Arthroscopic Knotless Rotator Cuff Repair With Decellularized Dermal Allograft Augmentation: The “Canopy” Technique

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Abstract: Repairability and clinical outcomes of full-thickness rotator cuff tears rely on tendon mobility, tissue quality, and subsequent tension on a repair. While repair of rotator cuff tears tend to yield excellent clinical results, poor tissue quality has been an important factor that has hampered successful outcomes. This Technical Note describes a double-row rotator cuff repair using a SpeedBridge configuration with dermal allograft “canopy” augmentation to bolster the repairable but thinned rotator cuff tissue. This technique employs a unique graft fixation strategy to simplify the procedure. This approach could provide surgeons with a great option when faced with mobile but thinned rotator cuff tissue.

Determination of the appropriate surgical technique when faced with a full-thickness rotator cuff tear is dependent on several factors, including tissue mobility, tissue quality, and tension on the subsequently repaired tissue. The ability of the tendon to mobilize to the insertion site at the greater tuberosity is paramount as an immobile tear may warrant more elaborate procedures like a superior capsular reconstruction (SCR).1-4 For the mobile tendon, the quality of and tension on the tissue also must be amenable to a repair. In the setting of a tear that can be reduced to the greater tuberosity, but has poor tissue quality, a repair may require additional reinforcement through graft augmentation to help prevent tear-through of the tissue and subsequent tissue failure. This Technical Note describes a technique for the arthroscopic repair of rotator cuff tears using a knotless SpeedBridge configuration and dermal allograft “Canopy” augmentation. A unique graft fixation technique is employed to simplify graft attachment during the procedure.

Surgical Technique (With Video Illustration)

Patient Setup and Preparation
The patient is placed in a beach chair position and a diagnostic arthroscopy is performed to evaluate the integrity of the rotator cuff including its mobility, thickness, and tissue quality (Video 1). Surrounding tissues also are evaluated to determine the need for additional procedures. In this setting, the need for additional reinforcement through graft augmentation to help prevent tear-through of the tissue and subsequent tissue failure have been described. This Technical Note describes a technique for the arthroscopic repair of rotator cuff tears using a knotless SpeedBridge configuration and dermal allograft “Canopy” augmentation. A unique graft fixation technique is employed to simplify graft attachment during the procedure.

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The authors report the following potential conflicts of interest or sources of funding: A.M.H. reports personal fees from Arthrex, personal fees and other from Clarus Mobile Health, personal fees from LifeNet Health, outside the submitted work. In addition, A.M.H. has a patent, TENSIONABLE CONTRACTS WITH MULTI-LIMB LOCKING MECHANISM THROUGH SINGLE SPLICE AND METHODS OF TISSUE REPAIR, pending to Arthrex, a patent, SUTURE ANCHOR AND METHODS OF KNOTLESS TISSUE FIXATION, pending to Arthrex, a patent, TENSIONABLE CONTRACTS WITH MULTI-LIMB LOCKING MECHANISM THROUGH SINGLE SPLICE, pending to Arthrex, a patent, SUTURE ANCHOR AND METHODS OF KNOTLESS TISSUE FIXATION, licensed to Arthrex, a patent, SUTURE ANCHOR AND METHODS OF KNOTLESS TISSUE FIXATION, licensed to Arthrex, a patent, MEASURING TOOL USING SUTURE AND SUTURE ANCHOR, licensed to Arthrex, a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex, a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex, a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex, a patent, SUTURE ANCHOR AND METHODS OF KNOTLESS TISSUE FIXATION, pending to Arthrex, a patent, SUTURE ANCHOR AND METHODS OF KNOTLESS TISSUE FIXATION, licensed to Arthrex, a patent, MEASURING TOOL USING SUTURE AND SUTURE ANCHOR, licensed to Arthrex, a patent, MEASURING TOOL USING SUTURE AND SUTURE ANCHOR, licensed to Arthrex, a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex, a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex, a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex, a patent, SUTURE ANCHOR AND METHODS OF KNOTLESS TISSUE FIXATION, licensed to Arthrex, a patent, SUTURE ANCHOR AND METHODS OF KNOTLESS TISSUE FIXATION, licensed to Arthrex, a patent, MEASURING TOOL USING SUTURE AND SUTURE ANCHOR, licensed to Arthrex, a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex, and a patent, JOINT KINEMATIC RECONSTRUCTION TECHNIQUES, pending to Arthrex. T.D. is an employee of Arthrex. In addition, T.D. has a patent, MEASURING TOOL USING SUTURE AND SUTURE ANCHOR, licensed to Arthrex. These are the products we have on hand to work with at Arthrex. They are all proprietary and unique to complete the canopy repair with a knotless tensionable technique. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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pertinent tissues are debrided of any adhesions and released to better visualize the torn rotator cuff and improve its mobility (Fig 1). Using a grasper, the leading edge of the rotator cuff tendon is pulled laterally in an attempt to reduce the tissue to the normal attachment site on the greater tuberosity. In addition, the quality of the rotator cuff tendon tissue is evaluated to further determine repairability and the need for augmentation. If the rotator cuff tear is determined to be amenable to repair but needs additional reinforcement, a rotator cuff repair with canopy graft augmentation is performed.

