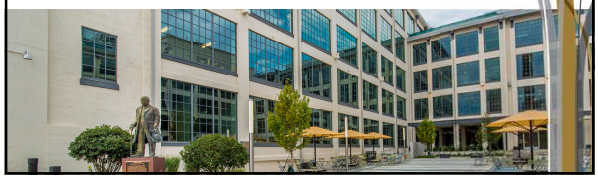
Wake Forest School of Medicine

Rotator Cuff Repair: Maximize Biomechanics!

Brian R. Waterman, MD
Associate Professor, Wake Forest Baptist Health
Team Physician, Wake Forest University & Winston-Salem Dash
Winston-Salem, NC



Disclosures

I (and/or my co-authors) have something to disclose.

Detailed disclosure information is available via:

Printed Final Program

Meeting App

or

AAOS Orthopaedic Disclosure Program on the AAOS website at

http://www.aaos.org/disclosure

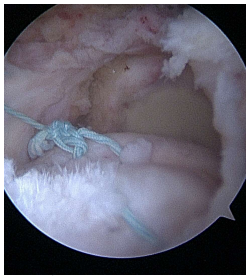
Acknowledgements: Brian Cole, Nikhil Verma, Anthony Romeo, Gus Mazzocca, Stephen Burkhart, Alan Barber

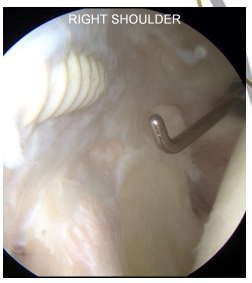
What happens after they are repaired?

- Structural failure rates after attempt of repair have been reported to range from 20-94%

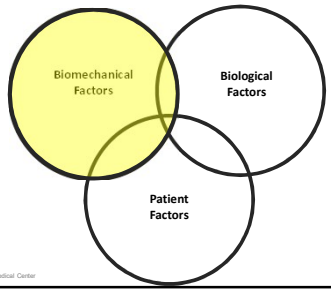
Audenaert E, *KSSTA*. 2006
Derwin KA et al. *J Shoulder Elbow Surg*. 2010.
Galatz LM et al. *J Bone Joint Surg Am*. 2004.
Harryman et al. *J Bone Joint Surg Am*. 1991.
Liu SH et al. *Arthroscopy*. 1994.

Failed Rotator Cuff Repair: The Aftermath





Pathogenesis of Rotator Cuff Disease



Goals of Rotator Cuff Repair

•Ideal rotator cuff repair will:

- Have high initial fixation strength
- Permit minimal gap formation
- Sustain mechanical stability

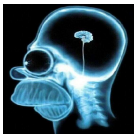
....until healing has occurred!

Gerber, JBJS B, 1994

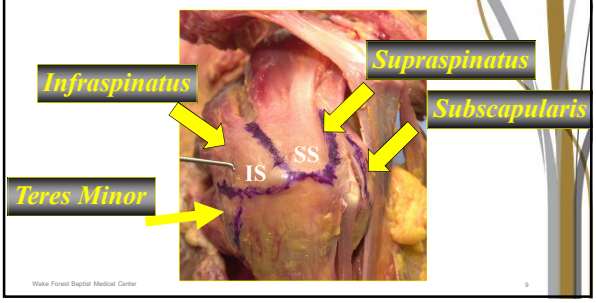
Roadmap to Optimized RCR Biomechanics

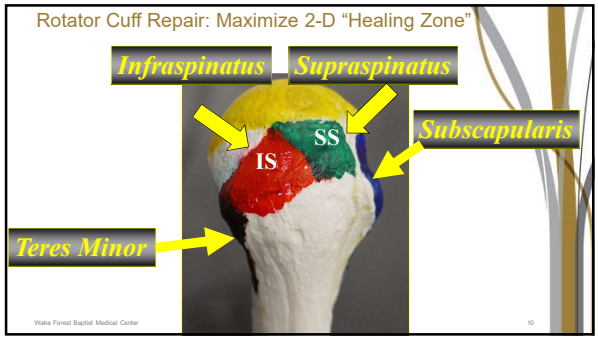
Optimized Biomechanics: Variables

- Footprint Anatomy
- Tear / Tendon
  - Pattern
  - Tissue Quality
  - Tension
  - Force Couples
- Tuberosity
  - Preparation
  - Bone Quality
  - Medialization
- Repair
  - Construct
  - Configuration
- Suture
  - Composition
  - Loop Configuration
  - Tension
  - Position
- Anchor
  - Angle of Insertion
  - Composition



