Biomechanical study comparing hybrid to all-inside and inside-out repair constructs for bucket-handle meniscus tears

Laura Snyder[1], Manuel Schubert[1], John Sharpe[1], Audrey Moffat[1], Nicolas Featherstone[2], Marc Kasabasic[2], Yawen Li[2], Chaoyang Chen[1], Todd Frush[1]
[1]Department of Orthopedic Surgery and Sports Medicine, Detroit Medical Center, Detroit, MI; [2]Department of Biomedical Engineering, Lawrence Technical University, Detroit, MI. Email of Presenting Author: cchen@wayne.edu

Disclosures: None

INTRODUCTION: A functional meniscus is crucial for optimizing performance of a healthy knee. Today we know preserving the meniscus has long term benefits over partial or total meniscectomies, especially with bucket-handle tears. Common techniques currently used for repairing bucket-handle tears are arthroscopic inside-out and all-inside techniques. Bucket-handle meniscus tears change the mechanics of the knee causing mechanical symptoms like catching, locking, popping or instability. Optimizing function of the meniscus helps maintain distribution of forces across the knee joint and decrease the risk of OA. As bucket-handle tears often involve a large percentage of the body of the meniscus, the alternative to repair of partial meniscectomy often leads to a significant amount of tissue being removed and alteration of contact pressures of the knee. Inside-out has been used to be the “gold standard”, the repair consists of small diameter suture on long needles guided through cannulas from inside the joint, out of a separate incision. Sutures are hand tied with knots on outside of capsule. Complications include nerve irritation/injury, infection. All-inside techniques are now also commonly used, in which specific devices have been designed for one-person deployment and are less invasive, less time, more expensive. Complications include implant irritation, neurovascular injury, chondral damage. Many biomechanical studies compared the use of inside-out and all-inside meniscus repair techniques. Clinical outcome studies using all-inside versus inside-out techniques have shown comparable overall results. Hybrid constructs are often used in practice, yet hybrid techniques have not been validated with biomechanical testing. Our hypothesis is that these 3 repair constructs are comparable in terms of biomechanical properties. The purpose of this study is to evaluate the biomechanical properties of hybrid meniscus repairs compared to traditional isolated inside-out and all-inside repair constructs for bucket-handle meniscus tears including assessment of displacement with cyclic loading, stiffness, and load-to-failure testing.

METHODS: Bucket-handle meniscus tears were created in 24 fresh-frozen porcine menisci then repaired using three different techniques (n=8 per group) including: inside-out repair, all-inside repair, and hybrid repair (combination of inside-out and all-inside). Porcine menisci were measured and marked evenly into fifths longitudinally and ½ in width. Full-thickness vertical tears were created, spanning the inner 3/5 halfway between the inner and outer borders of the menisci. Tears were repaired using one of three different repair techniques utilizing 4 repair sutures per meniscus, then the tears were completed to both edges the menisci for best consistency with testing despite different size menisci. The inside-out technique used 0.9mm suture on meniscus repair needles. An all-inside repair device contained a 2-0 Ultra High Molecular Weight Polyethylene (UHMWPE) & polyester suture, 4-0 and 6-0 braided Polyester suture anchors. The hybrid technique used 2 all-inside repair devices in the posterior horn and 2 inside-out repairs in the anterolateral meniscus (Fig. 1). Upon completion of the repair, the meniscus was removed from the tibial plateau and clamped into meniscus clamps. 3D printed holders of various sizes were used to match varying meniscus sizes. The meniscus was aligned perpendicular to the tear. The clamps were fastened to an Instron material testing machine (Model E10000, Norwood, MA). The repaired meniscus was preloaded with a 2N load and then subjected to cyclic loading at 1 Hz between 5.0 N and 30.0 N for 500 cycles. After 500 cycles, the load at 2 mm of displacement was measured. Load-to-failure testing was performed immediately after cyclic testing at a rate of 3.2 mm/s to measure the load and the displacement at the construct failure. Meaning – 3 groups initially analyzed to test for statistical difference with significance set at $p<0.05$. The variables of interest included: stiffness, displacement at a 10N load, load leading to 2mm displacement, displacement of max load, ultimate load to failure. Univariate analysis with PostHoc LSD analysis was performed to determine which groups demonstrated significant differences.

