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Clinical and Functional Outcomes of Arthroscopic Rotator Cuff Repair Using the Double Pulley - Triple Row Technique

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Abstract: ***Arthroscopic rotator cuff repair is the gold standard for treatment, but current techniques have shortcomings, especially for larger tears. Single - row repairs often fail to fully restore the footprint, leading to high retear rates. Although triple - row and double - row repairs show promise, concerns regarding retear persist. Biomechanical studies favor triple - row repair for better coverage and pressure distribution. Techniques such as linked double - row and double - pulley methods enhance strength. Secondary cuff failures near the musculotendinous junction are commonly caused by stress concentration. To address these challenges, novel methods have employed linked, knotless, and bridging constructs. Our approach, the double pulley - triple row, aims to minimize retears, especially at the musculotendinous junction, and provides uniform pressure distribution, which is particularly beneficial for large tears. The surgical steps involve standard arthroscopic procedures with specific instruments. Despite these challenges, our method integrates proven techniques to optimize outcomes, promising improved results in rotator cuff repair. This study provides valuable insights into the biomechanical advantages of the double pulley - triple row technique in reducing retears and improving clinical outcomes. Given the high failure rates of existing methods, this innovative approach could enhance the long - term success of arthroscopic rotator cuff repairs. Objective: This study aims to assess the functional and clinical outcomes of arthroscopic rotator cuff repair using the double pulley - triple row technique in patients with rotator cuff tears. Methods: We prospectively evaluated 34 patients who underwent arthroscopic rotator cuff repair using the double pulley - triple row technique. Pre and post - operative assessments included Oxford shoulder score and Quick disabilities of the arm, shoulder and hand questionnaire. Results: The mean Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) score improved from 46.1 preoperatively to 15.6 at final follow - up for massive rotator cuff repairs. Along with that the Oxford Shoulder Score improved significantly (p < 0.001) from 26.9 pre - operatively to 41.4 at final follow - up for massive rotator cuff repairs.***

Keywords: Rotator cuff repair, arthroscopic surgery, double pulley technique, triple row repair, tendon healing

1. Introduction

Arthroscopic rotator cuff repair is widely acknowledged as the most efficacious approach for addressing rotator cuff injuries on a global scale. Nevertheless, a variety of repair methodologies are available, none of which can be deemed flawless. The singular - row repair technique has been found to be inadequate in fully reinstating the anatomical footprint, resulting in a notable incidence of retear. As a result, surgeons are exploring alternative devices and techniques, such as knotless anchors and double - row repair. Despite these advancements, retear rates remain notably elevated, particularly in cases of large - to - massive tears, with reported rates varying between 5% and 33%. Previous studies have suggested that the utilization of the triple - row method for rotator cuff repair leads to a markedly greater contact area and contact pressure in comparison to both the double - row and standard suture - bridge techniques. (3) A biomechanical comparison of various constructs revealed that triple - row repairs led to the formation of smaller gaps and fewer instances of tendon tearing at the sutures compared to single row or double row repairs. (4) Biomechanical research has shown that linked double - row equivalent constructs, as well as the double - pulley technique, have significantly higher load to failure and increased survivorship with cyclic loading when compared to conventional transosseous - equivalent techniques. (5) Secondary cuff failure, commonly referred to as type II cuff failure, typically occurs close to the medial knots and the musculotendinous junction (MTJ) and is thought to result from medial stress concentration, tendon strangulation, and/or suture cut - out. (6) This complication can have severe consequences, leading to a large tear with poor quality remnant tissue. (3, 6) Primary prevention serves as a strategy for tackling these retears. Innovative techniques employing linked, knotless, and bridging constructs have been developed to reduce tissue strangulation medially by enhancing force distribution. (7)

This technique integrates double - pulley and triple - row methods to minimize retears at the MTJ and ensure even pressure distribution. This method is particularly effective for treating large - to - massive tears. Thus, we introduce our innovative construct, incorporating the benefits of established techniques, with the goal of reducing retears, particularly at the MTJ, and ensuring consistent contact pressure over a broader area, which is beneficial for treating large - to - massive tears. The strength of this technique lies in the introduction of a dual approach aimed at enhancing the outcomes of arthroscopic rotator cuff repair by increasing the contact area and ensuring uniform pressure distribution.

2. Surgical Technique

The procedure involves positioning the patient laterally and utilizing standard arthroscopic portals (anterior, posterior, anterolateral, posterolateral, and lateral). A 30° arthroscope, two 8 - mm cannulas, Lasso, and suture shuttling device were utilized. Additionally, a medial anchor (4.8 mm), a middle anchor (2.8 mm), a lateral anchor (5.5mm Knotless), radiofrequency, a cannula, 2 triple - loaded 5.5 - mm screw -

in suture anchors 1 double - loaded screw - in suture anchor, and 2 5.5 - mm knotless suture anchors were used.

