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Original Article

Biomechanical comparison of conventional double-row repair versus double row repair with the parachute configuration

Comparación biomecánica de la reparación convencional de doble fila frente a la reparación de doble fila con la configuración del paracaídas

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ABSTRACT. Introduction: The rotator cuff tears are a very frequent condition. The rotator cuff repair is a procedure often perform by the orthopedic surgeon. There are multiple techniques and suture configurations for this type of repairs. The double row configuration is one of the most used and consider very effective for mid-size and large size rotator cuff tears. The parachute configuration for this repair is a novel technique that may be useful for mid-size and large size tears, for this repair two medial double row anchors are used and one knotless lateral anchor. Our porpoise was to compare biomechanical performance and footprint coverage of a conventional suture-bridge double-row rotator cuff repair configuration versus a double-row-parachute. **Methods:** This paper shows the biomechanical behavior on a cadaver model of the parachute configuration, and also compares this conformation with a double row in a suture-bridge fashion. Our hipothesis was that the Parachute configuration's biomechanical performance is equivalent to the suture-bridging double-row technique. **Results:** The parachute configuration advantages show the advantage of using less anchors, which will decrease the surgical time and also the risks of using multiple hardware in the humeral head.

Keywords: Rotator cuff, repair, configuration, cadaver, test.

RESUMEN. Introducción: La lesión del manguito rotador es una patología común cuya reparación es un procedimiento realizado por los cirujanos ortopedistas. Existen muchas técnicas de reparación, así como múltiples configuraciones de anclas y suturas para realizar estos procedimientos. La técnica de doble fila es una de las más usadas para rupturas de tamaño mediano y grande con buenos resultados. La configuración en «paracaídas» para la reparación del manguito rotador puede llegar a ser útil para éstas, en este tipo de configuración se utilizan dos anclas mediales y un ancla sin nudos lateral. Nuestro objetivo fue la comparación de la eficiencia biomecánica y cobertura de la huella de una configuración convencional de doble fila «*suture bridge*» frente a una configuración en «paracaídas». **Métodos:** Este trabajo revisó el comportamiento biomecánico, en piezas cadavéricas, de la configuración de paracaídas y se comparó con la configuración de doble fila tipo «suture-bridge». Nuestra hipótesis era que el rendimiento biomecánico de la configuración de Parachute es equivalente a la técnica de doble fila «*suture bridge*». **Resultados:** Las posibles ventajas de la configuración de paracaídas son el uso de menos anclas, disminuyendo el tiempo quirúrgico y los riesgos de tener múltiples implantes en la cabeza humeral.

Palabras clave: Manguito rotador, reparación, configuración, cadáver, prueba.

Level of evidence: III

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Introduction

Purpose: to compare biomechanical performance and footprint coverage of a conventional suture- bridge double-row rotator cuff repair technique versus a double-row-parachute technique.

Arthroscopic rotator cuff repair is a common arthroscopic shoulder procedure. The use of a suture-bridge double-row technique for large and medium size rotator cuff tears has proven to be very effective. A modified anchor and suture configuration described as a parachute by Lorbach et al.[1] may provide equivalent biomechanical performance with lower procedure costs. This modified double row technique uses two medial anchors and one lateral anchor eliminating the need and extra cost of a second lateral anchor.

It is been shown that the biomechanical performance of a double row and a single row construct are similar.[2] However, larger tears may require a double row repair to protect the footprint and maximize footprint coverage.

In this parachute configuration, the specific type of anchor used for the medial row is important. We believe that a triple loaded suture anchor will be the best bet. We can also consider all suture medial anchors and bio anchors for the lateral row. No similar studies of this specific technique for complete rotator cuff tears were found.

Methods

Hypothesis: the Parachute technique´s biomechanical performance is equivalent to the suture-bridging double-row technique.

