Review Article

Arthroscopic Transosseous Rotator Cuff Repair

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VIDEO 1 VIDEO 2

ABSTRACT

Open transosseous rotator cuff repair (RCR) was the original benchmark surgical technique for RCR. The advent of arthroscopic and suture anchor technology shifted the paradigm from open to arthroscopic surgery. Although technological advances have progressed, they come at a cost. Suture anchor technology is expensive, optimal constructs have yet to be determined, and the technology may lead to challenging complications and revision scenarios. In more recent years, a return to transosseous bone tunnels has been described with new arthroscopic techniques, eliminating the need for suture anchors. The purpose of this article is to review the historical, biomechanical, clinical, and economic literature surrounding arthroscopic transosseous RCR.

Transosseous, open rotator cuff repair (RCR) was the original benchmark surgical technique for rotator cuff tears since it was described by Dr. Harrison McLaughlin. His technique used transosseous sutures passed through greater tuberosity bone tunnels, securing the rotator cuff to bone.[1] Over the past 15 years, the pendulum has swung from open surgery to more minimally invasive arthroscopic surgery.[2] This paradigm shift enabled surgeons to minimize deltoid muscle injury, visualize concomitant intra-articular pathology, better diagnose tear patterns, and decrease postoperative stiffness, all while maintaining surgical success.[3-5]

The adoption of arthroscopic cuff repair required the development of suture anchors as standard transosseous rotator cuff repair (TO-RCR) was not initially possible through the arthroscope. Anchor-based repair techniques such as single row (SR), double row (DR), or transosseous equivalent (TOE) have high time zero biomechanical strength in the laboratory. This coupled with the ease of use ushered in the new era of arthroscopic cuff repair. The imaging outcome of arthroscopic anchor-based repairs is variable and has high structural failure rates.[6] At present, the literature has not been able to determine an optimal repair technique. Studies comparing open versus arthroscopic, anchor versus anchorless, and single versus double row are inconclusive when looking at patient-specific outcomes.

In an effort to improve biomechanical strength and enhance footprint coverage, anchor-based technology has progressed rapidly. However, this has come at a cost including potential bone cysts/voids, anchor complications, musculotendinous retears, and economic burden. In more recent years, technological

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advances and an increasingly value-based paradigm facilitated by bundled payments have led to a renewed interest in arthroscopic transosseous rotator cuff repair (ATO-RCR). The purpose of this article is to review the historical, biomechanical, clinical, and economic literature surrounding ATO-RCR. Furthermore, the author's preferred ATO-RCR techniques will be illustrated.

Biomechanics

Biomechanical data comparing transosseous with anchored repair is mixed and complicated by heterogeneous experimental designs and repair constructs relying mostly on cadaver models (Table 1). Factors pertaining to strength of repair include bone and tendon quality, which may serve as surrogates to chronicity, size of the tear, and age of the patient. Therefore, clinical indications may play a large role in the applicability of biomechanical laboratory data. In addition, the strength and success of healing for the repaired tendon depends on the sum of multiple factors, which include the type of suture, number of limbs through the tendon, percentage of footprint coverage, stress concentration of the repair, tendon vascularity, and host comorbidity.

A recent advance in shoulder surgery is tape sutures. These have been applied to anchors and can also be used at the surgeon's discretion during transosseous repair. These constructs have higher strength and increased surface area of the tendon-bone interface. Broad-based suture tapes seem to be superior to simple sutures in biomechanical testing. Borbas et al assessed the mechanical properties of nine separate high-strength sutures and tapes. Material testing demonstrated statically significant superiority of tape to suture in stiffness, load to 3mm of displacement, and ultimate load to failure.[18] In a related study, Leishman and Chudik aimed to quantify the difference between SutureTape and FiberWire (Arthrex), which are composed of similar materials arranged in different orientations. They determined that the flat, evenly distributed SutureTape outperformed the rounded FiberWire in load to 1 and 2 mm of displacement while demonstrating greater stiffness and load to failure.[19] Transosseous repair is particularly suited for tape sutures, as multiple tapes may be passed through individual tunnels and further amplified by increasing the number of tunnels and ultimately strength of repair.

