

Friday March 9, 2018
1:00 PM – 3:30 PM

2018

Meniscus Transplantation Study Group Meeting



Hilton New Orleans Riverside
The Windsor Room
2 Poydras Street
New Orleans, LA 70130

2018 Meeting Agenda

1:00 Welcome

Kevin R. Stone, MD – Chairman, MTSG

1:05 Introduction and Presentation

Frank R. Noyes, MD – Moderator, MTSG

1:30 Presentations

Moderated by Frank R. Noyes, MD

1:30 Meniscal Allograft Transplantation: Does size matter?

*Ciara Stevenson, Ahmed Mahmoud, Francois Tudor & Peter Myers**

1:45 Meniscus Transplantation in Skeletally Immature Patients

Kocher, MS; Tepolt, FA; Vavken, P*

2:00 Meniscus Allograft Survival in Adolescents: Long Term Outcomes

Stone KR, Walgenbach AW, Hennessy S, Greene D, Turek TJ*

Meniscus Allograft survival in patients with low grade osteoarthritis: Long term outcomes

Stone KR, Walgenbach AW, Hennessy S, Greene D, Turek TJ*

2:15 Efficacy of Segmental Meniscal Allograft Transplantation using an Ovine Model

Strauss E, Caborn DNM, Nyland J, Horng S, Chagnon M, Wilke D.*

2:30 Increases in Meniscal Allograft but not in Anterior Cruciate Ligament Forces after Lateral Meniscal Allograft Transplantation With Bone-Block and Suture-Only Fixation

*João V. Novaretti, MD, Jayson Lian, BA, Andrew J. Sheehan, MD, Calvin K. Chan, MS, Joon H. Wang, MD, PhD, Moises Cohen, MD, PhD, Richard E. Debski, PhD, Volker Musahl, MD**

Lateral Meniscal Allograft Transplantation Can Partially Improve Knee Stability With Bone-Block and Suture-Only Fixation Techniques

*João V. Novaretti, MD, Jayson Lian, BA, Andrew J. Sheehan, MD, Calvin K. Chan, MS, Joon H. Wang, MD, PhD, Moises Cohen, MD, PhD, Richard E. Debski, PhD, Volker Musahl, MD**

2:45 Discussion

Refer to the suggested topics for discussion overleaf

3:15 Industry Session

Discussion regarding:

- State of the business of meniscus allografting
- State of sterilization and processing
- The Future of meniscus allografts from the industry perspective

3:30 Close

Suggested Topics for Discussion

- Augmenting Meniscus Allograft Transplantation with Stem Cells and Growth Factors
- Sterilization procedures and irradiation
- Meniscus tibial ligament preservation vs Skeletonizing
- Permanent suture and anchors vs resorbable suture only
- Return to full sports
- Prevention of arthritis
- Treatment of growth plate in adolescents
- Combined medial and lateral transplantation
- Meniscal Allograft Transplantation vs Unicompartamental Joint Replacement
- Combined Meniscus allograft transplantation and
 - Articular cartilage repair
 - ACL reconstruction
 - Osteotomy

Meniscal Allograft Transplantation: Does size matter?

*Ciara Stevenson, Ahmed Mahmoud, Francois Tudor & Peter Myers**

Presenting Author - Peter Myers

Purpose: To assess long-term survivorship of meniscal allograft transplantation (MAT) and determine the effect that pre-operative meniscal sizing has upon functional outcome and mechanical survivorship.

Methods: A prospectively collected database including patients receiving MAT from 2001 to 2017 was analyzed. Data includes demographic information; meniscal sizing measurements, complications, further surgery and patient reported outcome measures (PROM's). All allografts were sized using the Pollard technique and were fresh frozen and non-irradiated.