**Rotator Cuff Repair**

A SpeedBridge configuration (Arthrex, Naples, FL) is used to repair the full-thickness rotator cuff tear. With the greater tuberosity debrided down to bleeding bone in preparation for the repair, the medial row anchors are placed. A socket is punched along the articular margin anteriorly. A 4.75-mm Knotless BioComposite SwiveLock preloaded with FiberTape (Arthrex) is fixed into the socket. A posteromedial socket is punched, and a second Knotless SwiveLock is placed in position. The excess FiberTape is cut flush with the lateral anchors. This completes the rotator cuff repair using the SpeedBridge configuration (Fig 3).

If the repaired tendon tissue is thinned and its durability suspect, a Canopy augmentation is indicated to reinforce the repaired tendon (Table 1). Each anchor is accompanied by 2 additional sutures: a repair suture and a looped shuttle suture. These sutures are used to secure an augmentation graft. If an augmentation is not performed, the sutures are simply removed.

**Graft Preparation and Fixation**

The dimensions of the dermal allograft need to be specific to the construct. To determine the appropriate size of the graft (ArthroFlex 201, 2.0 mm thickness;
Fig 3. A view through the lateral portal of the right shoulder with a 30° arthroscope with the patient placed in a beach chair position. A completed rotator cuff repair using the SpeedBridge configuration (Arthrex, Naples, FL) can be seen. The medial row knotless sutures can be seen in the background of the image. Each of the anchors have associated repair and looped shuttle suture limbs (stars) that will be used to fix the dermal allograft for augmentation.

LifeNet Health, Virginia Beach, VA) (Fig 4), the distance between each of the 4 anchors is measured intra-articularly using a repair suture and the SCR Guide (Arthrex). The SCR Guide is attached to the repair suture and placed over the anchor of the repair suture. A hemostat is used to mark the zero point on the SCR Guide (Fig 5A and B). The repair suture is moved to an adjacent anchor, displacing the hemostat from the zero position. The distance from which the hemostat is displaced from the zero position corresponds to the distance between these 2 anchors and the dimension of that side of the graft (Fig 5 C and D). Each repair suture allows for the measurement of 2 adjacent sides of the graft, so using repair sutures from opposing corner anchors will yield the measurements of all 4 sides of the graft. Measurement of each side of the graft is imperative to prevent dog-ears or overtensioning of the graft.

