Technical Note

# Arthroscopic Superior Capsule Reconstruction Using Three-Dimensional Preoperative Planning: Technique Description

Guilherme Augusto Stirma, Paulo Santoro Belangero, Carlos Vicente Andreoli, Alberto de Castro Pochini, Nitamar Abdala, André Fukunishi Yamada, and Benno Ejnisman

**Abstract:** We describe a technique using a fascia lata autograft with 3-dimensional (3D) printing to reconstruct the rotator cuff. Prototyping constitutes the construction of physical prototypes with high complexity after virtual studies. Such models increase the knowledge of the characteristics and size of rotator cuff injuries, thus improving the accuracy of determining the correct size of the graft to be used in superior capsule reconstruction. We present a case of superior capsule reconstruction using 3D printing for enhancing the accuracy of fascia lata allograft size and tension determination; 3D reconstruction has never been described in the literature for rotator cuff injuries.

The treatment of rotator cuff tears (RCTs) remains challenging. Superior capsule reconstruction (SCR) restores glenohumeral stability and improves shoulder function.[1] Different graft options have been proposed, such as the use of fascia lata autograft, long head biceps tendon autograft, autologous semitendinosus tendon graft, and dermal allograft.[2-5] Both options are supported by the literature; however, one of the greatest challenges is to identify the appropriate graft tension and size.

Prototyping or 3-dimensional (3D) printing constitutes the construction of physical prototypes, with prototypes of high complexity after virtual studies. The ability to integrate tomographic or magnetic resonance images with 3D printing allows the production of personalized, unique, and anatomically perfect devices, masks, surgical prototypes, or models adapted to the anatomy of a case to be studied.[6] Herein, we present a case of SCR using 3D printing for the accuracy enhancement of fascia lata allograft size and tension determination.

**Fig 1.** The red arrow denotes a large-to-massive rotator cuff tear preoperatively a superior capsular reconstruction with absent of the biceps long head. MRI of the right shoulder, T2-weighted oblique-coronal. (MRI, magnetic resonance imaging.)

*From the Departments of Orthopedics and Traumatology (G.A.S., P.S.B., C.V.A., A.d.C.P., N.A., A.F.Y., B.E.) and Radiology (A.F.Y.), Universidade Federal de São Paulo (UNIFESP), Escola Paulista de Medicina, São Paulo, SP, Brazil.*

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*Address correspondence to Guilherme Augusto Stirma, Street Arruda Alvim, número 297, Ap 205—São Paulo. Cep: 05410020. E-mail: guilhermeaugusto89@hotmail.com*



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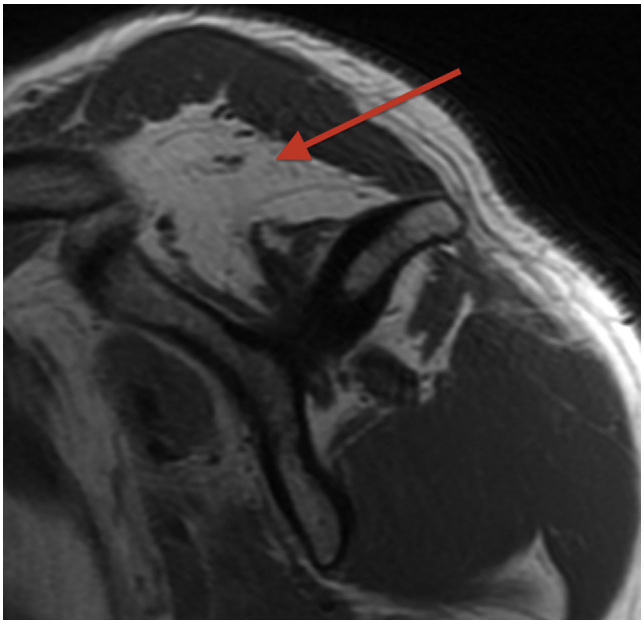

**Fig 2.** This image displays a preoperative fatty infiltration of the rotator cuff muscles after tendon rupture (red arrow). MRI of the right shoulder, T1 inversion recovery sagittal images. (MRI, magnetic resonance imaging.)