Results: 73 transplants were performed in 67 patients; mean age at transplant was 34 years (range 14-52 years). Males received 56% of the transplants and 62% were medial. The mean follow-up was 75 months (6.25 years). Mechanical survival at 5 and 10yrs was 96% and 89.4% respectively. There were statistically significant improvements in all PROM's; mean Lysholm score improved by 17.5 points (95% Confidence Interval (CI) 22.2 to 12.9, $p < 0.001$); mean IKDC score improved significantly by 13.3 points (CI 19.3 to 7.4, $p < 0.001$); mean OKS improved by 5.6 points (CI 9.2 to 2.2, $p < 0.002$) and the Tegner improved by 0.9 points (CI 1.5 to 0.32, $p < 0.003$). 41 MAT's (56 %) were undersized for width (range 1-11mm). 7 MAT's (10%) were undersized for length (range 1-4mm). There was a negative correlation between width and length i.e. If a graft was undersized in width it was oversized in length in order to replicate the circumference of the native meniscus.

There was no statistically significant difference in mechanical survivorship or clinical outcomes between undersized, matched or oversized grafts. However, subgroup analysis demonstrated increased failure when allografts were undersized by more than 5mm in width. The small number of grafts undersized in length made it impossible to assess statistical risk of failure.

Conclusions: MAT is an effective treatment to improve function and alleviate pain with excellent survivorship in this series. Accepting an allograft that is more than 5mm smaller in width than pre-operative templating increases the likelihood of clinical and mechanical failure. This study demonstrates that minor graft mismatch can be accommodated, if the circumference is close to the native meniscus, but under sizing by more than 5mm in width increases the risk of failure.

Level of evidence: Therapeutic Level II

Meniscus Transplantation in Skeletally Immature Patients

Kocher, MS; Tepolt, FA; Vavken, P*
Presenting Author - Kocher, MS

Background: Meniscus transplantation may be an option in skeletally immature patient's status post total or subtotal meniscectomy with knee symptoms or dysfunction.

Methods: We reviewed our clinical database for skeletally immature patients who had undergone meniscus transplantation with a minimum of 2 years of follow-up. Patients were contacted, invited for a physical exam, and asked to complete a Pedi-IKDC, Lysholm, and Tegner outcomes questionnaire.

Results: Three patients (two females / one male) were included in the study. Two patients had undergone subtotal discoid meniscus resection leading to early lateral compartment degeneration. One patient developed advanced degeneration after a delay in treatment for a medial bucket-handle tear associated with anterior cruciate ligament rupture. The mean age at the time of surgery was 12.6 ± 2.3 years. At a mean follow-up of 31 ± 20 months, the mean Pedi-IKDC score was 68.3 ± 4 , mean Lysholm 55.7 ± 22.3 , and median Tegner 7 points. There were no indications of growth deformity during the regular postoperative radiological assessments. One patient required subsequent lysis of adhesions along the lateral mini arthrotomy and mobilization under anesthesia. The other two patients were able to return to sports at the same level as before meniscus transplantation and were able to do so within 9 months postoperatively.

Conclusion: Over-resection of discoid menisci as well as untreated meniscus injury, the latter typically in conjunction with ligamentous instability, can lead to advanced cartilage degeneration and recalcitrant complaints necessitating surgical treatment before skeletal maturity. We were able to show that meniscus transplantation in skeletally immature patients leads to acceptable clinical outcomes without growth deviation

Meniscus Allograft Survival in Adolescents: Long Term Outcomes

Stone KR^{1,2} Walgenbach AW¹ Hennessy S² Greene D² Turek TJ²

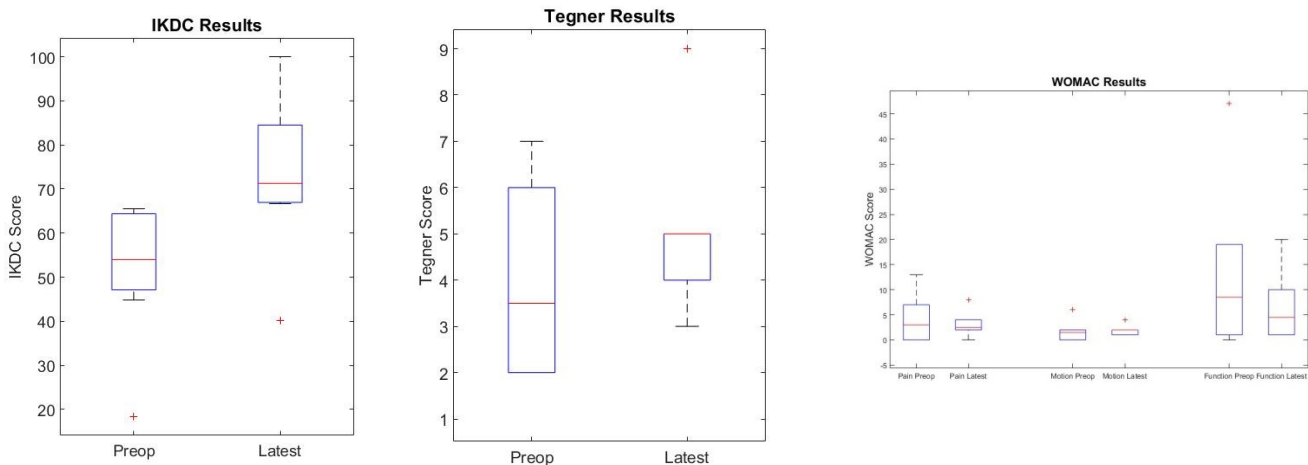
¹The Stone Clinic, ²The Stone Research Foundation, San Francisco CA