3. Surgical Steps

1) Diagnostic arthroscopy and subacromial decompression -
The procedure began with the patient in a lateral position. The posterior portal was used for visualization, and diagnostic arthroscopy was performed through the anterior portal. Subacromial decompression and clearance of adhesions from the anterior, posterior, and lateral gutters were carried out via a lateral portal. Acromioplasty was performed using a cutting block technique with a 5.5 - mm arthroscopic burr. Anterolateral and posterolateral working portals were established approximately 3–4 cm from the acromion. Rotator cuff mobility was evaluated and adjusted. An anterior subacromial portal was created, followed by the placement of cannulas in the anterior and lateral portals.

2) Footprint medialization and medial row anchor placement -
Using an arthroscopic drill, tuberoplasty was performed to address uneven surface and spurs as well as to provide a vascular bed for graft uptake, preserving cortical bone integrity. Two triple - loaded 5.5 - mm anchors were precisely placed adjacent to the humeral articular margin and strategically positioned at the anterior and posterior edges of the tear (Fig.1A). Microfracturing was performed around the intended footprint. The mini - lasso suture technique facilitated the passage of all anchor limbs through both the anterior and posterior margins of the medial healthy cuff tissue (Fig.1B).

3) Middle and lateral row anchor placement -
A lateral accessory portal was established adjacent to the outer edge of the acromion. A 5.5 - mm screw loaded with a suture anchor was inserted just inside the greater tuberosity and aligned with the peak of the rotator cuff tear (Fig.1C). The suture ends were threaded through the anterior and posterior cuff edges, and arthroscopic knots were tied to draw the cuff tissue towards the footprint (Fig.1D).

Double - Pulley Application
The sutures in the medial row were secured using the double - pulley method. Each suture end from the medial anchors was pulled through the lateral portal and tied as a 6 - throw surgeon knot outside the cannula (Fig.2A). The knot was then moved over the top of the tendon. Static knots were applied to prevent movement, and the second knot was tied with moderate pressure using a knot pusher (Fig.2B).

Third Row and Completion of Construct
A single strand and 1 suture limb from each anchor in the medial row were pulled through the lateral portal using a loop grasper. These strands were passed through the eyelet of a 5.5 - mm PEEK SwiveLock anchor and inserted immediately behind the bicipital groove (Fig.2C). Subsequently, the remaining sutures were retrieved and inserted to finalize the suture bridge formation (Fig.3).

Postoperative Protocol and Follow - up
Following surgery, patients were immobilized in an abduction sling for 6 weeks. Passive and active assisted range of motion exercises began progressively. At 12 weeks, the range of motion was unrestricted, and strengthening exercises were initiated. At 18 weeks postoperatively, patients were permitted to resume all activities except heavy lifting and participation in contact sports.


A B C D

Figure 1: Arthroscopic images. Thirty - degree scope viewing through the posterolateral portal showing the medial row (A), the posterolateral portal showing placement of the middle row anchor medial to the greater tuberosity (B), the lateral portal showing the passage of all medial suture anchors through the cuff tissue (C), and the lateral portal showing a reduced cuff with use of the middle row anchor (D).

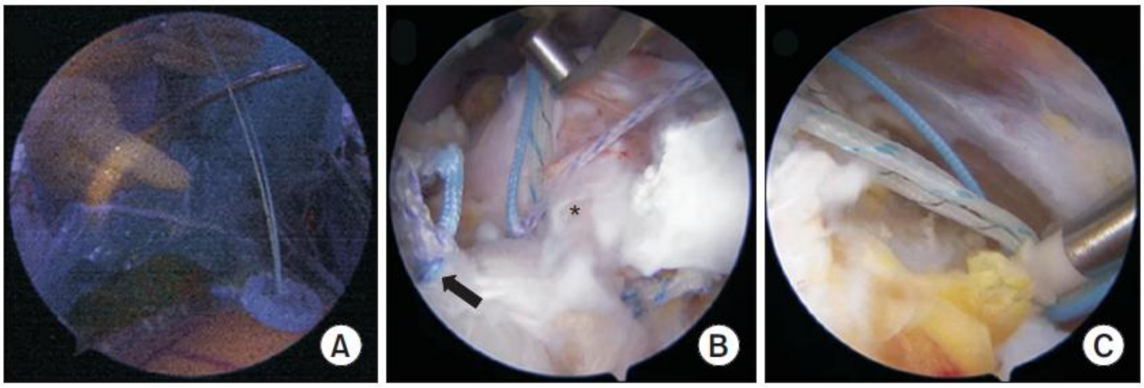

Figure 2: Arthroscopic images. (A) Extracorporealknotting over a switching stick. (B) Thirty - degree scope viewing through the lateral portal showingmedial double pulley application (black arrow, transported knot; asterisk, second knot with suture threads that will be incorporated into the lateral row). (C) Thirty - degree scope viewing through the lateral portal showing lateral row placement with 5 threads in the knotless anchor.