With the graft appropriately measured and trimmed to specifications, a PassPort Divider (Arthrex) is placed in a 12-mm PassPort Cannula (Arthrex) in the anterolateral portal to prevent suture entanglement. This device separates the cannula into 4 compartments. The repair suture and looped end of the shuttle suture for each SwiveLock are gathered and pulled extra-articularly into their respective compartments ensuring the sutures of each anchor remain isolated (Fig 6 A and B). The repair suture is passed through its respective corner of the graft using a SideLoader Scorpion Suture Passer. The repair suture is then loaded through the looped end of the shuttle suture (Fig 7). The remaining limb of the shuttle suture is pulled to thread the repair suture through its corresponding anchor and seat the repair suture in the anchor’s locking mechanism. This process is completed for each suture bundle (Fig 8).

The divider is removed from the cannula, and the graft is pushed into the joint using a BackGrasper (Arthrex). With the graft introduced into the joint, the repair sutures are pulled to tension the graft appropriately over the SpeedBridge repair. The excess repair sutures are cut. A biologic may be now placed in-situ both under the tendon repair at the bone interface and under the canopy between the graft and tendon. The canopy will help keep the biologic in place. This completes the Canopy augmentation of the rotator cuff repair with a decellularized dermal allograft (Fig 9).

Rehabilitation
The rehabilitation for this technique would follow a standard protocol for a rotator cuff repair. Our rotator cuff repair protocol consists of 5 phases under the guidance and direction of a physical therapist. Phase I

**Table 1. Indications and Contraindications**

| Indications          | Contraindications                          |
|----------------------|--------------------------------------------|
| Repairable full-thickness rotator cuff tear | Inelastic rotator cuff tissue |
| Thinned tissue       | Excessive tension on repaired rotator cuff |
| Mobilizable tissue   | Severe osteoarthritis                      |
(weeks 1-3) is focused on regaining pain-free passive range of motion (ROM) while diminishing pain and decreasing muscle tightness and spasm. Phase II (weeks 3-6) allows patients to begin active-assisted ROM and removal of the sling (without bolster) after week 4. By the end of phase II, patients should have achieved 70% to 80% of ROM in all planes. Phase III is divided into “early” and “late” phases, with the goals of Early Phase III (weeks 7-10) aimed at improving coordination in controlled movements and return of full ROM. Active ROM exercises against gravity and light tubing/scapular stabilization exercises are permitted. Patients should have achieved full active and passive ROM by the end of Late Phase III (weeks 11-16). In this Late phase, patients continue to progress with their tubing and scapular stabilization exercises and focus on establishing a foundation for the gradual restoration of shoulder strength and power. Phase IV (months 4-5) is strength-focused while maintaining full, pain-free ROM. Fast-twitch controlled movements are initiated and patients are gradually returned to functional activities. In Phase V (months 6+), patients continue to gradually return to functional, strenuous work, and recreational sport activities.

Discussion

Tissue mobility, quality, and tension are important considerations when determining the ideal method of surgical repair of full-thickness rotator cuff tears. If the rotator cuff tendon is unable to mobilize to the footprint...
or if there is excessive tension on the mobilizable tendon, procedures like the SCR or SCR combined with cuff repair\textsuperscript{1-5} should be favored over primary repair. For the repairable tear, poor tissue quality necessitates graft augmentation to provide additional thickness.

A repair alone for a mobile, yet thinned rotator cuff may lead to a poor outcome. The thinned tissue may not be able to hold the high-tensile strength sutures, or, even if the tendon heals, it may not withstand the forces required for day-to-day activities and ultimately result in a retear. This will result in the further loss of tendon tissue and make future revisions more difficult or impossible. In these settings, augmentation with a patch may improve the prognosis by thickening the tissue (Table 2). Graft augmentations can be completed in a variety of ways and can be either incorporated into the repair as part of the construct like the BioBridge (Arthrex) or, as detailed in this manuscript, laid on top of a repair like a canopy. The goal of this Canopy method is not meant to strengthen the repair but rather to add tissue to the rotator cuff tendon to make it more robust and resistant to retear.\textsuperscript{6}

The ArthroFlex decellularized dermal allograft (LifeNet Health) is remarkably strong and has existing vascular

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**Fig 6.** (A) An external view of the right shoulder with the patient placed in a beach chair position. A PassPort Divider (Arthrex, Naples, FL) is placed in the anterolateral 12-mm PassPort Cannula (Arthrex). Each anchor is accompanied by 2 sutures: a repair suture and a looped passing suture. The sutures from the medial row anchors are pulled through superior compartments of the divider and the sutures from the lateral row anchors are in the inferior compartments. (B) A view through the lateral portal of the right shoulder using a 30° arthroscope of the PassPort Divider (Arthrex) placed in the anterolateral cannula. The repair and looped shuttle sutures from the various anchors can be seen in their individualized compartments.

