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Shaping the bone autograft for reverse total shoulder arthroplasty without the use of any specific instrumentation

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Reverse total shoulder arthroplasty (RTSA) is a functional rather than an anatomical surgical procedure because it reverses the normal glenohumeral anatomy by transferring the convex component to the glenoid side and the concave component to the humeral side. The goal is to allow good shoulder function even in the absence of a functional rotator cuff.

At first, RTSA was developed to treat cuff tear arthropathy in the elderly. This was because there was no other viable surgical treatment for irreparable massive rotator cuff tears. Over time, the indications for RTSA have broadened to include the treatment of nonsynthesizable fractures of the proximal part of the humerus and massive rotator cuff tears, even those not associated with arthropathy.

The design of RTSA implants is constantly evolving with the goal of minimizing complications and improving range of motion (ROM). These evolutions have included the development of configurations with medialized or lateralized glenospheres, humeral inlay and onlay components, and neck-shaft angle modifications. The results of these configurations and possible couplings, along with their advantages and disadvantages in each case, have been studied to find the best compromise between stability and articularity.

Bony increased offset reverse shoulder arthroplasty (BIO-RSA) is an innovative technique that has emerged as a promising advancement in the field of shoulder arthroplasty. It addresses the challenges associated with insufficient bone stock and glenoid erosion, which can limit the success and durability of traditional reverse shoulder arthroplasty (RSA) procedures.

A special BIO-RSA technique, angled BIO-RSA, is used in some complex cases. Angled BIO-RSA is an intricate surgical method designed to address challenging shoulder conditions by strategically altering the bone anatomy at the glenoid to create a more favorable mechanical environment for the implant.

The surgeon strategically alters the bone anatomy at the glenoid and humeral sides creating an increased offset that enhances joint stability and functionality. This approach is especially valuable when dealing with patients who have significant bone deficiencies or complex shoulder problems that cannot be adequately managed with standard techniques. By customizing the implant placement and bone adjustments, this technique aims to improve shoulder biomechanics and patient outcomes, offering a promising solution for those facing otherwise limited treatment options in the realm of shoulder surgery.

Institutional review board approval was not required for this technical note.

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Table I
Pivotal surgical steps.

Pivotal surgical steps
• Deltopectoral approach to the glenohumeral articulation
• Cut a thin slice of the articular surface of the humeral head
• Use the glenoid reamer to obtain a socket for the baseplate
• Implant the baseplate
• Cut the bone all around the baseplate
• Remove the baseplate and perform humeral osteotomy
• Harvest the graft
• Shape the graft as planned
• Baseplate and graft placement
• Glenosphere placement
• Trial reduction
• Final implant placement

RSA has shown significant improvements in shoulder function for patients with rotator cuff tears, cuff tear arthropathy, and proximal humerus fractures. However, it is not without its limitations.

One of the major concerns with RSA is the potential for complications such as scapular notching, instability, and limited ROM.[9] These complications are particularly prevalent in cases with deficient bone stock and glenoid erosion, where achieving adequate glenoid fixation can be challenging.

BIO-RSA addresses these challenges by incorporating augmented bony support into the RSA procedure. This technique involves the use of a modular glenoid component that allows for additional bone grafting or the utilization of augmented components to restore the glenoid surface. By providing increased offset and enhancing glenoid fixation, BIO-RSA aims to restore the biomechanics of the glenohumeral joint and improve functional outcomes.

BIO-RSA is an innovative technique that offers potential solutions to the challenges associated with deficient bone stock and glenoid erosion in RSA. It has the potential to improve patient outcomes and further advance the field of shoulder arthroplasty.

Some companies have developed specific instrumentation that makes bone graft harvesting easier for both straight BIO-RSA and angled BIO-RSA. For example, Stryker Tornier has developed instrumentation that makes it easy to harvest a bone graft. However, this instrumentation has limitations, both in terms of correcting the bone defect and in terms of cost.

To further improve the accuracy and results and reduce the costs of BIO-RSA, the bone graft can be harvested and shaped freehand without the use of any dedicated tools. This can be done by following the steps described below.