Rotator Cuff Anatomy: Footprints & "Fault Lines"




Rotator Cuff Repair: Maximize 2-D "Healing Zone"
Infraspinatus
Supraspinatus
Subscapularis
Teres Minor
SS
IS
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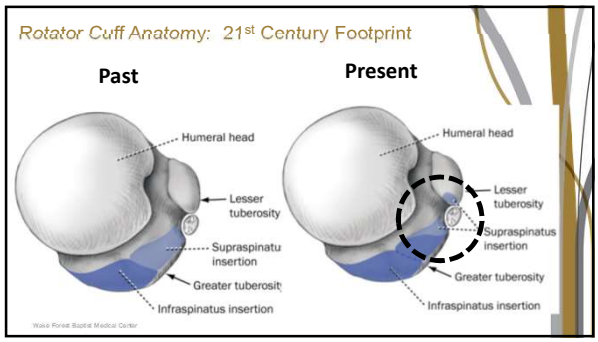
Rotator Cuff Anatomy: 21st Century Footprint
Past
Present
Humeral head
Lesser tuberosity
Supraspinatu insertion
Greater tuberosit
Infraspinatus insertion
Humeral head
Lesser tuberosity
Supraspinatus insertion
Greater tuberosity
Infraspinatus insertion
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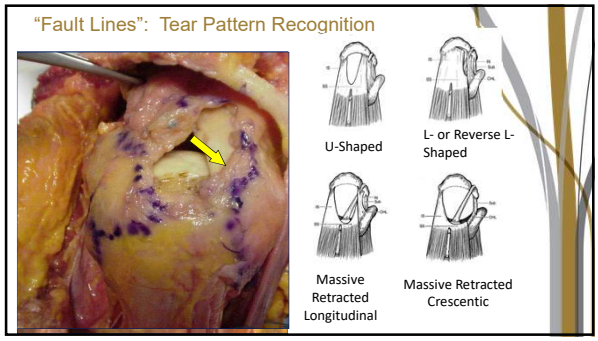

"Fault Lines": Tear Pattern Recognition
U-Shaped
L- or Reverse L-Shaped
Massive Retracted Longitudinal
Massive Retracted Crescentic

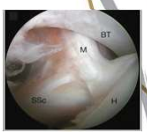
Tear Pattern Recognition

Recognize Subscapularis Pathology

- "The eye does not see what the mind does not know." –DH Lawrence
- Maintain "comma tissue" (i.e. SGHL, inf. CHL)

Lo & Burkhart. *Arthroscopy.* 2003.

- Reduces Leading Edge of Supraspinatus
- Load Sharing



Mechanical ⇨ Biological

- Suture strength
- Multiple Sutures
- Suture configuration
- Suture anchors
- ***Double Row Fixation***

- Prepare bone footprint
- Acromioplasty?
- Biologic Adjuncts?

Anatomic Repair
Margin Convergence
Interval Slides

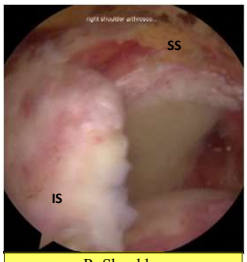
Evaluation of Repair Tension in Arthroscopic Rotator Cuff Repair

Does It Really Matter to the Integrity of the Rotator Cuff?

Do Hoon Kim,* MD, Young Hoon Jang,* MD, Young Eun Choi,* BS, Hwa-Ryeong Lee,* DPT, and Sae Hoon Kim,*† MD, PhD

- **Repair Tension** significantly correlated with:
  - Tear Size (p<0.001)
  - Tear Retraction (p<0.001)
  - Fatty Degeneration IS/SS (p<0.001)
- **Healing Failure**
  - Significant inverse correlation with **repair tension** (p=0.025)
  - Healed vs. Non-Healed (26.5 N vs. 37.2 N; p=0.040)

