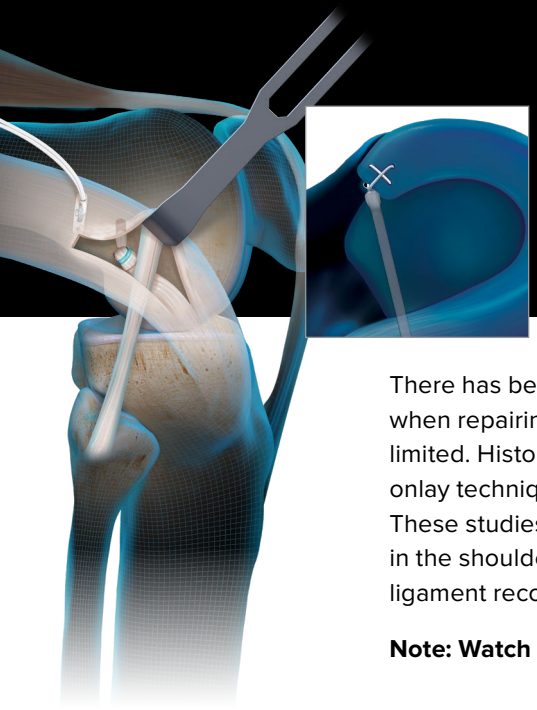

Inlay vs Onlay Meniscal Repair and Ligament Reconstruction

A review of the design rationale, techniques, and outcomes

There has been a long-standing discussion about the merits of an inlay vs onlay technique when repairing the shoulder, but literature specific to inlay vs onlay repair in the knee is limited. Historically, the inlay method is most common, but recent literature suggests the onlay technique may have a better rate of healing due to the tendon-to-bone interface. These studies, which analyze the techniques, histology, and biomechanics of these methods in the shoulder and knee, can be leveraged in discussions about meniscal repair and ligament reconstruction and repair.

Note: Watch Asheesh Bedi, MD (Ann Arbor, MI), discuss the significance of this research.

Animal Models

Rodeo SA, Arnoczky SP, Torzilli PA, Hidaka C, Warren RF

Tendon-healing in a bone tunnel. a biomechanical and histological study in the dog. *J Bone Joint Surg Am.* 1993;75(12):1795-1803. doi:10.2106/00004623-199312000-00009

- Study included 20 dogs with a long digital extensor tendon transplanted in the proximal tibial metaphysis. The authors evaluated the histological and biomechanics of the tendon-bone interface in 4 dogs at 2, 4, 8, 12, and 26 weeks post-transplant.
- Transplant failure due to the tendon pulling out of the bone tunnel was observed at 2, 4, and 8 weeks, but at 12 and 26 weeks, the transplant failed through midsubstance rupture or when the tendon pulled out from the clamp.
- Strength increased in correlation with the amount of bone ingrowth mineralization and maturation of the healing tissue.

Takeaway

Strength increased as time post-transplant increased due to further bone growth into the tendon during the healing process.

St Pierre P, Olson EJ, Elliott JJ, O'Hair KC, McKinney LA, Ryan J

Tendon-healing to cortical bone compared with healing to a cancellous trough. a biomechanical and histological evaluation in goats. *J Bone Joint Surg Am.* 1995;77(12):1858-1866. doi:10.2106/00004623-199512000-00010

- This study evaluated attaching a tendon to a trough in cancellous bone vs direct fixation of a tendon to cortical bone by treating 20 goats with either bilateral tenotomy of the infraspinatus tendon or tendon reattachment.
- Assessed load to failure, energy to failure, and stiffness at 6 and 12 weeks.
- No significant differences were found between the 2 repair types.

Takeaway

There was no benefit in attaching a tendon to cancellous bone instead of cortical bone.

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Tan H,
Wang D,
Lebaschi AH,
Hutchinson ID,
Ying L,
Deng XH,
Rodeo SA,
Warren RF

Comparison of bone tunnel and cortical surface tendon-to-bone healing in a rabbit model of biceps tenodesis. *J Bone Joint Surg Am.* 2018;100(6):479-486. doi:10.2106/JBJS.17.00797

- Study used biomechanical, micro-CT, and histological analyses to assess 32 rabbits 8 weeks after a unilateral proximal biceps tenodesis with tendon fixation either within a bone tunnel or on the cortical surface.
- There was minimal tendon-bone healing and no significant difference between the bone-tunnel and cortical-surface repair groups.