Presenting Author: Kevin R. Stone, MD

Purpose: This prospective, longitudinal study demonstrates long-term effectiveness of meniscus allograft transplantation performed by a single surgeon using a three-tunnel technique in adolescent patients with missing or severely damaged menisci, as measured by subjective outcome questionnaires and MRI.

Methods: Data (subjective questionnaires, clinical data, x-ray and MRI results) were collected pre- and postoperatively from 10 patients under 21 years at time of surgery. Institutional Review Board approval was granted and informed consent obtained prior to participation. Median pre- and postoperative IKDC, WOMAC, and Tegner values were compared using Wilcoxon signed rank correlation test. Significance was set at $\alpha = 0.05$. Graft failure was defined, surgical removal of the meniscus allograft or increased pain as reported by the patient.

Results: Ten adolescent patients underwent meniscus allograft transplantation (5 medial and 5 lateral); Mean age at surgery was 16.0 ± 1.7 years (13.0-19.0 years); 6 (60%) were female. Meniscus transplantation occurred at an average of 1.9 ± 1.3 years (0.05 to 4.1 years) after injury following a median of 2 (range 1-4) previous surgeries. Mean follow-up was 8.9 ± 6.0 years (1-19 years). At latest follow-up ten procedures (100%) were considered successful; Median IKDC scores improved from 54.0 to 71.3 ($p < 0.016$); WOMAC and Tegner scores showed improvement that was not statistically significant. Post-op MRI demonstrated a slight percentage increase in cartilage loss in same compartment in two patients but this was insignificant.



Conclusion: This study demonstrates that meniscus allograft transplantation can be used successfully to improve long-term activity, pain and function in a young patient population with loss of meniscus tissue after knee injury. Patients experienced significant improvements in IKDC subjective outcome measures and no MRI detectable progression of cartilage loss.

Meniscus Allograft Survival: Long Term Outcomes in Patients with Low Grade OA

Stone KR^{1,2} Walgenbach AW¹ Hennessy S² Greene D² Turek TJ²

¹The Stone Clinic, ²The Stone Research Foundation, San Francisco CA

Presenting Author: Kevin R. Stone, MD

Purpose: This study was designed to determine if the three tunnel technique for meniscal allograft transplantation (MAT) would be as effective in young patients with severely damaged menisci presenting with healthy knees or mild early osteoarthritis (Outerbridge (OB) II classification or lower) compared to MAT using the same technique in grade III or IV arthritis.

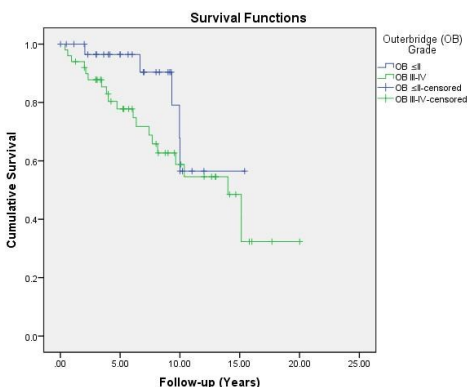
Methods: Subjective questionnaires, clinical data, x-ray and MRI results were collected from 68 (70.1%) men and 29 women with a recorded OB grade. Participants completed IRB approved pre and post op questionnaires at: 1,2,3,5 and 10+ years post-surgery. Thirty-eight patients had an OB score below II and fifty-nine concurrently operated patients had OB grade III and IV. Fifteen patients were lost to follow-up. Median pre- and postoperative IKDC, WOMAC, and Tegner values were compared using Paired T-test and Wilcoxon Signed-Rank correlation test, with significance set at $\alpha = 0.05$. Success was measured by Kaplan-Meier survival analysis. Graft failure was defined as surgical removal of the meniscus allograft or worsening WOMAC pain score.