Nine human cadaver supraspinatus tendons from 9 donor shoulders were harvested and prior to mechanical testing, after all other soft tissue was removed, the width (anterior-posterior) and the thickness (inferior-superior) were measured using digital calipers (Mitutoyo America Corp., Aurora, IL). Measurements were also made of the lateral edge of the musculotendinous junction. Each free supraspinatus tendon was attached to a flower dome cortical sawbones model which simulates the humeral head rotator cuff tendon footprint using polyurethane foam material (20 lbf/ft^3 density) (Pacific Research, Vashon Island, WA). These 9 supraspinatus tendons were divided into 3 equal groups. Group 1 (control): a conventional suture-bridging double-row repair with FiberTape and Biocomposite SwiveLock anchors (Arthrex, Naples) Group 2 (knotted parachute): two medial 5.5 mm Corkscrew FT anchors (Arthrex, Naples) with #2 knotted FiberWire sutures and the 4 suture ends fixed laterally in one 4.75 mm SwiveLock anchor. Group 3 (all-suture anchor knotless parachute): two medial 1.3 FiberTak (Arthrex, Naples) all-suture anchors with the 4 suture tapes (2 mm) passed through the supraspinatus tendon and fixed in one lateral 4.75 mm SwiveLock anchor without medial knot tying.

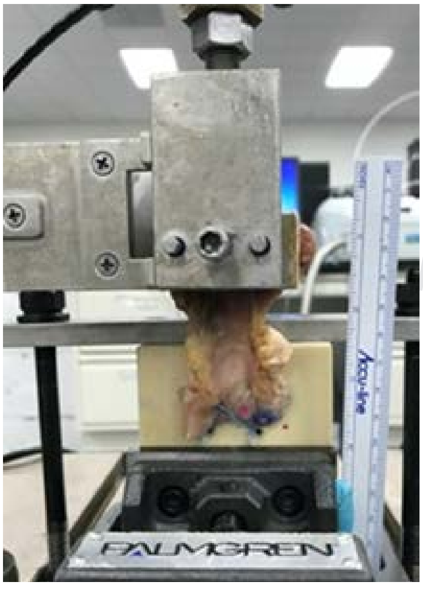

Figure 1:

Control group configuration.

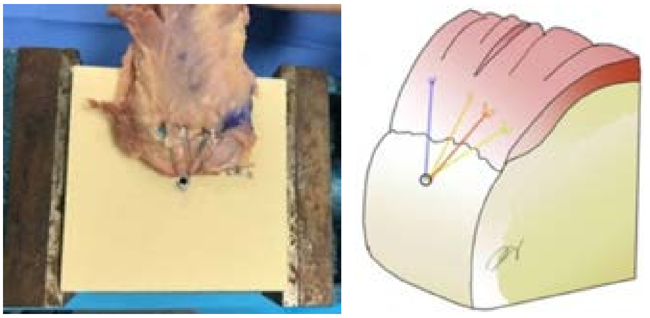

Figure 2: Group 2 double-row parachute repair.

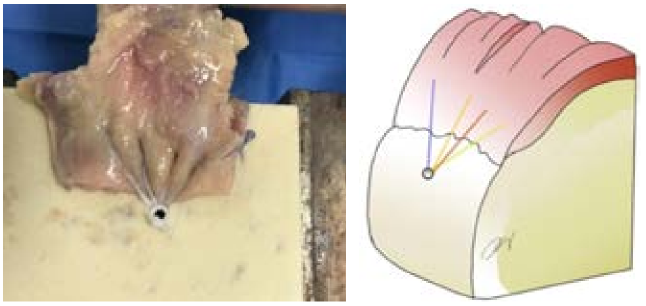

Figure 3: Group 3 double-row parachute without medial knot tying.