Traditional Capsular Releases



R. Shoulder
Beach Chair Position

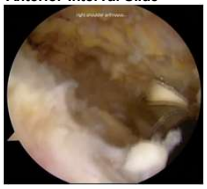
Scapular Spine

Superior Labral Recess

Interval Slides

Posterior Interval Slide

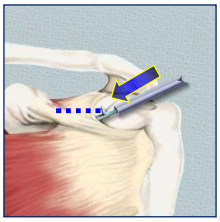
Anterior Interval Slide



*At Risk:
Suprascapular Nerve

Coracohumeral release

- Interval Release in Continuity
- Anterosuperior Tears of Subscapularis & Supraspinatus
- Achieves up to 5-10 mm increased excursion
- Preserves Laterally-based Comma Tissue



Tauro JC. *Arthroscopy.* 1999.
Lo & Burkhart. *Arthroscopy.* 2004.

Footprint Medialization

- Subscapularis
  - 4-7 mm acceptable
- Supraspinatus
  - Up to 10 mm acceptable
- Infraspinatus
  - Unknown

Medialization of the Subscapularis Footprint Does Not Affect Functional Outcome of Arthroscopic Repair

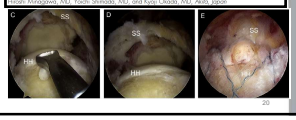
Patrick J. Denard, M.D., and Stephen S. Burkhart, M.D.

Medialized repair for retracted rotator cuff tears

Young-Kyu Kim, MD, PhD[a], Kyu-Hak Jung, MD[b,*], Jun-Sung Won, MD[c], Seung-Hyun Cho, MD[d]

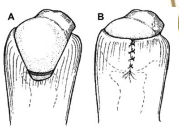
Glenohumeral joint motion after medial shift of the attachment site of the supraspinatus tendon: A cadaveric study

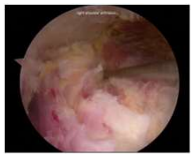
Nobuyuki Yamamoto, MD, Eiji Itoi, MD, Yilhamu Tuoheti, MD, Nobukazu Seki, MD, Hidekazu Abe, MD, Hisashi Minagawa, MD, Yoichi Shimada, MD, and Kunji Okada, MD, Akita, Japan



Margin Convergence

- Typically indicated for advanced L- or U-shaped tears
- Avoids tension overload at the tear apex and free edge strain
- Achieves head coverage



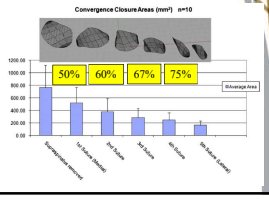


Margin Convergence

- Strain
- Gap Formation
- Surface Area for Repair

Biomechanical Evaluation of Margin Convergence

Augustus D. Mazzocca, M.S., M.D., Matthew Bollier, M.D., Drew Felsenfeld, M.D., Anthony Romeo, M.D., Kelly Stephens, B.S., Olga Solovyova, B.S., Elitho Obopilwe, M.S., Angelo Ciminiello, M.D., Michael D. Nowak, D.Sc., and Robert Arciero, M.D.



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Partial Repair

- "Functional Rotator Cuff Tears"
- Restore Force Couple
- Reinstate Cable System for Force Transmission

Partial Repair of Irreparable Rotator Cuff Tears

Stephen S. Burkhart, M.D., Wesley M. Nottage, M.D., Darrell J. Ogilvie-Harris, M.D., Harvey S. Kohn, M.D., and Anthony Pachelli, M.D.

Partial repair of irreparable supraspinatus tendon tears: clinical and radiographic evaluations at long-term follow-up

Giuseppe Porcellini, MD*,•, Alessandro Castagna, MD§, Eugenio Cesari, MD‖, Giovanni Merolla, MD‖, Andrea Pellegrini, MD‖, Paolo Paladini, MD‖

Isolated Subscapularis Repair in Irreparable Posterosuperior Massive Rotator Cuff Tears Involving the Subscapularis Tendon

Sung-Jae Kim,* MD, PhD, Yun-Rak Choi,* MD, PhD, Min Jung,* MD, Won-Yong Lee,* MD, and Yong-Min Chun,†‡ MD, PhD

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Repair Configurations

Arthroscopic Rotator Cuff Repairs:
An Anatomic and Biomechanical Rationale for Different Suture-Anchor Repair Configurations

Brian J. Cole, M.D., Neal S. ElAttrache, M.D., and Ammar Anbari, M.D.

