Editorial Commentary: Biology and Biomechanics Must Be Carefully Balanced for a Durable Rotator Cuff Repair

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Abstract: Arthroscopic rotator cuff repair strategies have evolved over 3 decades, but suture anchor design, anchor configuration, and stitches have been largely driven by repair biomechanics. In recent years there has been a shift toward repair strategies that enhance the biology of tendon repair. Double-row and transosseous equivalent suture anchor repair constructs demonstrate excellent time zero mechanical properties, but the resulting increased repair tension and tendon compression may compromise tendon healing. Modern single-row repairs employing medialized triple-loaded suture anchors, simple stitches, and lateral marrow venting avoid some of the problems associated with double-row repairs and demonstrate excellent short-term healing and clinical results. The most robust repair fails if the tendon does not heal. Biology and biomechanics must be carefully balanced.

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The history of arthroscopic rotator cuff repair is approximately 30 years old. When I entered orthopaedic residency in 1994, only Drs. Snyder and Altchek had presented, separately, on the outcomes of all arthroscopic rotator cuff repair.[1-4] A handful of other surgeons had performed arthroscopic rotator cuff repair previously but had not reported on their results. Since then, there has been a proliferation of arthroscopic techniques and strategies to effect tendon to bone repair, including various indirect and direct suture passing techniques, sutures and tapes, stitches, suture anchors, and anchor configurations.

In the 1990s and early 2000s, arthroscopic rotator cuff repair employed a single row (SR) of double-loaded suture anchors and simple stitches. Anchors were often placed laterally, so that if there was gapping at the repair and the tendon slid a few millimeters away from the anchor, the rotator cuff tendon could still contact the bony footprint, resulting in potential for healing.[5-7] Subsequently, concerns over the limited tendon-to-footprint contact motivated the development of unlinked double-row (DR) techniques[8] employing a second row of medially placed anchors with mattress stitches placed medially through the tendon in addition to the lateral row anchors with simple stitches placed through the tendon more laterally. These techniques demonstrated superior restoration of footprint contact compared with SR techniques.[9]

These unlinked DR constructs remained popular for several years, but concerns arose regarding the nonuniform footprint contact as well as the cumbersome technique and potential for suture abrasion and crepitus resulting from medially placed knot stacks. In 2005, Park et al.[10] reported on a transosseous equivalent (TOE) technique consisting of 2 rows connected by the sutures bridging the rotator cuff, otherwise referred to as a linked DR repair.[11] Biomechanical studies also demonstrated that TOE repairs improved tendon-to-bone contact and durability compared to SR repairs.[12,13] The technique was simplified further by replacing suture with tape for knotless repairs. Collectively, these TOE techniques remain very popular today, although different repair strategies are often employed according to tear size, geometry, retraction, and tissue quality.[14]

Over time, concerns have been raised regarding the potential consequences of TOE repairs. One concern relates to the tendon compression caused by the bridge of sutures and its effect on rotator cuff vascularity.[15]

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Another, possibly related, concern are the repair failures that arise medial to the TOE construct, also referred to as a Cho type 2 failure.[16] These failures near the muscle tendon junction leave a short medial tendon stump that is challenging to repair and heal. Another important concern in this era of value-based care relates to the fact that DR and TOE repairs require more time and more implants and therefore are more costly that SR repairs.[17]

Over 2 decades in clinical practice, I have observed a gradual but relentless movement away from prioritizing above all else the strength and mechanical durability of the repair construct toward an emphasis on optimizing both repair biomechanics and biology of tendon healing following repair. We currently employ suture anchors with substantial pull-out strength, ultra-high strength sutures, and stitch redundancy or suture bridging to effect a strong repair that withstands early loading. Yet the most robust repair fails if the tendon does not heal. We do not typically encounter dislodged anchors and unraveled knots at the time of revision repair but rather suture cutout through the tendon or a new tear arising medial to the previous repair. If durable tendon healing and restoration of comfort, strength, and function are the goals of rotator cuff repair, then we should not aim for the strongest time zero repair construct if it strangles the tendon or is otherwise tensioned excessively.

A recent systematic review summarized the results of several early comparative studies that demonstrated better healing rates and/or outcomes with DR or TOE repairs compared with traditional SR repairs employing double-loaded suture anchors typically placed away from the articular margin without any adjunctive intervention to promote healing.[11] However, modern SR repairs employing complex stitches and/or triple-loaded anchors have been shown to biomechanically outperform repairs using double-loaded anchors and simple or horizontal mattress stitches.[11,18,19]

In the paper "Arthroscopic Repair of Medium to Large Rotator Cuff Tears with a Triple-Loaded Medially Based Single-Row Technique Augmented With Marrow Vents" by Dierckman, Frousiakis, Burns, Barber, Wodicka, Getelman, Karzel, and Snyder,[20] the authors report on the outcomes of a modern SR repair strategy for medium-to-large rotator cuff tears 2 to 4 cm in length.[20] They employ a consistent technique featuring triple-loaded suture anchors placed medially, only 3 to 5 mm lateral to the articular margin. In addition, the authors employ bone marrow vents placed lateral on the footprint to improve the vascularity of the healing rotator cuff tendon and to augment the local biologic environment to promote healing.[21] It is possible that DR or TOE repairs employing vented anchors might fulfill that role, although the authors employ numerous closely spaced narrow punch holes rather than 4 or 5 larger holes for venting.