The group 1 (control) suture-bridging double-row repair used ultra-high molecular weight polyethylene (UHMWPE) containing suture plus UHMWPE containing 2 mm wide tape in a bridging technique (modified SpeedBridge) that employed four 5.5 mm Biocomposite SwiveLock anchors (Arthrex, Naples FL). A medial row of two biocomposite anchors approximately 2 cm apart were inserted into the footprint equivalent of the flowerdome model. Two strands of 2 mm wide UHMWPE containing tape (FiberTape, Arthrex, Naples FL) from each anchor were passed through the tissue medial to the mattress stitch. A similar construct was previously investigated (2;3). One tape strand from each medial anchor was threaded into one of the two lateral biocomposite anchors so that both lateral anchors received a single tape from each medial anchor in a crossing suture-bridge pattern. The lateral row knotless anchors were inserted at an orthogonal angle creating a transosseous equivalent (TOE) repair and a crossing suture pattern over the material *(Figure 1)*.

The group 2 double-row parachute repair used 2 medial row 5.5 mm Corkscrew FT anchors placed approximately 2 cm apart. The 8 no. 2 UHMWPE containing sutures from each anchor were passed through the supraspinatus tendon using a vertical mattress pattern. Each mattress stitch was then tied into a knot and one suture strand cut. The 4 remaining suture strands (2 strands from each anchor) were passed into a single lateral 5.5 mm Biocompsite SwiveLock anchor creating the parachute configuration *(Figure 2)*.

The group 3 double-row parachute was created using two medial all-suture 1.3 FiberTak anchors with a UHMWPE flat braided suturetape. This includes polyester and/or nylon. The 4 sutures were passed thru the supraspinatus tendon in a vertical mattress pattern and fixed laterally in one 4.75 mm SwiveLock anchor without medial knot tying *(Figure 3)*.

Mechanical testing was performed using a servohydraulic materials testing machine (Model 8871, Instron Corp., Norwood, MA), with a 5kN load cell. A custom interdigitizing freeze clamp and dry ice were used to freeze the proximal ends of the supraspinatus to the actuator. A vise fixture and horizontal plate held the foam block securely to the testing surface. The direction of pull was directly in line with the tendon (medially directed load).

Samples were cyclically loaded between 10 and 100N for 200 cycles at 1Hz, in a sinusoindal waveform. Following cyclic loading, a single cycle pull to failure was performed at 33 mm/sec. Load and displacement data were recorded at 1,000 Hz. Additionally, digital video recordings were used to capture the displacement of the tendon relative to the foam block during cyclic loading.

The load-displacement curve for each sample was used to determine the ultimate load and stiffness (determined from the linear portion of the curve just after cyclic loading). Cyclic displacement was determined using MaxTRAQ software (Innovision Systems, Inc., Columbiaville, MI). Study endpoints were ultimate load, stiffness, repair displacement (difference between 100 and 200 cycles), and mode of failure for each sample.

Table 1: Group 1: SpeedBridge samples.

Sample	Ultimate load (N)	Stiffness (N/mm)	Cyclic disp. (mm)	Mode of failure
1	293	64.4	5.58	Tendon tore at FiberTape
2	557	92.1	3.65	Tendon tore at FiberTape
3	479	94.7	1.83	Tendon tore at FiberTape
Average	443	83.7	3.69	
St Dev	136	16.8	1.88	

Table 2: Group 2: knotted parachute.

Sample	Ultimate load (N)	Stiffness (N/mm)	Cyclic disp. (mm)	Mode of failure
1	758	120.4	2.57	Foam block broke
2	614	71.5	1.45	Tendon tore at FiberWire
3	590	66.5	2.57	Foam block broke
Average	654	86.1	2.20	
St Dev	91	29.8	0.65	

Table 3: Knotless parachute.

Sample	Ultimate load (N)	Stiffness (N/mm)	Cyclic disp. (mm)	Mode of failure
1	324	64.3	4.19	Lateral anchor pullout
2	443	90.1	3.61	Lateral anchor pullout
3	393	72.8	3.60	Lateral anchor pullout
Average	387	75.7	3.80	
St Dev.	60	13.1	0.34	

Statistical analysis: ANOVA analysis t-tests ($\alpha = 0.05$) were used to compare the thickness and width measurements. the stiffness, cyclic displacement and ultimate load values.