Although the type of suture is important, the most essential characteristic of RCR strength is the number of sutures passing through the rotator cuff. Jost at al proved this in an ovine experiment as increasing number of suture limbs led to increased load to failure and decreased gap formation. Of note, when the number of sutures was kept constant, SR and DR repairs were equivalent. In a meta-analysis, Shi et al critically analyzed 40 biomechanical cadaver studies comparing RCR constructs. They found that as the number of suture limbs passed through the rotator cuff increased, gap formation was inversely correlated. In addition, the use of mattress and broad-based suture led to increased ultimate failure load. When controlling for the number of suture limbs, there was no significant difference among SR, DR, TOE, or TO-RCR.[20] It is likely that both anchor- and suture-based constructs can supersede the necessary strength of repair required for healing. In fact, one study found that the repaired tendon exceeded the strength of the control arm's native tendon when repaired using 14 sutures.[21] Transosseous repair allows for multiple fixation points facilitating the surgeon to maximize the point density per surface area of the tear. This feature maximizes load sharing, increases strength of repair, and decreases stress per fixation point. Multiple fixation points, with a more evenly matched modulus of elasticity, may also decrease peak loads (pressure spikes) of each fixation point at the suture-tendon interface and reduce strain in the tendon attachment site. This could decrease the likelihood of type 2 catastrophic failure (transection) of the rotator cuff.[22]

Increasing footprint coverage over the greater tuberosity in RCR is correlated with improved tendon healing, leading to the evaluation of DR, true transosseous, and TOE repair constructs.[3] In an ex vivo biomechanical study, Apreleva et al[9] obtained 10 cadaver specimens and compared TO-RCR, mattress TO-RCR, suture anchor repair, and suture anchor mattress repair for isolated supraspinatus defects. Using a three-dimensional digitizer, they discovered that TO-RCR provided a 20% larger repair site than the other constructs tested. In another biomechanical study, Dyrna et al[14] demonstrated that TO-RCR significantly reconstitutes greater tuberosity footprint coverage compared with SR repair. The term transosseous equivalent references the use of anchors placed at the articular margin of the humeral head and again laterally at the greater tuberosity, ideally reconstructing the transosseous cerclage effect of TO-RCR.[4] Compared with TOE, TO-RCR provided more homogeneous stress concentration within the repaired tendon when evaluated using pressure-sensitive radiograph and on finite-element models.[4,5] This may be clinically relevant as nonuniform stress concentration could restrict blood flow and provide suboptimal conditions for revascularization and healing, as well as induce tendon transection (type 2 failure) at the medial row.

Table 1. Biomechanical Data Comparing Transosseous with Anchored Repair

Study	Repair Tested	Methods	Pertinent Results	Conclusion
Chhabra et al[7]	(1) Open transosseous (TO) suture (two Mason-Allen stitches through three lateral drill tunnels); (2) two singly loaded suture anchors; (3) two doubly loaded suture anchors; and (4) arthroscopic cuff tacks	Rotator cuff cyclically loaded from 10 to 180 N. Number cycles to 50% and 100% gap failure	Number cycle to 100% failure greatest for doubly loaded suture anchors	SR > open TO repair
Tocci et al,[8] 2008	(1) Arthroscopic single-row (SR) and (2) open TO suture (two to three Mason-Allen stitches through three lateral drill tunnels)	Massive and large tears. RC tested at low load and high load for 4,000 cycles. Repair gapping measured.	No significant difference in gap formation	SR = open TO repair
Apreleva et al[9]	(1) TO simple (TOS); (2) TO mattress (TOM); (3) SSA; and (4) SAM	Supraspinatus insertion mapped in human cadavers. Repair techniques applied new insertion superimposed on old in 3-D digitizer	TO simple repair provided a 20% larger repair site than other repairs	TOS > TOM = SSA = SAM
Park et al[4]	(1) Simple TO; (2) suture anchor simple; and (3) suture anchor mattress	1 × 2 cm infraspinatus tear in the bovine shoulder. Mean contact area and mean interface pressure over footprint compared	TO had higher mean contact between tendon and tuberosity and greater interface pressure over the footprint	TO > suture anchor simple and mattress
Ahmad et al,[10] 2005	(1) Suture anchor and (2) TO tunnel	Cadaver supraspinatus tear measuring tendon motion relative to footprint with simulated muscle loading	TO significantly less motion compared with suture anchor	TO tunnel > suture anchor
Kilcoyne et al[11]	(1) Open TO (two tunnels, three sutures through the tunnel) and (2) TOE	25-mm supraspinatus tear, gap formation monitored in 3 planes. Cyclic loading, load to failure, and failure mechanism recorded	TOE higher ultimate failure load and less mean excursion. TOE MC failure type 2 (medial) and TO MC failure (type 1, avulsion)	TOE > TO
Salata et al,[12] 2012	(1) TOE; (2) curved bone tunnel; (3) TO simple; and (4) TO X-box	Tensile testing of the supraspinatus at 60°. Measured initial preload, cyclic loading, pull to failure, and localized elongation	TOE higher mean failure load. TO simple experienced highest first-cycle excursion	TOE > all others
Kummer et al,[13] 2013	(1) TOE and (2) TO X-box	Repairs cycled 150 N for 10,000 cycles. Movement of lateral cuff edge and cuff failure tested	Cuff edge displacement and load to failure equivalent	TOE = X-box
Dyrna et al[14]	(1) SR; (2) TO; and (3) SR failures repaired with revision TO	Cadaver shoulders tested with the hydraulic system. Load to failure and footprint coverage measured. After single repair failed, revision TO applied and experiment repeated	TO shoulder greater coverage of footprint. Load to failure equivalent for all constructs	TO > SR
Ménard et al,[15] 2017	(1) TO and (2) TOE	Cyclic loading, ultimate load to failure, and tendon	TOE significantly higher ultimate load. Less exposed footprint after cyclic load for	TOE > TO