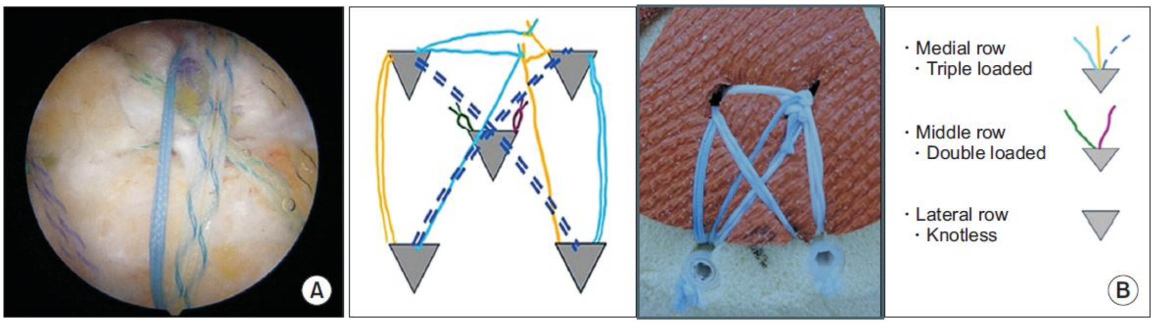

Figure 3: (A) Arthroscopic image using 30° scope viewing through the lateral portal showing the final construct. (B) Diagrammatic representation of the construct.

4. Discussion

Large - to - massive rotator cuff tears demand better construct to reduce retear. Despite the superior biomechanical properties and broader footprint restoration, double - row repair has shown failure to reduce retears. (8) In the arthroscopic transosseous equivalent technique, also referred to as the suture - bridge technique. (9, 10) following knotting of the medial row, the suture ends are crossed over the cuff tissue and secured to screws positioned 1 cm lateral to the lateral edge of the greater tuberosity. This configuration compresses the tissue between the screws and anatomical footprint, thereby preventing penetration and strangulation of the lateral cuff tissue by the knots, consequently preserving tendon vascularity. (8) The MTJ has been identified as the primary failure point for both double - row and TOE repairs. Thus, it is essential to position the medial row sutures lateral to the MTJ and avoid overstretching of the medial row. (9, 11) To address these concerns, modifications have been made to the TOE technique, which involves completely knotless approaches. Wider surface sutures were loaded onto the medial row anchors and passed through the tendon without knot tying. These sutures are then crossed over or fixed to lateral row knotless anchors. This technique, being technically simpler and faster due to the absence of knots, mitigates the risk of tendon strangulation at the medial row and reduces the elevated suture tendon surface pressure that could compromise the healing process. (7 - 9) Our technique employs a modified triple - row configuration featuring an additional anchor row situated between the customary medial and lateral rows of the suture bridge assembly. This supplementary row facilitates the anatomical alignment of cuff tissue within the footprint before securing the medial row anchor, thereby enhancing the footprint contact area and pressure distribution. (10) Previous biomechanical investigations have underscored the efficacy of incorporating linked medial anchors in rotator cuff repair. (5, 12) Consequently, we adopted the principles of the double - pulley technique to secure the medial row of our construct, wherein the medial knot was drawn down over the cuff using the eyelets of 2 medial suture anchors as pulleys. Ultimately, this method culminates in the compression of a cuff tissue bridge against the bone bed, establishing a robust construct within the medial aspect of the footprint. (12) The double pulley - triple row technique for arthroscopic rotator cuff repair introduces several significant advancements compared to existing methods, particularly the standard double - pulley and triple - row techniques.

This technical approach includes a modified triple - row configuration that incorporates an additional anchor row between the medial and lateral rows of the suture bridge assembly. This modification enhances the anatomical alignment of the cuff tissue within the footprint before securing the medial row anchor, leading to a more substantial footprint contact area and improved pressure distribution. (8, 11 - 13) Unlike conventional techniques, this method mitigates the risk of medial tissue bunching, which is a common complication of suture bridge techniques. (11, 13) Integration of the double - pulley mechanism ensures robust medial fixation while preserving tendon vascularity by minimizing tissue strangulation and ensuring consistent contact pressure across the footprint. Additionally, this technique simplifies the repair process by passing the medial row suture limbs through a single point in the rotator cuff, reducing the need for multiple tissue bites and medial knots, which can compromise vascularity. (9) These differences collectively enhance mechanical stability, promote better tissue healing, and reduce complications, such as secondary cuff failures and tendon necrosis, making this technique particularly beneficial for large - to - massive rotator cuff tears.