Takeaway

Similar healing results for biomechanics were observed for both tendon fixation in a bone tunnel and on the cortical surface. However, while minimal bone formation was found in the tunnel, these repairs had more healing as the tendon met the bone surface on the way into the tunnel.

Silva MJ,
Thomopoulos S,
Kusano N,
Zaegel MA,
Harwood FL,
Matsuzaki H,
Havlioglu N,
Dovan TT,
Amiel D,
Gelberman RH

Early healing of flexor tendon insertion site injuries: tunnel repair is mechanically and histologically inferior to surface repair in a canine model. *J Orthop Res.* 2006;24(5):990-1000. doi:10.1002/jor.20084

- Analyzed 70 tendon-bone specimens in dogs and evaluated mechanical, histological, and densitometric results at 0, 5, 10, or 21 days post-op to compare the healing of a traditional surface with tunnel repair for flexor digitorum profundus.
- At 21 days, tendons repaired in the tunnel demonstrated 38% lower force.
- Study saw comparable histology findings at 5 and 10 days, but at 21 days, there was more bone growth in the surface repairs as compared to the tunnel repairs.

Takeaway

Attaching the tendon to a traditional surface is biomechanically and histologically superior to tendons reattached in a tunnel.

Kyung HS,
Kim SY,
Oh CW,
Kim SJ

Tendon-to-bone tunnel healing in a rabbit model: the effect of periosteum augmentation at the tendon-to-bone interface. *Knee Surg Sports Traumatol Arthrosc.* 2003;11(1):9-15. doi:10.1007/s00167-002-0317-8

- Analyzed 20 rabbits to determine if periosteum enhances the tendon-to-bone healing process in a tunnel.
- Included histological and biomechanical testing at 3 and 6 weeks post-op.
- At both time points, histological examination showed more bone formation in the periosteum-wrapped tendon.
- The periosteum-wrapped tendon had higher tendon pull-out strength at both 3 and 6 weeks.

Takeaway

Periosteum augmentation may enhance the healing process in tendon graft transplants.

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Sun Y,
Ben H,
Zhou Y,
Jeon IH,
Tan J

Cancellous bone should not be exposed during medialized rotator cuff repair based on bone-to-tendon healing in a rat mode. *Knee Surg Sports Traumatol Arthrosc.* 2023;31(7):2700-2707. doi:10.1007/s00167-023-07395-y

- Study compared bone-to-tendon healing using 3 different bone-bed preparation techniques: cortical bone exposure, cancellous bone exposure, and no cartilage removal.
- Researchers performed rotator cuff repairs in both shoulders of 20 rats using medialized anchoring for each of the 3 techniques.
- At 6 weeks post-op, the group with exposed cancellous bone showed a significantly lower maximum load and less stiffness.
- In contrast, the group with cancellous bone exposure demonstrated inferior fibrocartilage formation and insertion healing.

Takeaway

Removal of excessive bony structure impairs bone-to-tendon healing, and cancellous bone should not be exposed to optimize healing.

Sato Y,
Akagi R,
Akatsu Y,
Matsuura Y,
Takahashi S,
Yamaguchi S,
Enomoto T,
Nakagawa R,
Hoshi H,
Sasaki T,
Kimura S,
Ogawa Y,
Sadamasu A,
Ohtori S,
Sasho T

The effect of femoral bone tunnel configuration on tendon-bone healing in an anterior cruciate ligament reconstruction: an animal study. *Bone Joint Res.* 2018;7(5):327-335. doi:10.1302/2046-3758.75.BJR-2017-0238.R2

- Researchers performed bilateral ACL reconstruction in 24 rabbits using adjustable-fixation or fixed-loop devices.
- Histological and biomechanical testing was evaluated at 4 and 8 weeks. At 4 weeks, both groups showed a mixture of indirect and direct healing patterns. By 8 weeks, both groups showed only indirect healing patterns.
- Additionally, at 8 weeks, the adjustable-fixation group showed graft adherence to the top of the femoral tunnel.
- Study found no significant difference in maximum failure load between timepoints.