**Fig 7.** An external view of the sutures used to fix the dermal allograft with the patient placed in a beach chair position. Three suture limbs from 2 sutures are used: one repair suture (which is fixed to the anchor) and 2 limbs from the looped shuttle suture. The repair suture is passed through the corresponding graft corner and then is loaded through the looped end of the shuttle suture. The looped shuttle suture can be pulled to pass the repair suture back through the knotless anchor. This process is repeated for each corner.

**Fig 8.** An external view of the graft with the patient placed in a beach chair position, with all repair sutures passed through their designated corners of the graft and their corresponding anchors. The PassPort Divider (Arthrex, Naples, FL) will be removed before when the graft is pushed into the joint. After the graft is introduced into the joint with a BackGrasper (Arthrex), the repair sutures (black stars) will be tightened to fix the graft in place.
channels. The graft has been shown to incorporate, revascularize, and recellularize over time when used in SCR. At time point zero of implantation, the graft just sits on the repair. Once it adheres and integrates, the tendon will have a greater cross-sectional area, which will give it greater strength and ability to withstand tearing. In addition to being thicker, the inherent, native strength of the dermal allograft, which has been shown to have a high ultimate pull to failure, will buttress the tendon even further, considerably enhancing the repair once integrated.

Rotator cuff augmentation has been avoided due to surgical complexity and poor graft selection. The method of graft fixation and use of a cannula divider to assist in suture management in this Canopy technique simplifies the augmentation procedure (Table 3). In addition, the knotless anchor technology avoids knot tying and knot stacks, which have shown to cause damage to peripheral tissues by attrition. This technique offers surgeons addressing mobile but thinned rotator cuff tears an excellent option for repair with dermal allograft augmentation.

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### Table 2. Advantages and Limitations

| Advantages                                      | Limitations                                      |
|-------------------------------------------------|--------------------------------------------------|
| The technique uses a standard rotator cuff repair with a double-row construct and then allows the surgeon to simply augment the repair as necessary without additional anchors or knot tying. A tissue spreader and holder is not necessary. The ArthroFLEX graft is very strong, resistant to suture pull-through, and has minimal DNA, which decreases the chance of an inflammatory reaction. The ArthroFLEX graft is capable of incorporation, revascularization, and recellularization by the host. The technique allows placement of a biologic under the graft, which will hold it in place. | Canopy augmentation is not ideal for rotator cuff that cannot be mobilized or has too much tension upon repair. ArthroFLEX graft may not be accessible worldwide. |

### Table 3. Pearls and Pitfalls

| Pearls                                                                 | Pitfalls                                                                 |
|-----------------------------------------------------------------------|--------------------------------------------------------------------------|
| The PassPort Divider prevents suture crossing and entanglement.       | Avoid suture crossing and entanglement.                                   |
| Knotless anchor technology allows for easy graft fixation without extra hardware. | Avoid musculotendinous junction during rotator cuff repair.               |
| Knotless anchor technology negates need for knot stacks that would cause damage to tissue. |                                                                         |
| If augmentation is not performed, the passing suture is pulled out, and the repair suture is cut. They also may be used alternatively as dogear repair sutures, additional tightening sutures, or horizontal mattress buttressing. |                                                                         |

### Fig 9. A view through the lateral portal of the right shoulder with a 30° arthroscope with the patient placed in a beach chair position. The dermal allograft canopy augmentation is seen sitting over the supraspinatus tendon repair. This is the final construct.
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