Advantages
1) Relatively easy and reproducible for arthroscopy surgeries.
2) The technique can also be used for primary and revision cases.
3) Less tissue bites and no tissue strangulation
4) Tension - free repair with biologically and biomechanically superior construct
5) More contact area and even pressure distribution
6) Augmentation with biceps/patch possible
7) No additional portals are required.

Pitfalls
1) Technically demanding for surgeons who are not trained in the regular cuff repair
2) Not suitable for anterior - based tears
3) More time consuming and an extra anchor compared to suture bridge
4) Only the rotator cuff that can be mobilised fully to footprint can provide optimum results.
5) Osteoporosis can compromise anchor placement.

Pearls
1) Adequate visualization by subacromial decompression and clearance of anterior, posterior, and lateral gutter are essential for performing the technique.
2) Adequate mobilisation of rotator cuff should be achieved.
3) The tear pattern must be correctly identified so that the middle - row anchor is placed in a position that allows for anatomic reduction.
4) Double pulley should be applied with controlled pressure to avoid strangulation of healthy cuff tissue.
5) Medial row knot should be small to prevent knot irritation.

5. Conclusion

The double pulley - triple row technique shows promise in improving clinical outcomes for arthroscopic rotator cuff repair, particularly in large - to - massive tears, by addressing some of the limitations found in single row, double - row, and standard triple - row techniques. (11, 13) Unlike single row repairs, which often fail to fully restore the anatomical footprint leading to high retear rates, the double pulley - triple row technique provides a significantly larger footprint contact area and more uniform pressure distribution, which are crucial for promoting tendon - to bone healing and reducing retears. (4, 9, 11, 12) This method also outperforms double - row repairs by enhancing the medial fixation strength and maintaining the vascularity of the tendon, which are vital for preventing secondary cuff failures often observed near the MTJ owing to stress concentration and tissue strangulation. (6) Compared with standard triple - row techniques, this novel approach introduces an additional anchor row between the medial and lateral rows, further optimizing anatomical alignment and minimizing the risk of medial tissue bunching, which can compromise repair integrity. (4, 6) Clinical studies have demonstrated that the biomechanical advantages of the double pulley - triple row technique translate into lower retear rates, improved functional outcomes, and greater patient satisfaction. (4, 10) For instance, patients undergoing this technique have shown better shoulder strength, range of motion, and overall shoulder function than those treated with conventional methods. The outcomes suggest (unpublished data) that the double pulley - triple row technique not only enhances the mechanical stability of the repair, but also supports better biological healing processes, making it a superior option for treating complex rotator cuff injuries. This double pulley - triple row repair technique combines the strengths of 2 established biomechanical methods. (3 - 5, 9, 10) The double pulley aspect ensures robust medial fixation while preserving tendon vascularity, whereas the triple row sutures enhance the contact area and distribute compression pressure evenly across the footprint. This suture bridging not only distributes the load across fixation points but also prevents synovial fluid from interfering with tendon - to - bone healing. This method helps by passing the medial row suture limbs from both anchors through a single point in the rotator cuff, eliminating the need for multiple tissue bites and medial knots that can compromise vascularity. Although there is a theoretical risk of irritation from the 6 - throw surgeon's knot in the subacromial space, we have not encountered this issue (Table 1).

Additionally, while our technique may incur higher costs owing to the use of extra anchors, it is justified by its aim to restore the anatomical footprint of the rotator cuff. The double pulley - triple row technique for arthroscopic rotator cuff repair introduces several innovative modifications that improve upon existing methods. It features a modified triple - row configuration with an additional anchor row between the medial and lateral rows, enhancing anatomical alignment and uniform pressure distribution. This method for securing sutures further optimizes tendon vascularity and stability, creating a sealed environment conducive to tendon - to - bone healing. These advancements aim to improve mechanical stability, tissue healing, and reduce complications compared to current techniques. The double pulley - triple row technique for arthroscopic rotator cuff repair distributes pressure uniformly over a larger contact area, thus mitigating tissue strangulation and necrosis. This method enables smooth repair and incorporates superior biomechanically validated elements. While these factors suggest potential advantages over previous methods, particularly in large to - massive rotator cuff tears, further studies are required to definitively establish its superiority. These findings suggest that this method may improve patient outcomes and should be considered as a viable alternative for large rotator cuff tear repairs in clinical practice.

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