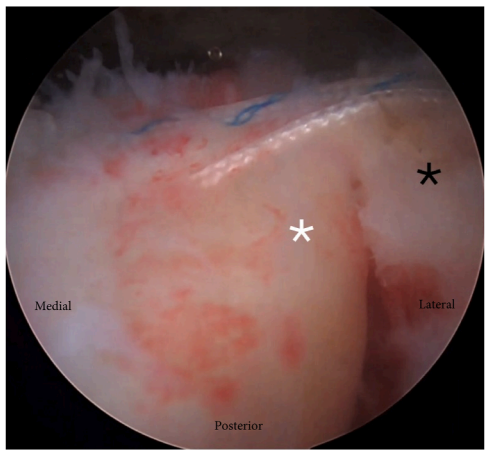

Fig 9. Arthroscopic view of the left shoulder, with the patient positioned in the lateral decubitus position. Via the posterior portal, the repaired rotator cuff is shown. The enthesis has been re-created with the rotator cuff contacting decorticated bone inferiorly and laterally. The rotator cuff tissue is marked with a white asterisk, and the proximal humerus is marked with a black asterisk. Visualization is performed with a 30° arthroscope.

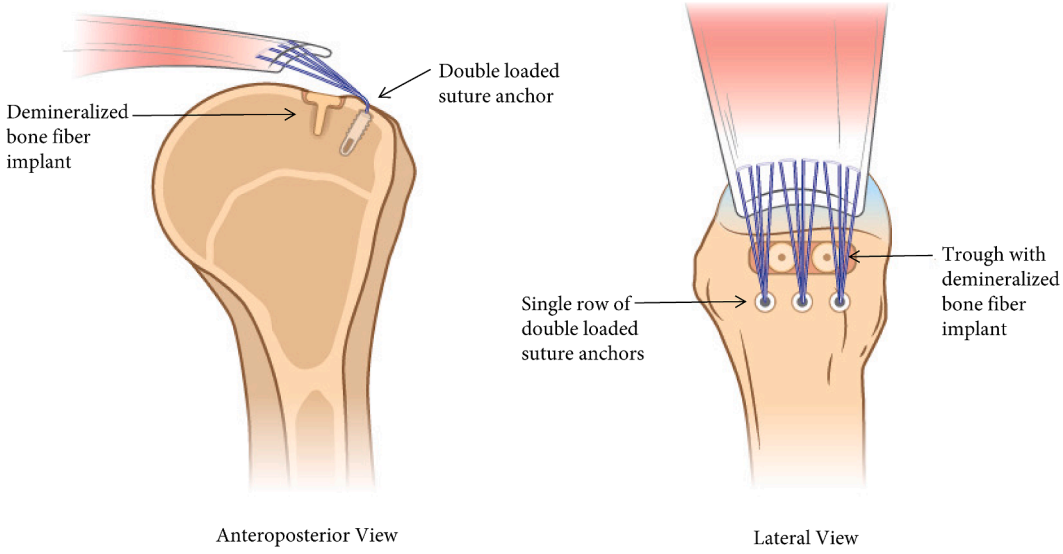

Fig 10. Anteroposterior and lateral views of rotator cuff repair. The anteroposterior view shows our single-row rotator cuff repair using a demineralized bone fiber implant. The implant is seen just medial to the double-loaded suture anchors. The lateral view shows the trough created to allow for bony healing at the enthesis, as well as the placement of 2 demineralized bone fiber implants just medial to a row of 3 double-loaded suture anchors used to repair the torn rotator cuff.

have reported promising results, with DBM scaffolds showing a more native-appearing enthesis than controls.[24-26] However, these studies are limited in number and applicability to human subjects. Similarly, studies analyzing an inlay biologic used at the enthesis are sparse. Although only 2 studies have reported an inlay biologic technique at the enthesis, these studies showed improved healing at the enthesis using both an allograft and type I collagen implant.[27]

Inlay biologic augmentation techniques targeting the enthesis, rather than the more commonly used onlay methods, have been infrequently described in the literature. To date, only 2 studies have reported interpositional scaffold techniques using either allograft or type I collagen implants, both showing favorable histologic and radiologic healing responses at the enthesis.[19] Although Villarreal-Espinosa et al.[21] recently introduced a double-row repair incorporating a DBM scaffold at the tendon-bone interface, no technique has yet been published describing a single-