Single Row
- UTS 275N-300N
- No footprint
- Gap formation

Double Row
- UTS 300-350 N
- Better footprint
- Reduced "gap formation"

TOE w/ Anchors
- UTS 350-400 N
- Best footprint
- Least "gap formation"
- Resistance to shear

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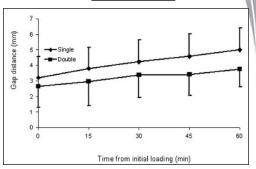
Repair Strength: SR vs. DR

A Biomechanical Comparison of Single and Double-Row Fixation in Arthroscopic Rotator Cuff Repair

DR repair
- less gap formation ($p<0.05$)
- trend towards higher load to failure under cyclic conditions ($p=0.058$)

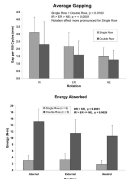


Repair Strength: SR vs. DR

Biomechanical Performance of Rotator Cuff Repairs With Humeral Rotation

A New Rotator Cuff Repair Failure Model

- Double Row Repairs
  - Less gapping at repair site
  - Greater energy required to reach failure of repair



Repair Strength: SR vs. DR

Biomechanical Evaluation of Arthroscopic Rotator Cuff Repairs: Double-Row Compared with Single-Row Fixation

- Double Row Repair
  - Higher ultimate tensile strength
  - Lower peak to elongation (difference in displacement between 1st and 5th cycles of cyclic loading)
  - No difference in stiffness

Repair Strength: SR vs. DR

Single versus double-row repair of the rotator cuff

Does double-row repair with improved anatomical and biomechanical characteristics lead to better clinical outcome?

Stephan Pauly · Christian Gerhardt · Jianhai Chen · Markus Scheibel

- Tendon to bone contact area is 60% greater with DR techniques
- Improvement in contact pressures with DR repair
- Less gap formation, higher initial fixation strength, and increased number of cycles to failure with DR techniques

Repair Strength: SR vs. DR

Conclusion: Compared with single row repairs, biomechanical studies support **double row repair** as the **stronger constructs** with **more anatomic restoration** of the rotator cuff footprint.

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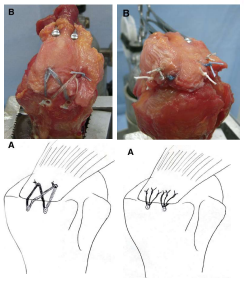
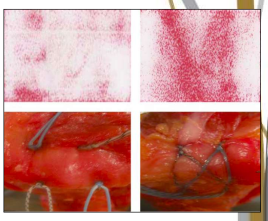


Repair Strength: DR vs. TOE

Part I: Footprint contact characteristics for a transosseous-equivalent rotator cuff repair technique compared with a double-row repair technique

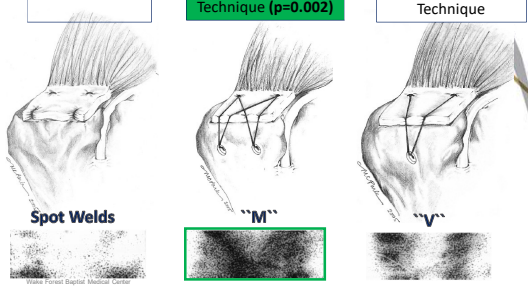
Maxwell C. Park, MD,* Neal S. ElAttrache, MD,* James E. Tibone, MD,* Christopher S. Ahmad, MD,† Rongbo Jun, MS,‡§ and Thay Q. Lee, PhD‡§ *Los Angeles, Long Beach, and Irvine, CA, and New York, NY*

- Higher contact pressures achieved with TOE technique compared with standard double row technique with suture anchors