Results: Mean follow-up time was 7.06 ± 4.67 years (range: 2-20.01 years). Patients with Grade I and II arthritis underwent meniscus transplantation at an average of 1.16 ± 1.18 years (range: 0.01 to 4.56 years) after injury compared to 2.15 ± 1.46 years (range 0.06 – 5.68) in patients with OB III and IV. In healthy knees 86% of procedures were considered successful compared to 60% in arthritic knees; there was no significant difference in mean survival time ($p=0.155$) in healthy knees 12.4 ± 1.03 years (95% CI 10.47-14.46) compared to 12.2 ± 1.18 years (95% CI 9.91-14.55) in arthritic knees (Figure 1). There was a significant improvement in IKDC function, WOMAC pain score and Tegner activity rating in both groups (Table 1)

Table 1: Descriptive Statistics

Variable	Measure	OB ≤II			OB III-IV		
		Preop Score	Postop Latest Score	P value	Preop Score	Postop Latest Score	P value
IKDC Function	Mean [SD]	51.1 [13.9]	72.1 [21.0]	0.000	44.4 [16.1]	60.8 [17.9]	0.000
WOMAC Pain	Median (range)	5 (0-11)	2 (0-11)	0.028	5 (1-16)	3 (0-15)	0.000
Tegner Activity	Median (range)	3 (1-6)	5 (1-8)	0.022	3 (0-8)	4 (1-9)	0.000

Figure 1: Kaplan-Meier Survival Curve



Conclusion: This study demonstrates that Meniscus Allograft Transplantation using the three tunnel technique is equally effective in providing improvements to pain, function and activity levels in patients with healthy knees compared to those presenting with more severe osteoarthritis. Although patients with greater osteoarthritis presented with a slightly higher rate of failure, the benefit to all patients is still long lasting.

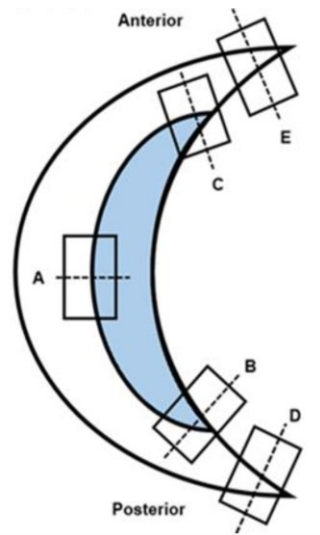
Efficacy of Segmental Meniscal Allograft Transplantation using an Ovine Model

Strauss E, Caborn DNM, Nyland J, Horng S, Chagnon M, Wilke D.

AccellAB Inc., Quebec, Canada, JRF Ortho, Colorado, USA

Presenting Author: Caborn DNM

Purpose: To evaluate 3month segmental meniscal allograft transplant healing in a sheep model.



Methods: Fresh-frozen medial meniscus, treated and stored per standard protocols were transplanted in the right medial meniscus of six female sheep (lateral parapatellar approach and medial femoral condyle (MFC) osteotomy). Formalin fixed right medial meniscus, distal femur and proximal tibia underwent junction evaluations using Rodeo (cellularity/collagen), Ishida (reparative bonding), Collagen I IHC (collagen I), and Mankin (cartilage organization) scores at the MFC and medial tibial plateau (MTP). (Figure 1: A: peripheral, B: posterior, C: anterior, D: posterior horn control, E: anterior horn control).

Results: Three animals were euthanized at 39 ± 2.6 days post-surgery due to poor treated knee condition (Table 1). Three animals were euthanized at 90 days (Table 2).