Surgical technique

This technical note (Table I) describes the procedure for planning, harvesting, and shaping your own bone graft when performing RTSA surgery (Supplementary Video 1).

Preoperative planning

When considering an important and delicate surgery such as RTSA, it is of crucial importance to perform preoperative planning.[1] In this regard, special attention is focused on evaluating the glenoid, its morphology, and any bone deficit if present (Fig. 1).

We are greatly helped by the classifications of Walch[10] and Favard.[7] The first evaluates the bony defect in axial view and version of the glenoid, while the second classifies the inclination defect in the coronal plane.

With a CT scan, we can assess the patient's glenoid version in the axial plane and the inclination in the coronal plane. This gives us all the data we need to plan our graft perfectly. The goal of preoperative planning is the anatomic correction of version and inclination, to preserve glenoid bone stock, and to obtain the maximum contact between the component and the underlying bone (the seating).

A simple formula was developed to determine the thickness of the graft, so that a perfect graft can always be created and have guidance during surgery. The formula is: $C = A \times Tg$ (RSA Angle), where A is constant and corresponds to the diameter of the baseplate, and the RSA angle is easily calculated when planning the implant on the CT scan (Fig. 1).

With this technique, complex defects can be corrected with grafts that vary in thickness depending on the surgeon's choice. Indeed, since the graft is shaped by hand, it is possible to have different thicknesses over the entire graft surface so as to maximize contact with the baseplate (Fig. 2).

Surgical approach and graft harvesting

Patient positioning

The patient is positioned semi-seated decubitus (beach chair) on the operating table with the use of a lateral support placed at the side to prevent possible falls caused by traction during surgery, with the affected limb placed in the sterile Trimano Fortis (Arthrex) brace during preparation of the operating field.

Surgical approach and graft harvesting

A deltopectoral approach is routinely used (Fig. 3). Before the skin incision, it is injected with a solution composed of tranexamic acid, adrenaline, and ropivacaine to create a clear surgical field. The incision is made slightly lateral to the deltoid and pectoralis major muscles to facilitate exposure. The cephalic vein is identified in the Morenheim fossa. The fibers of the deltoid and pectoralis major muscles are distinguished by their different orientations (Fig. 4). Sometimes, it is necessary to coagulate small connecting vessels. An Hohmann retractor is placed over the coracoid. The insertion of the pectoralis major muscle is exposed and released for at least 1 cm. The four edges of the subscapularis tendon are identified. The anterior humeral circumflex artery and its venae comitantes, collectively called the “three sisters,” are identified and ligated. The conjoint tendon and nerves are identified medially. The biceps tendon is identified laterally. The joint can be opened in three different ways: subscapularis tenotomy,[6] small tuberosity osteotomy, or tendon peeling. Tendon peeling is the simplest option. With the subscapularis peeling, it is simpler to medicalize the footprint at the end of the procedure, following the bicipital groove. The most inferior part of the humeral head is then exposed, and the capsule attachment with the arm in forward flection and external rotation, and once a release is performed, it is easy to dislocate the humeral head.

Graft harvesting, modeling, and humerus preparation

After dislocating the joint and exposing the humeral head, the procedure can be continued with removal of osteophytes and identification of the surgical neck of the humerus, and then a thin slice of the harder articular surface is cut in order to create a flat footprint (Fig. 5). At this point, reaming of the created surface is