RESULTS: Mean stiffness (N/mm) was 20.0 for Hybrid, 20.7 for All-inside, and 28.8 for Inside-out respectively. After 500 cyclic loadings, mean loads generated at 2mm displacement was 22.8 N for Hybrid, 33.2 N for All-inside, and 45.1 N for Inside-out. There was no difference between hybrid and all-inside group (p=.168), between all-inside and inside-out group (p=.118). There was a statistical difference between hybrid and inside-out group (p=.006). There was no difference in stiffness (N/mm) between hybrid and all-inside group (p=.862). There was a statistical difference between all-inside and inside-out groups (p=.048), and between hybrid and inside-out groups (p=.034). There was no statistically significant difference in maximum load to failure between all groups (p=0.197), displacement at 10N load between all groups (p=.053), displacement at maximum load after cyclic loading between all groups (p=0.426) (Table 1). Primary modes of failure: in all-inside repairs, the suture/anchor was pulled through tissue. In inside-out repairs, suture breakage was seen during pulling to max load. Hybrid construct showed the failure of each suture based on repair technique as listed above.

DISCUSSION: Meniscal tears have become an intriguing topic in orthopaedics. In the past, meniscal tears were treated with partial meniscectomy or neglect. Now many techniques have been developed to be performed arthroscopically for meniscus tear repair in addition to ‘inside-out’ and ‘all-inside’ techniques. Complication rates of ‘inside-out’ are similar to those for ‘all-inside’ techniques, which can be related to joint stiffness, neurovascular injuries, and failure of the meniscus to heal. Nerve injuries were more frequent in inside-out techniques (9% vs. 2%). In this study, three different techniques used to perform a repair for vertical tears of the meniscus were evaluated in this study. The results of this study basically confirmed our original hypothesis. The inside-out appeared to have stronger biomechanical behavior. Limitations of this study included 1) porcine menisci were used instead of human cadaveric tissue, 2) porcine menisci were denser with increased thickness which led to increased rate of misfires of the All-inside device requiring alteration in technique. The conclusion of this study is that Hybrid meniscus repair constructs have comparable biomechanical properties to all-inside and inside-out repair constructs.

SIGNIFICANCE/CLINICAL RELEVANCE: These findings offer surgeons greater flexibility to personalize repairs while helping to reduce complications.

Fig. 1. Three repair techniques for meniscus vertical tears and testing setup

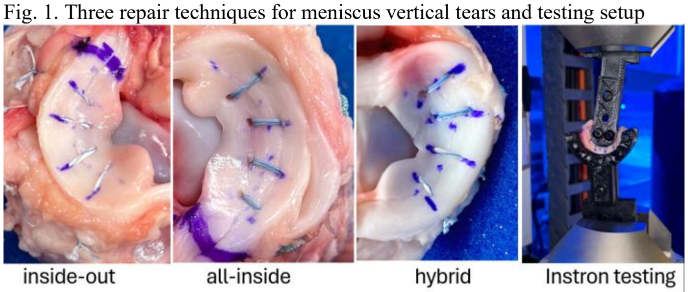

Table 1. Mean of measured variables (Mean ± SD)

	Displacement at 10 N (mm)	Displacement at max Load	Load at 2mm displacement (N)	Maximum failure load (N)	Stiffness (N/mm)
All inside	0.72±0.46	10.95±5.73	33.23±13.94	145.27±50.96	20.7±7.90
Hybrid	1.29±0.52	13.51±3.88	22.83±9.34	169.86±33.02	20.02±4.67
InsideOut	0.68±0.55	11.14±3.57	45.11±18.55	196.47±66.69	28.84±9.64