(continued)

Table 1. *(continued)*

Study	Repair Tested	Methods	Pertinent Results	Conclusion
		displacement measured on the rotator cuff	TOE. Failure mode was suture cutout in both constructs	
Reed et al,[16] 1996	(1) TO and (2) TOE	Full-thickness supraspinatus biomechanically loaded. Load to displacement, ultimate strength, and mode of failure recorded.	Suture anchor outperformed TO repair in all metrics	TOE > TO
Tashjian et al,[17] 2007	(1) TO and (2) SR	Massive RCT tested for gap formation and repair displacement	No significant difference in maximal gapping. Gapping less anteriorly compared with posterior	TO = SR

SR = single row, TO = transosseous, TOE = transosseous equivalent, TOS = transosseous simple, SAM = suture anchor mattress, SSA = simple suture anchor

The mechanobiology of the human rotator cuff is complex and involves transitioning high stress from soft tissue (cuff), to semi–soft tissue (tendon/fibrocartilage/Sharpey fibers), to hard tissue (bone). Because of the poor biological healing and a long time of incorporation, a more natural stress gradient may lead to formation of a natural enthesis-type tissue at the tendon-bone interface and less catastrophic mechanical failure at earlier periods in healing. A finite-element study has shown that transosseous repair is favored in reducing medial row stress peaks, which could be detrimental to long-term healing and success of repair.[23] Although poorly understood at this time, modulus mismatching of the tendon-bone interface may be important in providing a better healing environment. For example, a very high stiffness at the medial row anchor may impart high forces at the medial tendon, causing failure of the weaker tissue. Conversely, the longer compression effect, coupled with the slight bungee effect of sutures, may absorb the forces in a more natural way.[9] Thus, allowing the tendon to gradually adapt to forces as healing ensues and load is transmitting to tissue. A physiologic transfer of load to tissue and less tissue strangulation leads to better vascularity at the repair site: a basic biological principle of any healing system. Urita et al used contrast-enhanced ultrasonography to evaluate the vascularity of the rotator cuff after TO-RCR and TOE using knotless suture anchors. The authors found that blood flow was significantly greater for the cuff at one and two months postoperatively for the TO-RCR cohort.[24]

Clinical Outcomes

The outcomes of RCR research are confusing and occasionally illogical. Multiples studies have been conducted, finding little correlation between patient-reported outcomes (PROs), pain, and healing.[25] However, studies also report improved PRO after surgery and healed cuffs tending to show superior strength.[26] Within open, arthroscopic, anchored, and anchorless RC surgery, various outcome differences are worthy of highlighting.