Table 1. Advantages and Disadvantages of Arthroscopic Single-Row Rotator Cuff Repair With Demineralized Bone Fiber Implant Augmentation

Advantages
Decreased surgical time and anchor cost with single-row technique
Provides biologic environment that promotes tendon-to-bone healing and re-creation of enthesis
Potential for more robust healing rates and repair integrity
Disadvantages
Cost of DBM implant
If surgeon adds extra large portal to facilitate implant placement, arthroscopic visualization may be decreased
Double row potentially offers better biomechanical advantage

DBM, demineralized bone matrix.

Table 2. Pearls and Pitfalls of Arthroscopic Single-Row Rotator Cuff Repair With Demineralized Bone Fiber Implant Augmentation

Pearls	Pitfalls
The trough needs to be only 2-4 mm in depth. In addition, the tap should be used to create a 2-mm-deep circle into the trough itself, allowing the implant to lie flush with the surrounding bone.	Anchor placement abutting the trough (too medial) does not allow adequate bone stock between anchor and DMB implant and may compromise the integrity of the construct.
The surgeon must not overly enlarge the lateral superior portal used for DBM implant placement; the same portal should be used to place suture anchors.	Anchor placement too far lateral does not allow the tendon to rest in the trough or on the implant.
The surgeon should consider using double- or triple-loaded knotless suture anchors to increase biomechanical stability.	The rotator cuff repair itself should not be overly tensioned. In general, single-row repair facilitates decreasing tension on the repair.
The postoperative protocol should take into consideration the quality of the tendon tissue.	Overly aggressive rehabilitation can lead to disruption of the graft.

DBM, demineralized bone matrix.

row repair construct with interpositional DBM augmentation.

Using a single-row technique can provide adequate restoration of anatomy, with the added benefit of enhanced healing at the enthesis when combined with inlay interpositional bone fiber augmentation. This technique offers stability and the capacity to restore the enthesis, and it decreases costs by using a single anchor. We believe that this technique can potentially improve healing rates as well as cuff repair integrity. This is particularly important in older patients and those with large or degenerative tears. In comparison to xenograft-based or synthetic grafts, there may be less of an inflammatory response. In addition, an interpositional graft at time zero adds structural stability to the cuff repair construct. The benefits and ease of use, with minimal added surgical time, likely outweigh the potential disadvantages of this technique. Disadvantages include the learning time to incorporate this technique efficiently into practice, added cost of graft material, risk of graft displacement, and lack of long-term data comparing the outcomes of this technique with those of current standard techniques. Further studies will be needed to determine long-term outcomes and analyze the healing capacity at the bone-tendon interface.

Beyond anatomic and biomechanical restoration, the described approach prioritizes biologic integration at the tendon-bone interface, a critical determinant of long-term surgical success. Future prospective studies will be essential to determine the durability of outcomes, the biologic behavior of DBM in human applications, and the broader clinical implications of this enthesis-targeted, single-row augmentation technique.

Disclosures

All authors (T.M.G., A.D., F.R.L., B.A.Z., A.M., D.F. 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.

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Video 1. Arthroscopic single-row rotator cuff repair with demineralized bone fiber implant augmentation of the left shoulder with the patient in the lateral decubitus position. The patient is placed in the lateral decubitus position. A standard posterior viewing portal is established, followed by a standard anterior portal. The rotator cuff tear is identified in the subacromial space, and a trough is created just lateral to the articular margin using a high-speed burr. Sutures are passed from a lateral portal into the rotator cuff in a horizontal mattress fashion. A superior portal is established, and a cutting awl with a circular blade is used to make a hole for placement of the demineralized bone fiber implant. If 2 implants are used, the proximal humerus can be rotated to allow placement of the second implant either anterior or posterior to the first implant. Next, the implant is placed into its prepared hole through the superior portal. The implant is tapped into final position gently with the insertion handle. Next, double-loaded suture anchors are used to perform a modified knotless Southern California Orthopaedic Institute row technique.