		A	B	C	D	E
Rodeo	Mean	3.6 ±	2.3 ±	2.3 ±	5.0 ±	5.0 ±
	± SD	0.5	1.5	1.1	0.0	0.0
Ishida	Mean	1.3 ±	1.0 ±	1.3 ±	1.5 ±	1.0 ±
	± SD	2.3	1.0	1.5	0.7	1.4
Collagen I IHC	Mean	5.0 ±	5.0 ±	4.0 ±	5.0 ±	5.0 ±
	± SD	0.0	0.0	1.7	0.0	0.0
Mankin	Mean	MFC	5.0 ±	MTP	9.3 ±	
	± SD		2.7		0.6	

		A	B	C	D	E
Rodeo	Mean	3.6 ±	3.3 ±	3.6 ±	5.0	5.0 ±
	± SD	0.5	1.5	0.8		0.0
Ishida	Mean	2.6 ±	1.6 ±	2.0 ±	2.0	1.3 ±
	± SD	1.5	0.5	1.0		1.1
Collagen I IHC	Mean	5.0 ±	5.0 ±	5.0 ±	5.0	5.0 ±
	± SD	0.0	0.0	0.0		0.0
Mankin	Mean	MFC	4.3 ±	MTP	10.3 ±	
	± SD		4.2		0.6	

Conclusions: Early euthanized animals (Table 1) displayed moderate Rodeo scores, low Ishida scores, and high Collagen I staining scores indicating moderately high fibrocartilage changes, mild or minimal meniscal healing and high collagen I content. Cartilage scores were low in the MFC and moderately high in the MTP, indicating mild MFC cartilage changes and moderately high MTP cartilage changes.

Data for full-term euthanized animals (Table 2) revealed improving Rodeo scores with mean scores of 3.3 and 3.6 at junctions (B) and (C), respectively. Ishida scores displayed similar improvements at all sections. Collagen I staining revealed strong (grade 5) levels in all sections, with mean collagen I scores of 5, 5 and 4 for the peripheral (A), posterior (B) and anterior (C) junctions, respectively. Despite unchanged Mankin scores between the early and 90 day scheduled euthanization groups, an improving healing progression was observed in terminally euthanized animals.

Increases in Meniscal Allograft but not in Anterior Cruciate Ligament Forces after Lateral Meniscal Allograft Transplantation With Bone-Block and Suture-Only Fixation

João V. Novaretti, MD^{1,2}, Jayson Lian, BA¹, Andrew J. Sheean, MD¹, Calvin K. Chan, MS¹, Joon H. Wang, MD, PhD¹, Moises Cohen, MD, PhD², Richard E. Debski, PhD¹, Volker Musahl, MD¹

¹Orthopaedic Robotic Laboratory, University of Pittsburgh, Pittsburgh, PA, USA; ²Paulista School of Medicine (EPM), Federal University of São Paulo, São Paulo, Brazil

Presenting Author: Volker Musahl, MD

Introduction: The effects of lateral meniscal allograft transplantation (MAT) on resultant forces in the lateral meniscus and anterior cruciate ligament (ACL) in situ forces are unknown. The purposes of this study were to: 1. Quantify the effects of two lateral MAT fixation techniques —bone block and suture-only— on the resultant forces in the meniscal allograft and on the in situ force in the ACL, and 2. Compare the two lateral MAT fixation techniques results on the same forces.

Methods: Ten fresh-frozen human cadaveric knees (mean age 75.0; range, 55-92 years) were tested using a 6-degree-of-freedom robotic testing system (MJT Model FRS2010). Three loading conditions were applied while the knees were continuously flexed from full extension to 90° of knee flexion: (1) 134-N of anterior tibial load + 200-N of axial compression, (2) 5-N·m of internal tibial torque + 5-N·m of valgus torque and (3) 5-N·m of external tibial torque + 5-N·m of valgus torque. After loading the intact knee, a total lateral meniscectomy was performed arthroscopically. A lateral MAT with bone-block fixation was performed, and vertical inside-out sutures were placed arthroscopically to secure the allograft. The meniscal attachments to the bone block were cut and a lateral MAT suture-only fixation technique was used to secure the anterior and posterior horns of the allograft. The allograft was removed and previous positions of the knee were repeated to quantify the resultant forces in the meniscal allograft for all four knee states (intact, total lateral meniscectomy, lateral MAT with bone-block, and lateral MAT with suture-only technique) using the principle of superposition. The same positions were repeated after removal of all soft-tissue except for the ACL in order to quantify in situ forces in the ACL for all four knee states using the principle of superposition. A repeated measures ANOVA and a Wilcoxon signed rank test (for non-normally distributed data) were used for statistical analysis. Significance was set at $P < .05$.