Open Versus Arthroscopic Transosseous Repairs

Before the advent of arthroscopy and suture anchors, rotator cuff surgery was conducted open with the tendon secured to tuberosity via bone tunnels. Transosseous repair thus became the benchmark technique, and the results were favorable. In fact, the longest available follow-up data available today pertain to open TO-RCR. Using an open TO technique, the authors report a 24-point average improvement in the Constant score, 10% revision surgery rate, and good to excellent outcomes in most patients at 20-year follow-up.[27] Plachel et al[26] investigated ATO-RCR for full-thickness RCT at 12- to 18-year follow-up. The authors noted sustained long-term improvements in the Constant, UCLA, and ASES scores at final follow-up. To our knowledge, these two studies demonstrate the longest available data for rotator cuff surgery available in the literature.

Arthroscopic Anchor-Based Rotator Cuff Repair Versus Arthroscopic Transosseous Repair

Several short-term studies have demonstrated ATO-RCR to improve pain, range of motion, strength, and PROs.[28,29] One prospectively matched cohort study directly compared ATO-RCR with TOE-RCR. At 12-month follow-up, there was no significant difference

Table 2. **Advantages and Disadvantages of Transosseous Rotator Cuff Repair**

Advantage	Disadvantage
Cost-effective and eliminates the cost of anchors	Technically demanding and learning curve
Improved biology at rotator cuff footprint	Requires new device
Ability to fully visualize the cuff on postoperative MRI	Suture management, knot tying
Less pain postoperatively	Concerns with fixation in osteoporotic bone
Ability to increase fixation point density, load sharing, and decrease stress riser	—
Type I failure easier revision	—
Synergistic use in hybrid constructs with existing fixation paradigms (not mutually exclusive)	—

in VAS, SANE, or SST.[30] In a larger prospective randomized control trial, patients were allocated to receive ATO-RCR using the Arthrotunneler (Tornier, Wright Medical) or single-row repair with two to three metallic anchors. Patients were assessed up to 3 years postoperatively for clinical outcomes and repair integrity. Pain was significantly less for the ATO-RCR cohort at 15 and 21 days. At final follow-up, there were no differences in the QuickDASH, Numerical Rating Score, or Constant score, leading the authors to speculate on the superiority of the ATO-RCR due to improved pain control early in the recovery process.[31] The physiologic mechanisms accounting for this effect are at present poorly understood. It has been theorized that decreased intraosseous pressure and less plastic deformation of bone inducing fracture physiology, may allow ATO repairs to vent pressure earlier in the time course and lead to less pain generated by humeral bone trauma in the short-term healing period. Postoperative pain after RCR is significant, and improvement in early pain control and speed of recovery seen with ATO-RCR is noteworthy.

One useful advantage of transosseous tunnels is the ability to avoid metallic or PEEK anchors and appropriately visualize the integrity of the RC on postoperative MRI.[32] Garofalo et al compared SR-RCR with ATO-RCR and evaluated healing characteristics with postoperative MRI. No difference was noted in the Constant or ASES scores. On postoperative MRI investigation, retear occurrence was the same. However, when a subgroup analysis was conducted, specifically examining type III Sugaya changes on MRI (insufficient tendon thickness without discontinuity), ATO-RCR was noted to be significantly higher, suggesting a potential postoperative benefit of ATO-RCR. Ultrasonography may also be used to postoperatively evaluate RCR. Srikumaran et al compared outcomes, postoperative cuff integrity, and retear rate using ultrasonography in ATO-RCR and TOE-RCR. Not only did they find no difference in range of motion, strength, or ASES scores, but they also found equivalent (14%) retear rates between cohort groups.[33] For a comprehensive list of advantages and disadvantages, please see Table 2.