The rationale underlying the authors' repair strategy is to minimize repair tension by using medial-row anchors and simple stitches and maximize healing potential by using bone marrow vents rather than a TOE construct that optimizes footprint contact at expense of increased repair tension and the potential for tendon strangulation. Previous study has demonstrated that repairs requiring greater tension for tendon reduction to the footprint had significantly inferior outcomes scores.[22] However, one should not deduce from the authors' preference for a medial-based repair that large, retracted rotator cuff tears should be summarily reduced to the medial footprint without first releasing, meticulously and systematically, any dense bursal and articular sided adhesions[7] to minimize repair tension.

One of the authors of this paper, Dr. Snyder, has described several SR repair techniques, including one that employs triple-loaded anchors and simple stitches placed medial to a broad lateral mattress stitch that acts as a rip-stop.[23] More recently, he and his colleagues have demonstrated that even with a medially based SR repair, the footprint is able to reconstitute itself from the "super clot"[20] or ''crimson duvet'' created by these bone marrow vents.[21,24] This technique also has been used to promote graft incorporation after dermal allograft reconstruction of irreparable rotator cuff tears.[25]

Dierckman et al.[20] have employed a consistent technique and robust magnetic resonance imaging (MRI) follow to demonstrate excellent outcomes. They report 91% patient satisfaction, 92% healing by high-field MRI, and low complication and reoperation rates that represent excellent results for repair of medium-to-large rotator cuff tears.[20] The low re-tear rate confirms that excessive gap formation preventing tendon to footprint healing does not occur in the early postoperative period. Triple-loaded anchors help in this regard because these maximize the number of sutures spanning the repair, which is a critical determinant of repair construct strength.[26,27]

Several recent studies have demonstrated equivalent results comparing modern SR and TOE repairs for tears 3 cm in length or smaller, as compared with the 2- to 4-cm tears in the study by Dierckman et al. Barber[28] published a level I study comparing SR and TOE repairs, augmented with platelet-rich plasma, and demonstrated 85% healing rates in both groups. In addition, all failures in the TOE group were Cho type 2 and all failures in the SR group were type 1.[28] In a retrospective cohort study comparing medial SR and TOE repairs, Tashjian et al.[29] demonstrated similar re-tear rates and outcomes in both groups, except for a greater improvement in patient reported outcomes among patients undergoing SR repair. Jeong et al.[30] reported equivalent clinical outcomes and re-tear rates in their retrospective cohort study of the 2 repair constructs.

Recently, Yamakado[31] compared the clinical and imaging outcomes for TOE and medial SR repairs and found no significant differences across range of motion and outcomes measures at final follow-up. Cho type 2 failures were observed only following TOE repair, but only 6.5% of patients with TOE and 2.1% of patients with medial SR demonstrated a re-tear.[31] The author observed regeneration of the lateral rotator cuff tendon in 93% of patients with medial SR, echoing the observations in the study by Dierckman et al. Writing the Editorial Commentary for the study by Yamakado, Chalmers[32] concluded that "footprint coverage may be less important than previously thought regarding restoration of a full tendon attachment."

However, the study does have some important limitations, many of which the authors acknowledge. Despite the robust clinical and MRI follow-up with low patient attrition, the study is retrospective and lacks a control group. In addition, the authors employed a validated patient reported condition-specific outcomes tool, the Western Ontario Rotator Cuff score,[33] as the secondary outcomes measure, but they did not complement this score with any objective assessment of active shoulder range of motion and rotator cuff strength.

The authors employ MRI to assess rotator cuff healing according to the method of Sugaya et al.,[34] but they did not specifically study the influence of tendon length and muscle–tendon junction position on healing. Tashjian et al.[35] previously correlated tendon length and muscle–tendon junction position with healing following SR repair. They opined that in chronic retracted tears, muscle elongation may be limited, and the native tendon may be short because of tendon loss. Furthermore, if healing is to occur, then tendon lengthening with scar in continuity may be necessary to fill the defect.[35] Further studies are clearly needed to better understand the elasticity of the muscle–tendon unit and its correlation with healing as well as the tendon lengthening that occurs during healing.

Most tears occur in the hypovascular region of the tendon, 5 to 15 mm medial from the tuberosity,[36] so that reattaching a shortened tendon to the medial footprint is more anatomic than extending the repair across the entire footprint. Dierckman et al.[20] describe clearing all soft tissues to expose the entire footprint for bone marrow venting, including any residual tendon stump off the anatomic footprint on the grounds that the stump is avascular. However, triple-loaded anchors also facilitate the incorporation of a thick lateral tendon stump whenever present, so it is unclear if repairs that incorporate the tendon stump, especially using vented anchors, would heal just as predictably.

The authors present their findings at a median follow-up of 32 months (range 24-48 months) so longer follow-up is clearly needed. A recent study reporting on rotator cuff healing following SR repair at minimum 10-year follow-up revealed a complete re-tear in one-half of all cases[37] and another recent study comparing healing and clinical outcomes following SR and DR repairs at minimum 10-year follow-up revealed that DR repairs were more durable but clinical outcomes were similar with the numbers available.[38] It follows that Dierckman et al. should aim to follow their study patients long-term to determine whether the excellent short-term results obtained with their modern SR repair techniques hold up over time.

Overall, the study by Dierckman et al. demonstrates the short-term effectiveness of modern SR rotator cuff repair. It highlights many of the contributions of Dr. Snyder and his colleagues to the art and science of arthroscopic rotator cuff repair. The authors are to be commended for following their patients, closely and with imaging, nearly 30 years after Dr. Snyder's early reports helped usher in the era of arthroscopic rotator cuff repair. However, a long-term comparative study between various DR and TOE repairs and modern SR repair is needed to determine which strategy provides the more durable and optimal clinical result.

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