Takeaway

Tendon-bone healing after ACL reconstruction primarily occurs as indirect healing, regardless of bone tunnel configuration. Surface area and firm positioning of the tendon are important components for the healing process.

Human Studies and Literature Reviews

Haidamous G, Noyes MP, Denard PJ

Arthroscopic biceps tenodesis outcomes: a comparison of inlay and onlay techniques. *Am J Sports Med.* 2020;48(12):3051-3056. doi:10.1177/0363546520952357

- Study compared postoperative healing and functional outcomes of arthroscopic biceps tenodesis (ABT) high in the groove performed using inlay and onlay techniques.
- A total of 37 patients received an inlay technique and 53 received onlay.
- Both groups had the same postoperative range of motion, functional outcomes, and elbow flexion strength.
- However, the inlay group had a 27% rate of popeye deformity and 10.8% rate of revision surgery, while the onlay group had only a 9.4% popeye deformity rate and 0 patients requiring revision surgery.

Takeaway

An onlay technique was equivalent with the inlay healing process and resulted in lower complication rates.

Jackson GR, Meade J, Coombes K, Young BL, Hamid N, Piasecki DP, Fleischli JE, Trofa DP, Saltzman BM

Onlay versus inlay biceps tenodesis for long head of biceps tendinopathy: a systematic review and meta-analysis. *J Am Acad Orthop Surg Glob Res Rev.* 2022;6(12):e22.00255. doi:10.5435/JAAOSGlobal-D-22-00255

- Literature analysis comparing clinical outcomes of onlay and inlay techniques for tendinosis of the long head of the biceps tendon.
- Evaluation of 6 studies that included 252 onlay patients and 166 inlay patients found no difference in visual analog scale (VAS), Constant-Murley, and American Shoulder and Elbow Surgeons scores.
- Popeye deformity occurred in 7.8% of onlay patients and 11.28% of inlay patients.

Takeaway

While both techniques showed equivalent clinical outcomes, the complication rate for patients who received the inlay technique was higher.

Bedi A, LaPrade RF, Burrus MT

Radiographic and anatomic landmarks of the major knee ligaments. *J Bone Joint Surg Am.* 2018;100(14):1241-1250. doi:10.2106/JBJS.17.01135

- The ligaments of the knee are the primary restraints against different forces, so proper knee function relies on them.
- Failure rate of repair or reconstruction can increase if the ligaments are not returned to native anatomy.

Takeaway

It is imperative to disrupt the native footprint as little as possible. This paper provides a thorough explanation of the anatomic and radiographic landmarks in the knee.

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Lumsdaine W, Smith A, Walker RG, Benz D, Mohammed KD, Stewart F

Morphology of the humeral insertion of the supraspinatus and infraspinatus tendons: application to rotator cuff repair. *Clin Anat.* 2015;28(6):767-773. doi:10.1002/ca.22548

- Study aimed to define the supraspinatus and infraspinatus footprints.
- Authors defined the supraspinatus footprint as triangular with a calculated area of 122.0 mm ± 66.6 mm, while the infraspinatus footprint was trapezoidal with a calculated area of 294.9 mm ± 74.1 mm.

Takeaway

Supraspinatus and infraspinatus footprints are distinct and important to understand.

Hoffman TR, Lamplot JD, McClish SJ, Payne C, Denard PJ

Three medial all suture anchors improves contact force compared to two hard body anchors in a biomechanical two-tendon rotator cuff tear model. *Arthrosc Sports Med Rehabil.* 2022;4(5):e1601-e1607. doi:10.1016/j.asmr.2022.05.012

- Cadaveric study compared knotless double-row construct with 3 medial all-suture anchors (3AS) to a standard 2-anchor medial hard-body construct (2HB).
- Authors implanted the 3AS construct into 6 specimens with three 2.6 mm all-suture anchors placed adjacent to the articular margin and secured laterally with 4.75 mm knotless hard-body anchors. The other 6 specimens received the 2HB construct, with two 4.75 mm hard-body anchors placed medially and secured in the same fashion as the 3AS construct.
- Study found no differences in cyclic displacement, cyclic stiffness, ultimate load, or load to failure between the construct types, but the 3AS repair construct had increased contact pressure.

Takeaway

The size decrease for the all-suture anchor allows for creation of a larger surface area, which can lead to greater contact force and healing without compromising biomechanics.