Modes of Failure

The failure mode appears to differ between anchored and anchorless repairs. In a cadaver study examining the mechanism of failure between transosseous sutures and suture anchors, Burkhart et al[34] found that transosseous sutures failed by cutting through bone, whereas suture anchors failed as the suture pulled through the tendon. The authors suggest that suture anchors transfer the weak link of repair from the bone to the tendon. In clinical practice, the failure mechanism may not be as discrete as implied, as more numerous and different sutures or tapes are routinely used than were tested, bone cadaver quality may vary, and different suture anchor configurations potentially overconstrain the remaining tendon to bone. Transferring the weak link of repair from the tissue with the most regenerative capacity (bone) to the least regenerative portion of the construct (tendon) has repercussions on revision surgery strategies. In one biomechanical study, Kilcoyne et al[11] found that TOE-RCR was more likely to fail at the musculotendinous junction compared with ATO-RCR, which failed laterally when the tendon avulsed from the greater tuberosity. Truncation of the rotator cuff tendon and more medial failure with the TOE-RCR may be due to overtensioning of the tendon on the greater tuberosity with superimposed strangulation of tissue leading to a stress riser and attrition at the muscle-tendon junction. It may be desirable for the RCR construct to approximate the modulus of native tissues more closely rather than exceed normal physiologic load at the tendon insertion point. Although the multitude of biomechanical factors necessary for adequate rotator cuff healing in not fully understood, the clinical distinction between an avulsion off the greater tuberosity, and a more medial musculotendinous based retear, has clear surgical, technical, and cost related implications for revision surgery. Tendon transection renders less tendon available to repair and a challenging clinical scenario to rectify. In addition, after failure, anchors leave nonbiologic bone voids and/or retained implants in the greater tuberosity, limiting the bony area for tendon fixation and further impairing the revisability of a failed RCR or complicating a future arthroplasty operation. In contradistinction, transosseous tunnels do not leave bone voids or implants and are available for retunneling or anchor placement as desired. In addition, suture tapes have also significantly reduced concern over cut-through. Transosseous tunnels essentially mimic a microfracture, causing an influx of bone marrow–derived cells and growth factors to further enhance healing.[35] To document the clinical course of revision surgery in recurrent tears, Chillemi followed 11 consecutive patients over 12 months treated with ATO-RCR. In this small case series, postoperative MRI demonstrated that 10 of 11 patients healed their rotator cuffs, with all patients decreasing in VAS pain scores and UCLA shoulder scores.[36]

Economic Burden of Rotator Cuff Repair

There is rising pressure on providers and systems to contain healthcare expenditures while still providing optimal patient care. The burden of rotator cuff pathology continues to rise as the frequency of surgery increases, accounting for $1.2 to $1.6 billion US dollars spent annually.[37] This pressure is moving value-based care to the forefront of RCR. Value is simply evaluating outcomes with cost. All new technologies are burdened by this underlying principle. Expensive innovations must drastically improve quality, or innovation can maintain quality at a reduced cost. Anchor-based SR-RCR has been found to be cost-effective, producing a net savings of $13,771 per patient over a patient's lifetime, with up to 94% of patients returning to work.[38,39] However, the total number of suture anchors is the principal driving factor for the cost of RCR surgery, and as more anchors are used with DR or TOE techniques, value decreases.[40] In an analysis of the direct cost of outpatient arthroscopic RCR, Narvy et al found the total cost of surgery to be $5904.21, with the total average anchor cost of $3432.67. When DR repair was independently examined, the cost incurred for implants was $4570.25.[41] Unlike arthroscopic anchor-based repairs where more anchors are needed to provide fixation points and better footprint coverage, ATO-RCR can improve biomechanical RCR constructs at minimal cost by adding more tunnels and sutures, thus improving value.

The cost of RCR surgery can vary dramatically. The location of care along with implant costs is the main source of variability. To clarify the factors that correlate with cost and outcome, Chalmers et al retrospectively analyzed postoperative results with direct costs associated with rotator cuff surgery. Their study demonstrated that the price of surgery varied widely, with the maximum cost of RCR surgery being three times the mean cost of surgery. Supplies accounted for 36% of the total cost of care, with incremental increases in cost directly proportional to the number of anchors used. None of the factors that increased the expense of surgery improved postoperative Simple Shoulder Test, VAS pain, or ASES scores.[42] Biomechanical data suggest that increasing fixation points, number of sutures, and footprint coverage improve time zero RCR strength, but the fiduciary and global responsibility to limit the episode of care must also be considered. Thus, alternate strategies to increase the tensile strength of repair other than increasing the number of anchors are worth considering.