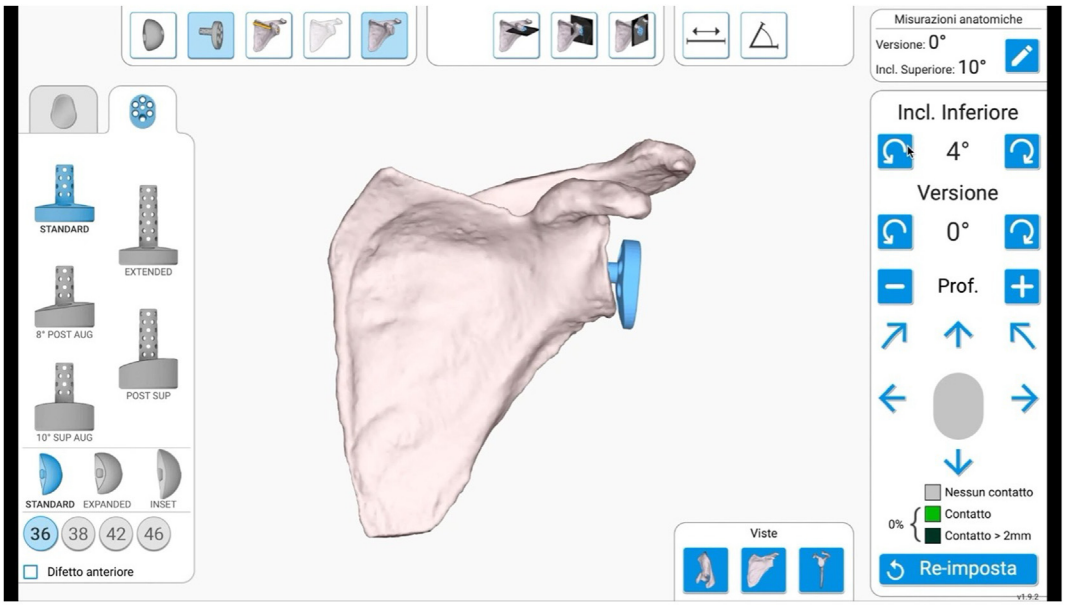

Figure 1 Image taken from the planning of a BIO-RSA (Exactech Equinoxe planning app; Exactech, Gainesville, FL, USA): you can see the glenoid with the implanted baseplate and a gap between the two; this is the gap to be filled by our autograft once it is modeled for the specific patient. *BIO-RSA*, bony increased offset reverse shoulder arthroplasty.

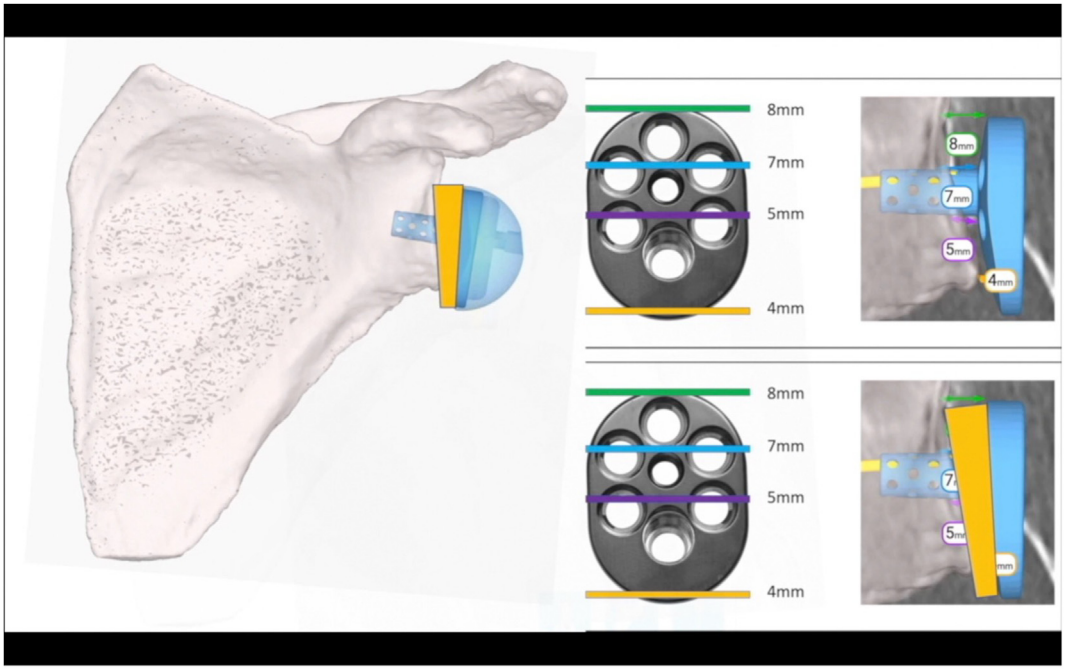

Figure 2 Graft shaped and inserted into the planning imaging between the glenoid and baseplate; final positioning of the baseplate and the glenosphere to be obtained in the operating theater.

performed using the glenoid reamer, which will also be used to prepare the glenoid surface. This allows us to temporarily implant the glenoid baseplate on the humerus (Fig. 6).