Double Row | TOE

Double Row | 4 Suture-bridge Technique **(p=0.002)** | 2 Suture-bridge Technique



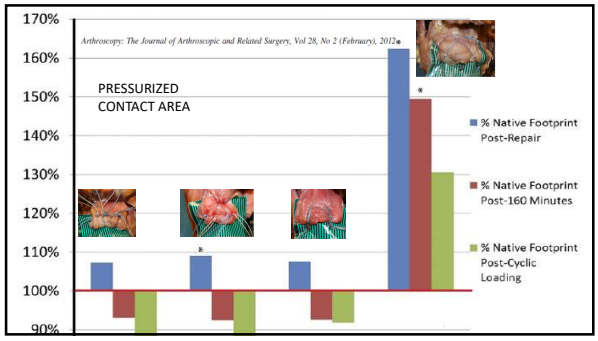
Repair Strength: DR vs. TOE

Part II: Biomechanical assessment for a footprint-restoring transosseous-equivalent rotator cuff repair technique compared with a double-row repair technique

Maxwell C. Park, MD,* James E. Tibone, MD,* Neal S. ElAttrache, MD,* Christopher S. Ahmad, MD,† Rongbo Jun, MS,‡§ and Thay Q. Lee, PhD‡§ *Los Angeles, Long Beach, and Irvine, CA, and New York, NY*

- TOE repair had greater ultimate load to failure ($p<0.05$)
- No difference in gap formation or stiffness of the constructs

	Double-row repair	Transosseous-equivalent repair	*P* value
Initial stiffness (N/mm)	33.8 ± 15.8	47.5 ± 31.1	.274
Linear stiffness (N/mm)	69.6 ± 16.8	69.1 ± 15.2	.777
Yield load (N)	214.3 ± 31.1	260.3 ± 69.5	.196
Ultimate load (N)	299.2 ± 52.5	443.0 ± 87.8	.029
Energy absorbed (N-mm)	1190.5 ± 291.1	3210.8 ± 1055.7	.008
Gap at yield (mm)	1.81 ± 0.57	2.37 ± 1.27	.451
Gap at ultimate (mm)	3.47 ± 0.78	5.88 ± 3.42	.150



Repair Strength: DR vs. TOE

Conclusion: Biomechanical studies suggest that TOE repairs result in in stronger constructs with higher load to failure and more resistance to shear and rotational stress.

TOE repair also results in more anatomic restoration of the rotator cuff footprint, as well as, a higher pressurized contact area compared with single row repairs

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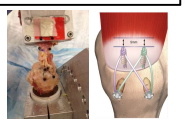
Suture Position

Biomechanical Properties and Suture Placement Relative to the Musculotendinous Junction for Arthroscopic Rotator Cuff Repair Utilizing Transosseous Equivalent Techniques

Virk MS, Bruce B, Hussey K, Luthringer T, Shewman EP, Wang VM, Verma NN, Romeo AA, Cole BJ

- **TOE Repair of RCT in Cadaver**
- **Medial Row at MTJ vs 1 cm Lateral to MTJ**



Higher failure rate during cyclic testing for TOE when medial row placed at MTJ

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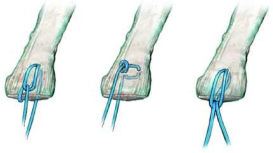
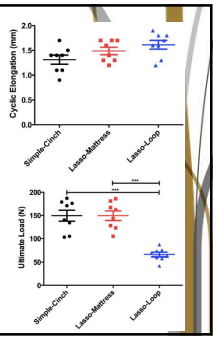
Suture Configuration

- Self Grasping Stitches
  - Independent point of fixation
  - Significantly higher load to failure
  - Address margins / "dog ears"

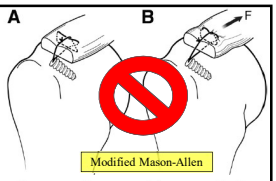


Liodakis et al. *AOTS*. 2016.

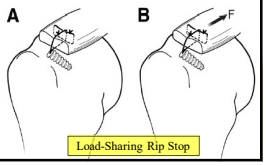


Suture Configuration

- Load-sharing Rip Stop Suture
  - 1st: Horizontal mattress
  - 2nd: Simple sutures medial to rip stop
  - 3rd: Mattress tied / fixed
  - 4th: Sutures tied
- Vs. Modified Mason-Allen
  - Comparable load to failure
  - Less self-cinching with cyclic loading
  - Better loop security



Modified Mason-Allen



Load-Sharing Rip Stop

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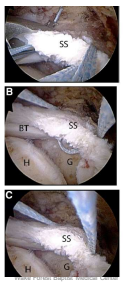
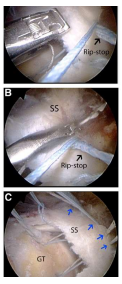
Suture Configuration