## 3D Preoperative Planning Reconstruction (With Video Illustration)

Magnetic resonance imaging (MRI) of the right shoulder demonstrated a supraspinatus tendon tear with retraction to the glenoid (Figs 1 and 2). After extracting the MRI in digital imaging and communications in medicine format, the image data were transferred to a dedicated image postprocessing workstation, on which 3D segmentation and visualization were performed to create a computer-aided design model based on nonuniform rational B-spline technology. The sizes and anatomy of lesions created reflected those of a real patient, and the lesion was measured from the glenoid to the entire coverage of the greater tuberosity. The printed lesion was 3.8 mm thick and measured 4.2 and 5.6 cm (Figs 3 and 4; Video 1). A humeral model with a rotator cuff injury and a tear model were applied to the software (Simplify3D, Cincinnati, OH) and thereafter sent to the printer for physical object manufacture and printing. All configurations used were for printing with thermoplastic polyurethane (Realmarket Company) with printing by Sethi3D S4X (Rio de Janeiro, Brazil).

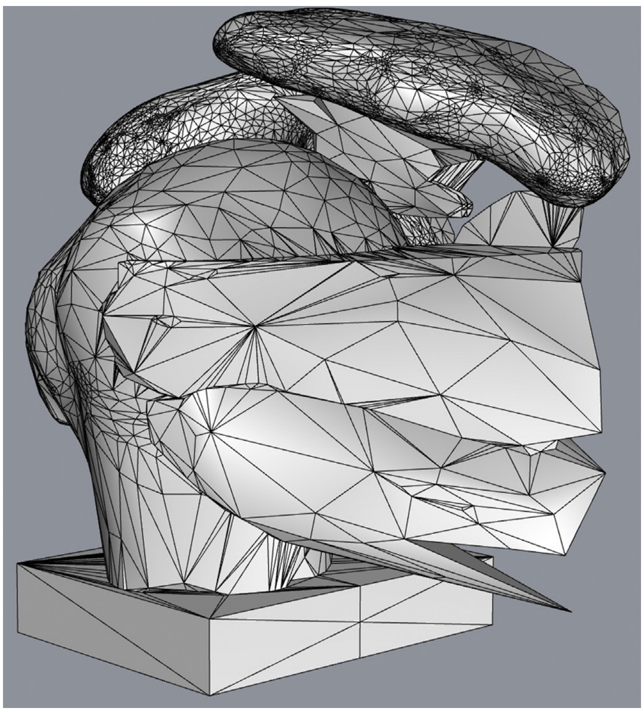

**Fig 3.** The image, a perspective view, displays a preoperative rotator cuff tear in a computer-aided design model (red arrow) with a large-to-massive rotator cuff tear. The sizes and anatomy of lesions created reflect those of a real patient.

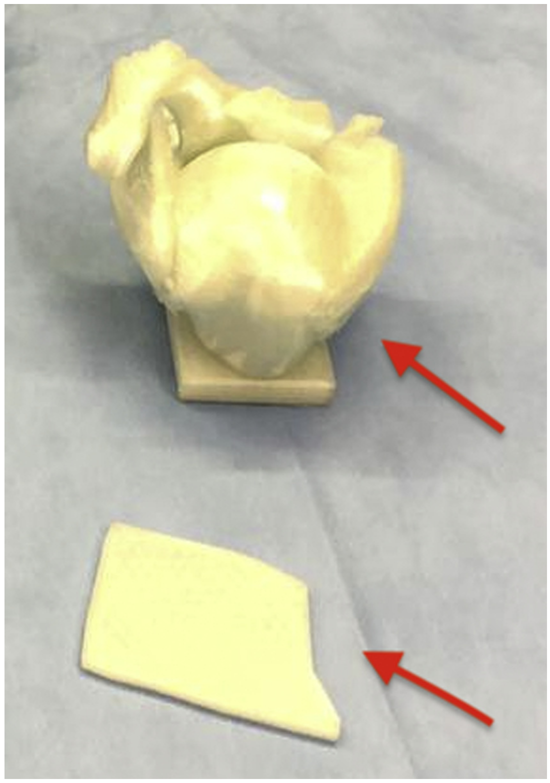

**Fig 4.** Rotator cuff tear in a 3D printing model and the accurate graft size required to produce the accurate tension (rotator cuff tear size) (red arrow). The lesion was measured from the glenoid to the entire coverage of the greater tuberosity. The printed lesion was 3.8 mm thick and measured 4.2 and 5.6 cm. (3D, 3-dimensional.)