Using a sagittal saw, start to cut out the bone graft following the contour of the baseplate.

Next, the baseplate is removed, and with the same sagittal saw, the graft harvesting is completed at the desired thickness, and finally, the definitive humeral osteotomy is performed (Fig. 7).

With the help of a Luer, the graft is perfected as established by the preoperative planning (Fig. 8).

At this time, the surgery proceeds by performing the humeral canal preparation with successive broaches until the desired fit is achieved.

Glenoid preparation and humeral fixation

Once the humeral preparation is complete, the glenoid is approached. Care is taken to move the humerus posteriorly with retractors. In this case, rigid Wolfe-type retractors are preferred, as they allow greater force to be applied to the humerus and move it

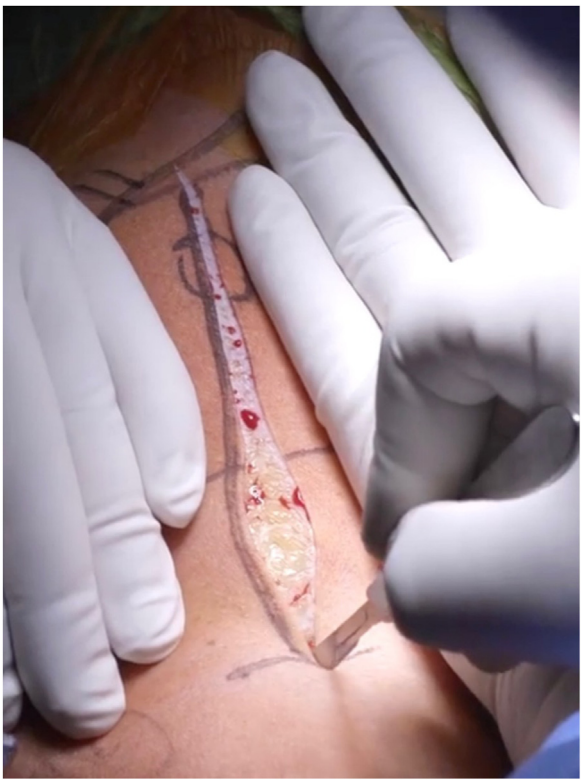

Figure 3 Deltopectoral approach.

more posteriorly. The first retractor to be placed is the one that stands on the posterior margin of the glenoid. This allows the release of the subscapularis to be completed and the anterior capsule to be released from the glenoid labrum. Next, the middle and inferior glenohumeral ligaments are identified using a pair of scissors. Subsequently, a posterior release and finally an inferior release are performed. After the releases and the complete removal of the glenoid rim, the glenoid is well exposed and can be prepared. This step is crucial to ensure that the reaming is performed correctly and that as little bone stock as possible is wasted. The previously shaped graft is then properly implanted together with the baseplate. Once the implant is in place, it is fixed with screws. The length of the screws is determined using a measured drill and by trying to maximize the socket in the glenoid vault. When the fit of the screws is satisfactory, the surgical team proceeds with the complete glove change and then implants the glenosphere. To properly implant the glenosphere, the T-handle is aligned in the north/south axis of the glenosphere to ensure that it is properly oriented with the glenoid plate. The pilot tip fits into the baseplate to aid in orienting the glenosphere to the correct position on the baseplate. The glenosphere is secured in place with the appropriate fastening screw, which is inserted perpendicular to the humeral adapter tape trial that is now attached to the humeral stem by threading the humeral adapter tray, which is captured by a screw, into the humeral stem's screw hole. Once the humeral tray and liner are assembled, a trial reduction is performed with the aim of assessing the correct positioning of the components, the proper lateralization on the glenoid side, and distalization on the humeral side of the implant, and thus the best ROM and stability. If needed, many firms offer the opportunity to choose lateralizing eccentric glenospheres, as well as distalizing humeral trays and liners, in order to achieve the best implant performance and thus the best patient outcome.[3] When the prosthesis is satisfactory on all accounts, the surgical team proceeds to the complete glove change