Patient-reported outcomes (quality) after RCR surgery are favorable; however, attempts to improve PROs with more robust fixation techniques such as DR-RCR and TOE-RCR have failed to show results. Therefore, to improve value, one must decrease cost, and it stands to reason that the most effective means to decrease cost is to eliminate the dependence on suture anchors. Seidl et al set out to determine the difference in price between ATO-RCR and DR TOE-RCR. The price of surgery was significantly higher for the TOE-RCR compared with TO-RCR, averaging $946.41 more ($P < 0.001$). The authors extrapolated their results and calculated an annual savings of $250 million dollars if all RCTs were fixed transosseously.[30] In a larger comparison of the cost of ATO-RCR versus DR TOE-RCR, Black reproduced similar findings. Their study of 344 patients found an average implant cost of $1014.10, again significantly higher than ATO-RCR. As the size of their rotator cuffs increased, their use of more suture anchors also increased, leading to higher costs for larger surgery. Therefore, the value of ATO-RCR increases with larger rotator cuff tears as the price stays relatively the same no matter the number of tunnels or sutures used.[42] Although suture anchors are expensive, one must consider time in the operating room when implementing various surgical techniques. In an economic analysis of 40,610 RCR, Li et al[43] found that

Table 3. Pertinent Abbreviations

Abbreviation	Term
RCR	Rotator cuff repair
SR	Single row
DR	Double row
TOE	Transosseous equivalent
TOE-RCR	Transosseous equivalent rotator cuff repair
TO-RCR	Transosseous rotator cuff repair
ATO-RCR	Arthroscopic transosseous rotator cuff repair

each minute of surgery costs $47. One criticism of ATO-RCR raised is the technical demands causing longer surgical times. Despite the size of the tear, both Black and Seidl did not show any significant time differences in their studies. A learning curve does seem to exist when beginning to implement ATO-RCR. One experienced shoulder surgeon's beginning cases averaged 10 minutes longer than normal. After 25 operations, his case time normalized and was on par with similar arthroscopic procedures.[29] An advantage of the ATO-RCR is the fixed cost of surgery despite the size and number of fixation points. This is particularly of importance when one considers the potential for bundled payments in rotator cuff surgery and the cost of implants to outpatient surgical centers. Limiting the cost of surgery by using ATO-RCR is advantageous to the surgeon, insurance carrier, healthcare institution, patient, and, ultimately, society (Table 3).

History, Authors' Preferred Technique, and Other Applications

ATO-RCR was first introduced in 2002 using a cannulated, sharp, hooked bone-cutting needle through the greater tuberosity. Suture limbs were pulled through the cannulated needle and sliding knots passing through the rotator cuff defect, securing the rotator cuff to bone.[44] Since the first generation of ATO-RCR, multiple devices have been introduced, attempting to facilitate the application of this technique. Regardless of the technique or implant used, the physiologic principles of RCR remained the same: ample fixation strength, minimal gap formation, and sufficient mechanical stability for tendon-bone healing.[45]

Suture Configurations and Other Applications

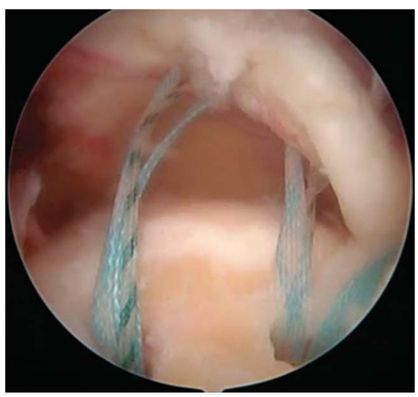
ATO-RCR allows the surgeon flexibility in choosing virtually unlimited amounts of suture configurations depending on clinical scenario and specific needs. The simple repair, box repair, and X-box repair have all been described to allow multiple fixation points and allow repair at the surgeon's discretion. Indications for transosseous tunneling extend past traditional RCR. For small or partial articular-sided tendon avulsions, a "2 for 1" may be used where a single transosseous tunnel allows two circumferential sutures to be passed. Arthroscopic transosseous suprapectoral biceps tenodesis occurs when two tunnels within the bicipital groove are placed and locking loop stitches secure the biceps tendon to bone.[46]

Much as the early arthroscopists transitioned from open, to mini-open, to arthroscopic surgery, similarly, one may use a transosseous hybrid technique to start the transition to transosseous techniques. The hybrid ATO-RCR uses two tunnels with three sutures in each. Sutures are passed through and tied, leading to four points of fixation. This construct is enough for a stand-alone repair, but the addition of a knotless anchor laterally satisfies the two most common concerns of

Figure 1

Arthroscopic view of the tensor tunneling device in the greater tuberosity.

Figure 2



Arthroscopic view of transosseous sutures passed through bone tunnels and the supraspinatus tendon.

Figure 3

Arthroscopic view of the final repaired rotator cuff with transosseous sutures.