Results: Resultant Forces in the Lateral Meniscus

From the absence of resultant forces in the lateral meniscus after total lateral meniscectomy, in response to anterior tibial loads coupled with axial compression, lateral MAT with bone-block and with suture-only techniques increased the resultant forces in the meniscal allograft at 0°, 30°, 60° and 90° of knee flexion by 63.2%, 56.3%, 47.5% and 44.6% and 39.1%, 51.2%, 40.5% and 34.1%, of the forces in the lateral meniscus in the intact state, respectively ($P < .05$)(Figure 1).In response to

rotatory loads, both lateral MAT techniques increased the resultant forces in the meniscal allograft, but neither technique increased the forces to that of the intact state.

ACL in situ Forces

In response to anterior tibial loads coupled with axial compression, total lateral meniscectomy significantly decreased in situ force in the ACL by 27.3% and 17.5% of that observed in the intact state at 30° and 60° of knee flexion, respectively ($P < .05$). However, no significant decreases in in situ force in the ACL after total lateral meniscectomy were observed in response to coupled internal and valgus tibial torques ($P > .05$). Neither lateral MAT technique was able to increase ACL in situ forces to that of the intact state ($P > .05$). No differences between lateral MAT techniques were observed at all knee flexion angles tested ($P > .05$).

Discussion: The findings of this study demonstrate that lateral MAT significantly increased resultant forces in the meniscal allograft to nearly 2/3 of the forces in the lateral meniscus in the intact knee. These results show that lateral MAT may reduce loads transferred through cartilage to cartilage contact in a meniscectomized knee[1,2], which might decrease the risk for knee osteoarthritis. ACL in situ forces were decreased after total lateral meniscectomy, but only at certain knee flexion angles and applied loads. However, neither lateral MAT technique was able to increase ACL in situ forces. This finding may suggest that other structures may be overloaded and therefore predisposed to further injury. No significant differences were observed between lateral MAT techniques. Therefore, we suggest that both techniques could be performed with equivalent effects on meniscal allograft and ACL forces.

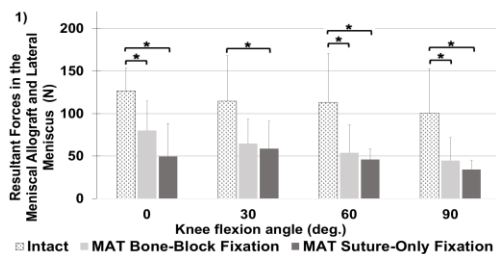


Figure 1: Resultant forces in the meniscal allograft and lateral meniscus in response to anterior tibial load + axial compression. * $P < .05$.

References: 1) McDermott, KSSTA, 2008. 2) Paletta, AJSM, 1997.

Lateral Meniscal Allograft Transplantation Can Partially Improve Knee Stability With Bone-Block and Suture-Only Fixation Techniques

João V. Novaretti, MD^{1,2}, Jayson Lian, BA¹, Andrew J. Sheehan, MD¹, Calvin K. Chan, MS¹, Joon H. Wang, MD, PhD¹, Moises Cohen, MD, PhD², Richard E. Debski, PhD¹, Volker Musahl, MD¹

¹Orthopaedic Robotic Laboratory, University of Pittsburgh, Pittsburgh, PA, USA; ²Paulista School of Medicine (EPM), Federal University of São Paulo, São Paulo, Brazil

Presenting Author: Volker Musahl, MD

Introduction: The effects of lateral meniscal allograft transplantation (MAT) on knee stability in the setting of a lateral meniscus-deficient knee are currently unknown[1,2]. The purposes of this study were to: 1. Quantify the effects of two lateral MAT fixation techniques —bone block and suture-only —on translational and rotatory knee stability, and 2. Compare the capacity of the two lateral MAT fixation techniques to increase translational and rotatory stability.