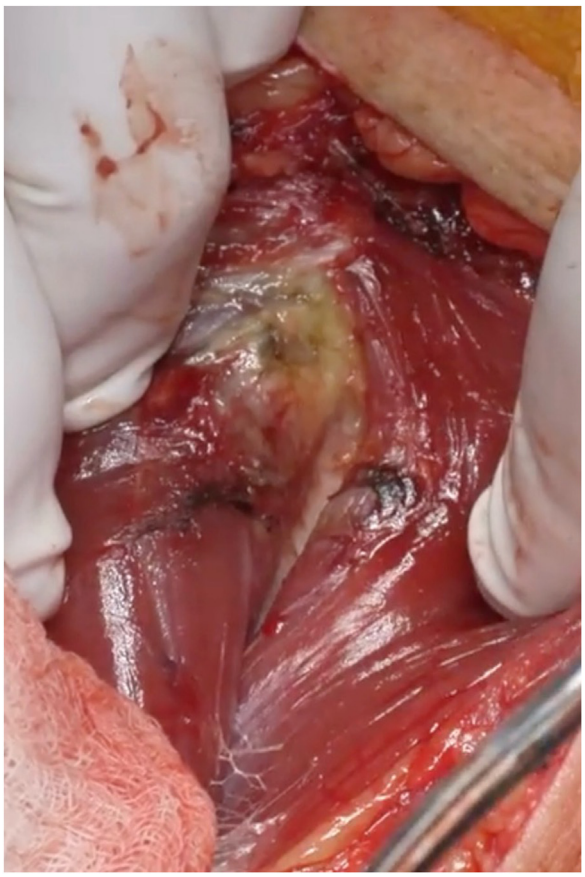

Figure 4 Deltoid and pectoralis major muscles easily recognized by different fiber orientation.

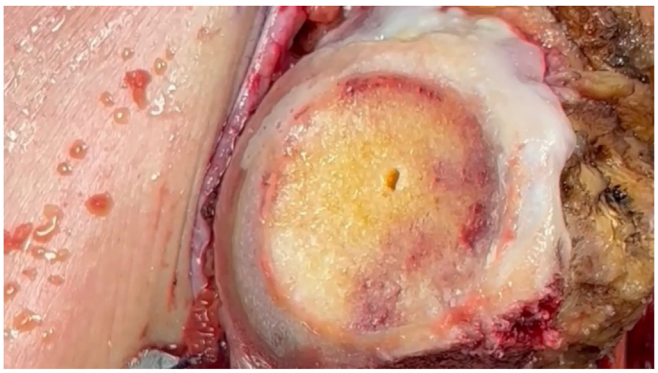

Figure 5 Humerus preparation to temporarily implant the baseplate.

and then to the final implantation and the final trials. At this point, an intra-articular drain is placed, the subscapularis tendon is sutured with high-resistance wires (Fiber Wire, Arthrex) when it is in reasonable condition, a layered suture is placed, taking care to revise the hemostasis, and Tranex is infiltrated to limit postoperative bleeding as much as possible. A sterile dressing is performed, and finally, a postoperative control X-ray is taken (Table II).

Discussion

Limited clinical studies have investigated the outcomes of BIO-RSA. However, the available evidence suggests promising results. Preliminary studies have shown improved stability, reduced