Figure 4

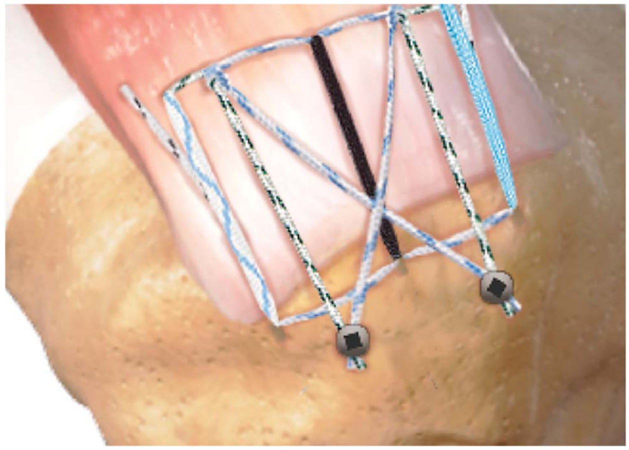


Image showing true hybrid transosseous repair.

surgeons: knot tying/tensioning and additional cortical support in the case of soft bone.[47] Thus, the advantages of both paradigms are used synergistically.

Fully Transosseous

ATO-RCR is done with the patient in the beach chair position (Video 1, Figures 1–3). The glenohumeral joint is accessed through a standard posterior portal, followed by an anterior accessory portal through the rotator interval. Standard diagnostic arthroscopy is done, and intra-articular pathology is addressed. Next, the scope is placed in the subacromial space through the posterior portal. A lateral subacromial portal is established and cannulated, and a bursectomy is done. The scope is then placed in a posterolateral portal for better visualization of the rotator cuff tear. The greater tuberosity is débrided with a curet to prepare the bed for repair. The TransOs Tunneler (Tensor Surgical) is used to pass sutures through the greater tuberosity. For standard two-tunnel repair, three sutures are placed through each tunnel. All six sutures are next passed (using a suture passer) through the rotator cuff. The ends of the second and fifth sutures previously passed through the cuff are brought out through the cannula and tied together. The knot is next shuttled into the shoulder by pulling on the opposite ends of the sutures and tied alongside the greater tuberosity to create a box stitch. The box stitch acts as a medial row fixation and as a ripstop that strengthens the four remaining sutures tied in a simple vertical mattress configuration around the box against pullout.

True Transosseous Hybrid

To address concerns of possible weak bone and issues with knot tying, a hybrid transosseous suture anchor repair technique was developed (Video 2, Figure 4). This technique may be used for those transitioning into ATO repair to maximize the advantages of both anchor-based and fully transosseous paradigms.[46] The patient position and portals are used as described above. The footprint reconstruction is planned in one step by making the medial anchor points with a graduated 2.9- to 3.5-mm awl, and the lateral aspect of the tuberosity is débrided and microfractured using the same awl for bone marrow vents. A reusable transosseous tunneling device (TransOs Tunneler, Tensor Surgical) is introduced through the anterior-inferior portal and three sutures passed into each tunnel as previously described. The two most anterior tunnels are created from the anterior-inferior portal, and the posterior tunnel is created from a posterior-inferior portal. The sutures are passed as simple sutures according to surgeon preference, with a self-retrieving antegrade passer in this case. A mattress suture between the anterior and middle tunnel is created by retrieving sutures from these tunnels and tying them extracorporeally. The inferior limbs are then used to pull the medial knots back into the joint, and the inferior limbs are then tied to create a mattress suture. The same technique is used to create a mattress between the middle and posterior tunnels, thus completing a double box. The remaining sutures are tied with simple knots. The medial tails that were left long can then be placed into two commercially available knotless anchors and positioned below the horizontal limb of the mattress suture. This construct simultaneously retensions the construct, while providing cortical augmentation, and creating a self-reinforcing triple row construct with no inert material in the healing zone.[46]

Summary

ATO-RCR adequately restores the anatomic footprint of the rotator cuff, minimizes the stress concentration of the repair, and allows vascularity to the tendon at the tuberosity. Transosseous techniques may have less postoperative pain and enhanced biological and revision considerations. Recently, economic and clinical analyses of transosseous techniques have highlighted the cost-effectiveness and equivalent healing and outcome rates. ATO-RCR obviates the need for anchors in repair and has clinical use beyond the treatment of primary rotator cuff repairs.

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