Methods: Ten fresh-frozen human cadaveric knees (mean age 75.0; range, 55-92 years) were tested using a 6-degree-of-freedom robotic testing system (MJT Model FRS2010). Three loading conditions were applied while the knees were continuously flexed from full extension to 90° of knee flexion: (1) 134-N of anterior tibial load + 200-N of axial compression, (2) 5-N·m of internal tibial torque + 5-N·m of valgus torque and (3) 5-N·m of external tibial torque + 5-N·m of valgus torque. A total lateral meniscectomy was then performed arthroscopically. Next, a lateral MAT with bone-block fixation was performed and vertical inside-out sutures were placed arthroscopically to secure the allograft. The meniscal attachments to the bone block were then cut and a lateral MAT suture-only fixation technique was used to secure the anterior and posterior horns of the meniscal allograft. Six degrees of freedom kinematic data was recorded for all four knee states (intact, total lateral meniscectomy, lateral MAT with bone-block, and lateral MAT with suture-only technique). A repeated measures ANOVA and a Wilcoxon signed rank test (for non-normally distributed data) were used for statistical analysis. Significance was set at $P < .05$.

Results

Medial-Lateral Translation of the Tibia

In response to anterior loads, total lateral meniscectomy significantly increased medial translation of the tibia by 175.0%, 150.0%, 178.5% and 200% of the intact state, at 0°, 30°, 60° and 90° of knee flexion, respectively ($P < .05$) (Figure 1). Lateral MAT with bone-block technique reduced the increases in medial translation of the tibia observed after total lateral meniscectomy by an absolute difference of 54.2%, 48.0%, and 50.0%, at 30°, 60° and 90° of knee flexion, respectively ($P < .05$) (Figure 1). Still, medial translation after lateral MAT was significantly different compared to the intact knee ($P < .05$). Similarly, lateral MAT with suture-only technique reduced the increases in medial translation of the tibia observed after total lateral meniscectomy by an absolute difference of 50.0%,

40.0% and 34.6%, at 30°, 60° and 90° of knee flexion, respectively ($P < .05$) (Figure 1). In response to rotatory loads, total lateral meniscectomy also increased medial translation of the tibia at all knee flexion angles tested ($P < .05$). However, no improvement in medial-lateral translation of the tibia was observed after either lateral MAT fixation technique ($P > .05$).

Internal-External Rotation of the Tibia

In response to coupled external and valgus tibial torques, total lateral meniscectomy significantly increased external rotation of the tibia by 48.9%, 28.0%, 27.8% and 23.2% of the intact state at 0°, 30°, 60° and 90° of knee flexion, respectively ($P < .05$). However, neither lateral MAT fixation technique was able to reduce internal-external rotation of the tibia to that observed in the intact knee ($P < .05$). No differences between lateral MAT techniques were observed in medial-lateral translation and inter-external rotation of the tibia in response to anterior or rotatory loads, at all knee flexion angles tested ($P > .05$).

Discussion

The findings of this study demonstrate that lateral MAT may partially improve knee stability from a meniscectomized condition, although not to the intact state. Surgeons may consider this potential benefit of MAT when deciding the appropriate treatment for symptomatic patients after total lateral meniscectomies. Both lateral MAT fixation techniques showed comparable joint motion outcomes, with no technique demonstrating superiority in terms of a capacity to improve the kinematics to that of the intact knee. Therefore, we suggest that both techniques could be performed with equivalent results in knee stability.

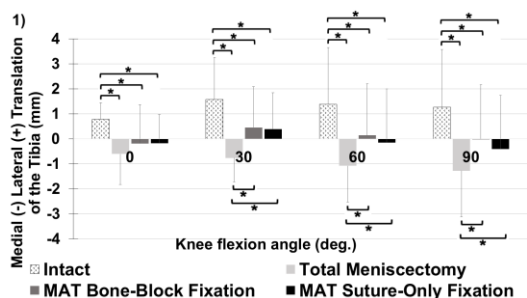


Figure 1: Medial translation of the tibia in response to anterior tibial load + axial compression. $*P < .05$.

References: 1) Getgood, AJSM, 2016. 2) Rosso, AJSM, 2015.