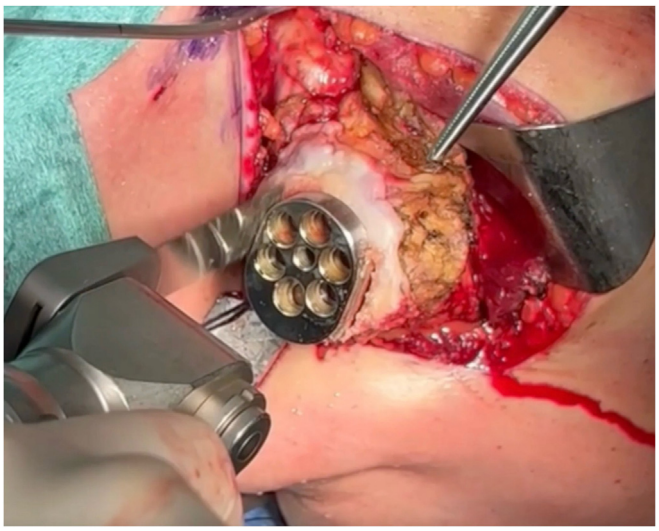

Figure 6 Cut around the baseplate implanted on the humerus to shape the bone autograft.

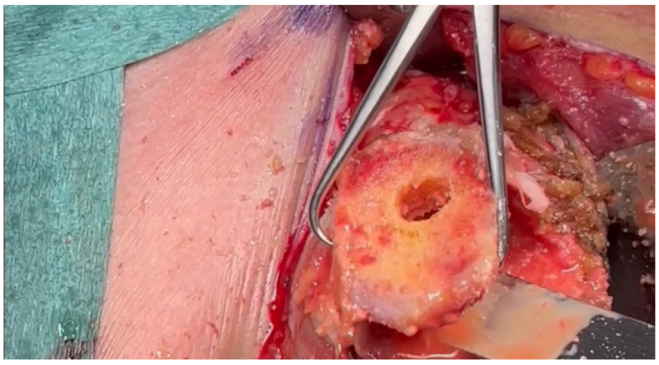

Figure 7 Performing the definitive osteotomy and autograft harvesting for shaping.

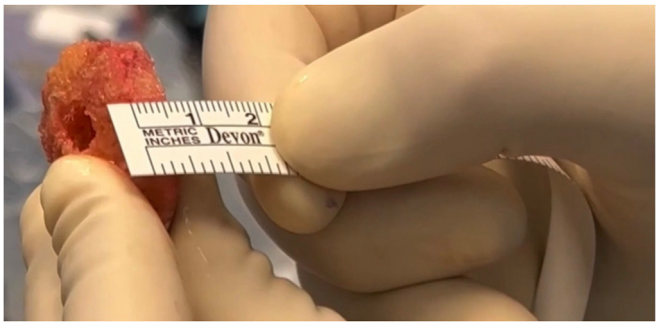

Figure 8 Measurement of the thickness of the obtained autograft.

complications, and increased patient satisfaction compared to traditional RSA techniques. BIO-RSA's ability to restore glenoid surface anatomy and enhance glenoid fixation has resulted in improved joint biomechanics and functional outcomes.[2] Nevertheless, long-term data on the durability and longevity of BIO-RSA implants are still needed. Further research and follow-up studies are necessary to establish the long-term efficacy and safety of this innovative technique in managing glenohumeral pathology. This technique offers the potential for improved stability and longevity of the prosthesis compared to traditional RSA. Despite the advantages discussed above, graft resorption remains the main challenge of BIO-RSA, which can lead to implant instability and early failure.[4]

Causes of bone graft resorption in BIO-RSA

Several factors contribute to bone graft resorption in BIO-RSA including glenoid bone quality. Poor glenoid bone quality, often associated with degenerative conditions like osteoarthritis, can make it challenging for the bone graft to integrate with the native bone. Graft size and location: smaller graft size or an unfavorable location within the glenoid can compromise the graft's vascularity and healing potential. Surgical technique: improper preparation of the glenoid and graft bed, inadequate graft fixation, and excessive force during implantation can all hinder graft integration. Patient factors: Overall health, nutritional status, and smoking habits can influence bone metabolism and the healing process, increasing the risk of graft resorption.

Impact of bone graft resorption on BIO-RSA outcomes

Bone graft resorption in BIO-RSA can have detrimental effects on patient outcomes. **Implant instability:** As the bone graft resorbs, the prosthesis may become loose or unstable, leading to pain, instability, and reduced ROM. **Early revision surgery:** Recurrent instability or bone loss may necessitate early revision surgery, which is associated with higher risks and potential for further complications. **Reduced patient satisfaction:** Loss of function and the need for additional surgery can significantly impact patient satisfaction and overall quality of life.