## Surgical Technique

The procedure is performed with the patient in the beach chair position under general anesthesia with a single-shot interscalene block. The joint is first accessed

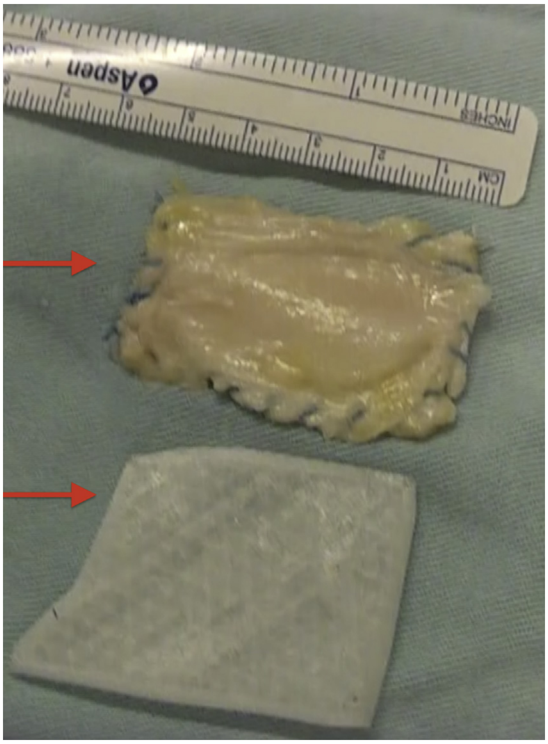

**Fig 5.** Fascia lata graft size required for accurate tension determination (red arrow). 3D printing model of graft size required for SCR (red arrow). (3D, 3-dimensional; SCR, superior capsule reconstruction.)

through the posterior portal using a 30° arthroscope (Karl Storz, Tuttlingen, Germany) with an anterior working portal to assess the RCT size and to confirm the absence of the biceps tendon. A 3.75-mm suction radiofrequency cautery device (Super TurboVac 90;

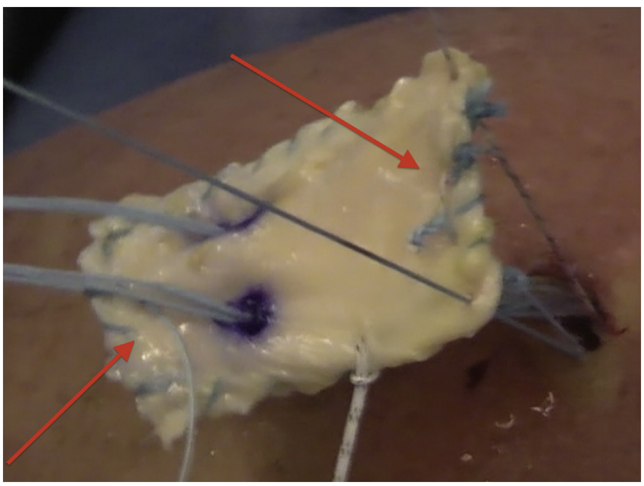

**Fig 6.** Arthroscopic view of right shoulder with patient in beach-chair position view through posterior portal. Two FiberWires (each glenoid anchor) were placed on the medial fascia lata allograft side (red arrow). One wire side for each glenoid anchor was sutured to create a double pulley. Two FiberTapes (Arthrex) were passed on the lateral graft side to create a double row (red arrow).

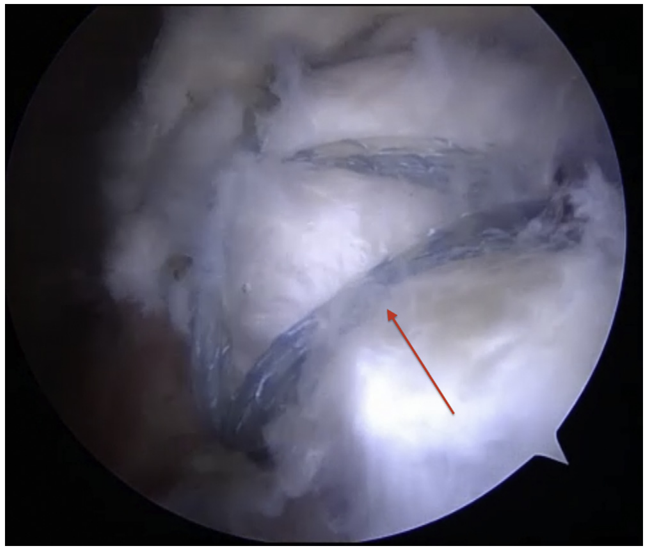

**Fig 7.** The final construct was arthroscopically visualized in the shoulder from the posterior portal with the patient in a beach-chair position. Stability was tested during dynamic shoulder examination.

ArthroCare, Austin, TX) is used for synovectomy and adhesiolysis.

The arthroscope is directed to the subacromial space, and a lateral port is created. Complete subacromial bursectomy is performed to better visualize and inspect the rotator cuff tissue for quality and mobility. The superior glenoid and greater tuberosity are prepared with a motorized rasp (PoweRasp, 5.5 mm; Arthrex) to improve graft-to-bone healing. The tear and fascia lata allograft sizes are measured and compared with those of the 3D prototype (Fig 5).