Results

Group 1 (control) supraspinatus tendons demonstrated an average width of 39.07 mm ± 0.58 and a tendon thickness of 6.41 mm ± 0.33. Group 2 (parachute with medial knots) supraspinatus tendons averaged 38.8 mm ± 2.1 in width and 6.63 mm ± 1 in thickness. Group 3 (parachute without medial knots) supraspinatus tendons averaged 36.5 mm ± 5 wide and 4.37 mm ± 0.3 thick. Group 2 (parachute with medial knots) had a statistically significant difference in tendon thickness and width ($p = 0.009$). The ultimate load, stiffness, cyclic displacement, and mode of failure is reported in *Table 1 to 3*.

The knotted parachute (group 3) showed statistically more ultimate strength than the other two groups $p = 0.03$. No statistically significant difference in stiffness or cyclic displacement existed between groups ($p > 0.5$).

Discussion

The knotted parachute repair had greater ultimate failure strength (654N) than the knotless parachute (387N) or the conventional double row repair (443N) ($p = 0.03$). However, no statistically significant difference in stiffness or cyclic displacement could be demonstrated.

This study found biomechanical performance similarities between the double-row and the knotless parachute configuration, much like the study of (Barber and Drew 2012).

The knotless parachute configuration showed an inferior behavior compared with the other two groups. This data supports the hypothesis that the knotted parachute configuration provides sufficient strength for a rotator cuff repair and is at least as strong as the standard double-row suture-bridging repair.[3]

Jost et al.[4] demonstrated in an ovine infraspinatus tendon model that increasing the number of sutures from 2 to 4 to 6 decreased cyclic gap formation and increased load to failure. Most importantly they pointed out that both single-row and double-row repairs are biomechanically equivalent when the number of sutures are the same. This suggests that it is not the number of anchors in a double row repair that is important, but the number of sutures in the tendon.

Lorbach et al.[1] compared the biomechanical effectiveness of single-row versus double-row repairs using human supraspinatus tendons with either 25 mm or 35 mm tears. No statistical differences in ultimate load to failure strength was shown. Also, cyclic displacement was not different between repair types for the 25 mm tears, but in the 35 mm tears the single-row repairs showed statistically less cyclic displacement at the higher loads than the double-row repairs. This study used modified suture configurations in the triple loaded single row sutures to provide more effective footprint coverage and added strength which outperformed the double row repairs.

These two studies explain why the knotted parachute was stronger than the knotless parachute and no different from the conventional double row repair. These sutures are key. The knotless double row had only 4 sutures passing through the tendon. As Jost et al.[4] showed, having half as many sutures securing the tendon will result in a significantly weaker construct.

Furthermore, it did not matter that only 4 strands came from the 4 medial knotted sutures to the lateral anchor. It seems that the main purpose of the lateral anchor or anchors is to hold the tendon lateral to the knotted sutures in contact with the footprint for healing to occur. It has been reported that the medial row of a double row repair contributes about two-thirds of the repair strength.[5] Whether one of two anchors is used laterally to supplement the medial row probably does not provide a clinically significant biomechanical advantage.[6,7] Using the parachute technique will not only shorten the surgical time but will reduce costs without compromising the repair strength.

If we compare our parachute configuration with Natera paper[8] configuration, our parachute using 3 anchors will be useful for bigger tears. While Natera uses 1 anchor for small size tears or PASTA tears. What is important to understand is that the suture positioning and configuration is what is going to give enough support for the repair. Form the cost point of view. This configuration model can also show a cost difference due to a lateral anchor spare.[9] If the parachute shows a similar behavior on the biomechanical tests to the double row, we may be facing a cost effective technique for rotator cuff tears.

Study limitations include the small sample sizes, limited number of different test configurations, and the use of polyurethane foam instead of a biologic substrate. This was a biomechanical bench test performed at room temperature in a non-aqueous environment. A direct comparison to a clinical environment cannot be made.

Conclusions

A knotted parachute repair had greater ultimate failure strength (654N) than a knotless parachute (387N) using all-suture anchors or a conventional double row repair (443N) ($p = 0.03$). No statistically significant difference in stiffness or cyclic displacement was demonstrated in this lab design.

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