Strategies to minimize bone graft resorption in BIO-RSA

Several strategies can be employed to minimize bone graft resorption in BIO-RSA: Select appropriate patients: Careful patient selection is crucial, prioritizing those with good bone quality and minimal preoperative bone loss. Optimize graft preparation: proper preparation of the glenoid and graft bed enhances graft incorporation. Secure graft fixation: Meticulous graft fixation techniques, such as bone grafting with screws or suture anchors, can prevent graft displacement. Manage patient factors: addressing patient factors like nutritional status, smoking cessation, and appropriate medications can support bone healing. The freehand graft picking and shaping technique undoubtedly offers many advantages. First, if careful planning is performed to perfectly define the defect to be corrected, this technique allows to obtain a graft of exactly the shape and thickness needed for optimal implantation of the prosthesis. Despite the absence of studies regarding the technique of freehand graft harvesting and its subsequent shaping, studies regarding conventional BIO-RSA, whatever the technique by which the graft is harvested, show more than promising results. It seems clear that the freehand technique offers endless possibilities for correction and eventual lateralization, where a metal augment would be limited by the types provided by the manufacturer and may need substantial reaming for its proper placement, wasting the few remaining high-quality bone. Second, it is an extremely inexpensive technique to use. Metal inserts with augment and tilt corrections, in addition to the limitations just mentioned, also have a cost, which freehand harvesting cancels out completely, dealing with the harvesting of the patient's bone with only a few surgical gestures and a few minutes of operating theater occupancy. It also does not involve any dedicated instrumentation, but only that which is normally used for the implantation of an RTSA. It is an extremely safe technique from a surgical point of view, as there are no structures at risk during harvesting, and for its implantation, it

Table II
Pearls and pitfalls.

Pearls	Pitfalls
• Always ask for a CT scan preoperatively • Do an accurate preoperative planning • Establish the defect to be corrected • Shape the graft as planned • Always achieve good primary fixation • Perform a trial reduction to make sure the result is consistent with the planning	• Take care when performing the release to avoid implant instability • Avoid overreaming • Take great care in retracting the deltoid as not to damage its fibers • Do not damage the axillary nerve • Do not damage the subscapularis tendon

CT, computed tomography.

Table III
Advantages and disadvantages.

Advantages	Disadvantages
• Graft perfectly shaped to correct the defect • Cost-effective technique • No limitations in graft design • No dedicated instrumentation needed • Bone stock augmentation • Low donor-site morbidity	• A learning curve is required • Not all prostheses are suitable • A good humeral bone stock is needed

simply requires a baseplate that is compatible with the addition of a bone graft. If, finally, revision of the prosthetic implant should be required, the addition of bone graft and the reduction of glenoid reaming ensure greater available bone stock in what is already a challenging surgery[8] (Table III).

Like any surgical technique, it requires a learning curve and some consistency in performing such implants, but once you have mastered the technique, it gives great satisfaction to both the surgeon and the patients.

Conclusion

Limited clinical studies have delved into the outcomes associated with BIO-RSA. The existing evidence, albeit limited, points to promising outcomes.[5] Initial research indicates that BIO-RSA may offer enhanced stability and patient satisfaction, as well as a decrease in complications, when compared with conventional RSA methods. BIO-RSA's ability to restore glenoid surface anatomy and enhance glenoid fixation has resulted in improved joint biomechanics and functional outcomes. However, there is still a necessity for long-term data to gauge the durability and longevity of BIO-RSA implants. Nevertheless, long-term data on the durability and longevity of BIO-RSA implants are still needed. Further research and follow-up studies are necessary to establish the long-term efficacy and safety of this innovative technique in managing glenohumeral pathology.

The freehand technique described in the earlier paragraphs makes BIO-RSA even more accurate, customizable, and therefore effective in approaching difficult prostheses while reducing its cost because it does not use any dedicated instrumentation.

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

Supplementary Data

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