Two 4.75-mm Bio-Composite Vented SwiveLock anchors with attached swedged FiberTape (Arthrex) are placed—the first into the lesser tuberosity to repair the upper partial subscapularis lesion and the second posterior to the greater tuberosity to suture and advance the infraspinatus. A Neviaser portal is created, through which two 3.0-mm Bio-Composite SutureTaks (Arthrex) are placed medial to the glenoid labrum, one anteriorly and another posteriorly. Through a lateral portal, two 4.75-mm Bio-Composite Vented SwiveLock anchors (Arthrex) with FiberTapes (Arthrex) are introduced into the medial row at the greater tuberosity lateral to the humeral head cartilage.

The fascia lata allograft is prepared. Two wires (each glenoid anchor) are placed on the medial allograft side

**Table 1.** Pearls and Pitfalls

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|---|
| 3D objects can improve the analysis of structures. |
| Surgical time **i**s reduced. |
| Correct graft size **i**s used to determine the correct tension. |
| The prototype function**s** as an educational tool. |
| The models increase the knowledge of the characteristics and size of rotator cuff injuries. |

3D, 3-dimensional.

**Table 2.** Advantages and Disadvantages of 3D Printing

| Advantages | Disadvantages |
|---|---|
| Increases the accuracy of preoperative planning with the use of new 3D models | MRI provides a 2D image |
| Decreases anesthesia time | Creating a 3D model requires time |
| Enhances the determination of rotator cuff tear size | Printers and 3D models are costly and not readily available |
| Incorrect size determination may result in a graft that is too large or too small | |

2D, 2-dimensional; 3D, 3-dimensional; MRI, magnetic resonance imaging.

to sutures. Each glenoid anchor is sutured to create a double pulley. Two FiberTapes (Arthrex) are passed on the lateral side (anterior and posterior) (Fig 6). The graft is passed into the shoulder joint by maintaining constant tension. The graft is advanced to the superior glenoid neck using the double pulley. Each of the anterior and posterior goalpost sutures are then tied.

Two 4.75-mm Bio-Composite Vented SwiveLock anchors (Arthrex) are introduced into the lateral row to complete the configuration of a transosseous equivalent reconstruction (Fig 7).

One 4.75-mm Bio-Composite Vented SwiveLock anchor (Arthrex) is introduced anteriorly to increase the tension, and the patch is sutured side-to-side to the native rotator cuff tissue. The final construct is arthroscopically visualized in the shoulder from the lateral portal. Stability is tested during dynamic shoulder examination.

## Discussion

MRI has become the standard imaging technique for the diagnosis of rotator cuff injury. However, MRI provides a 2-dimensional image with representation on a monitor, with projected images that can hinder anatomical interpretation. Moreover, Bryant et al.[7] showed that MRI can underestimate rupture size by up to 30%. Prototyping or 3D printing provides a solution to this problem. Computer-aided design can produce solid physical models of 3D objects that can improve the analysis of structures, and therefore facilitate preoperative planning.[7]

The SCR is an anatomic reconstruction of the superior capsule to replace the physiologic restraint to superior translation. Recent studies have shown clinical improvement in patients with irreparable massive RCTs after SCR.[8,9] We describe a case of SCR using 3D printing to enhance the accuracy of fascia lata allograft size and tension determination (Table 1).

In agreement with the original technique with side-to-side sutures, and a greater tuberosity with a compression double-row technique. There are concerns about allograft structural integrity and strength after SCR of massive RCTs, as revealed in the biomechanical study of Mihata et al.[9] Therefore, we describe SCR using a fascia lata allograft patch for an irreparable massive posterosuperior RCT[9]; a 3D reconstruction of rotator cuff injuries has not been previously described in the literature. In our patient, we found that the use of rapid prototyping was instrumental in determining the correct size of the rotator cuff injury. The model to provide an understanding of the size of the graft used (Table 2). Moreover, we found the model useful for preoperative simulation and determination of the placement, number of anchors, and sutures. In our experience, the use of preoperative 3D-printed models reduced surgical time (30-40 minutes), decreased anesthesia time, and demonstrated the required graft size and tension. Finally, the prototype also functioned as an educational tool in and out of the operating room.

We hope that our 3D models will reduce the complexity of this procedure and enhance efficient surgical performance and reproducibly. Moreover, we believe that this new technology is an excellent way to facilitate SCR by an arthroscopic shoulder surgeon.

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