- Ideal for poor tendon quality
- Less suture cut-out
- Facilitates multiple points of fixation

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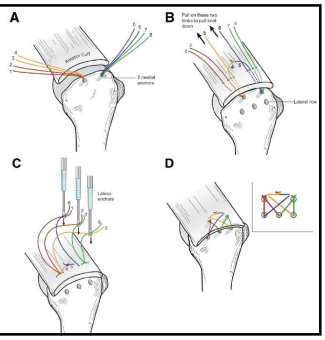

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Suture Type

Tape Versus Suture in Arthroscopic Rotator Cuff Repair

Biomechanical Analysis and Assessment of Failure Rates at 6 Months

Rui Wen Liu,*† MD, Patrick Hong Lam,† PhD, Henry M. Shepherd,† MD, and George A. C. Murrell,† DPhil

Tape vs. Suture

- Significantly **greater footprint contact pressure**
  - -Tape 0.33 ± 0.03 vs. Suture 0.11 ± 0.3 MPa ($p<0.001$)
- Significantly **greater ultimate load to failure**
  - - 217 ± 28 vs. 144 ± 14 N ($p<0.05$)
- Similar re-tear rates (16% vs. 17%)

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Suture Tension

The Optimum Tension for Bridging Sutures in Transosseous-Equivalent Rotator Cuff Repair

A Cadaveric Biomechanical Study

Ji Soon Park,* MD, Michelle H. McGarry,† MS, Sean T. Campbell,† MD, Hyuk Jun Seo,† MD, PhD, Yeon Soo Lee,§ PhD, Sae Hoon Kim,† MD, PhD, Thay Q. Lee,†¶ PhD, and Joo Han Oh,†‡ MD, PhD

- ↑ Bridging Suture Tension (at all positions)
  - ↑ Increased Contact Force
  - ↑ Contact Pressure
  - ↑ Peak Pressure
- Significant differences between 60 & 90 N, but **not** 90 to 120 N
- **No** association with ultimate failure loads

Conclusion: Due to risk of overtensioning, it may be beneficial to keep tension under 90 N.

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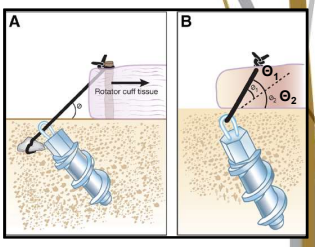
Suture Anchor: Design & Insertion

- Fully Threaded Design
  - +/- Vents
- Angle of Insertion
  - "Deadman's Angle"
  - Ideal < 45°
  - Minimize Pullout
- Θ_1: Pull-Out Angle
- Θ_2: Tissue Reduction Angle



Denard & Burkhart. *Arthroscopy.* 2011.

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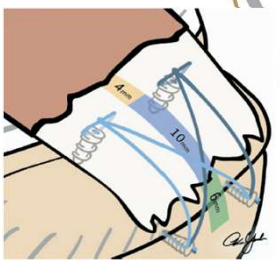

Tuberosity Preparation

Suture Anchor Biomechanics After Rotator Cuff Footprint Decortication

Adam E. Hyatt, M.D., Kyle Lavery, M.D., Christopher Mino, B.S., and Aman Dhawan, M.D.

- Decorticated specimens demonstrated significantly lower ultimate load to failure
- Decreased final pullout strength: decortication (p<0.0001), female gender (p=0.008), and BMD (p=0.0005)

Table 1. Suture Anchor Cyclic Data

		Final Pullout Strength, N			Difference in Final Pullout Strength, N		No. of Cycles	
	n	Mean	SE	SD	Mean ± SE	95% CI	Mean	95% CI
Non-decorticated	19	244.035	20.431	89.06	181.2 ± 22.311	135.213-227.187	24.85	21.25-28.45
Decorticated	18	62.834	8.966	38.04				

CI, confidence interval; SD, standard deviation; SE, standard error.

Thank You!

Brian R. Waterman, MD
Associate Professor
Assistant Fellowship Director
Sports Medicine & Shoulder Surgery
Team Physician, Wake Forest University
Wake Forest University School of Medicine
Winston Salem, NC