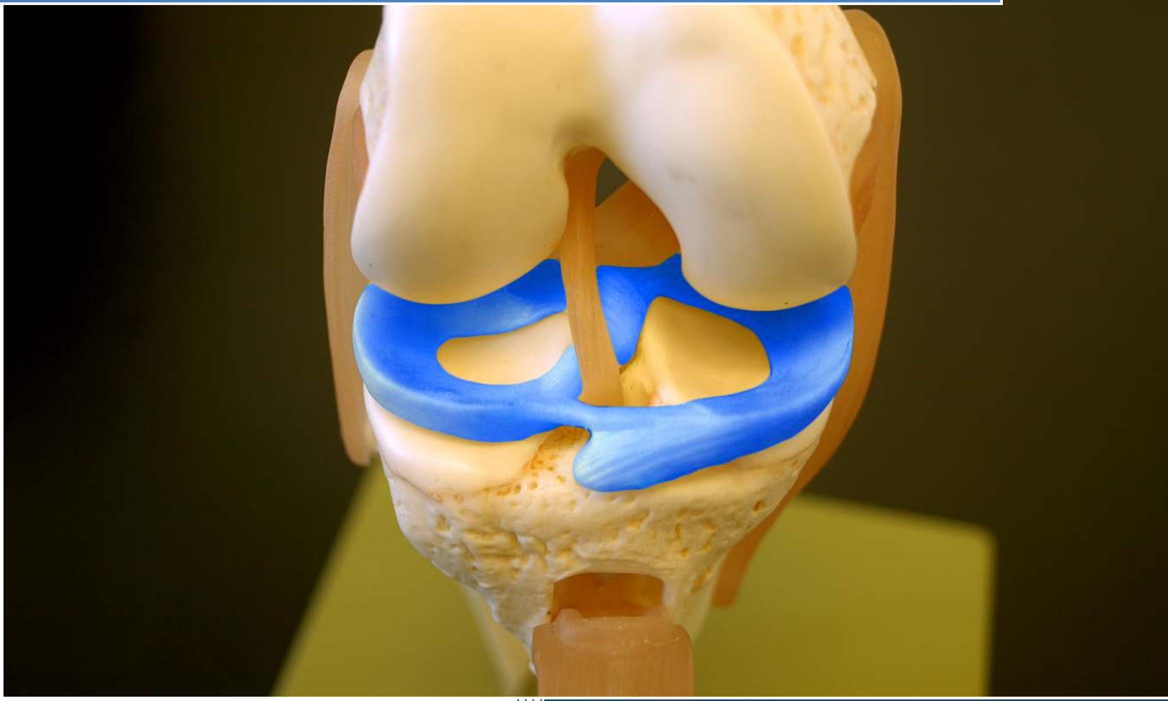
Friday March 27, 2015
12:00 PM – 2:30 PM

2015

Meniscus Transplantation Study Group Meeting



Harrah's Las Vegas

Laughlin Room

3475 Las Vegas Boulevard South
Las Vegas, NV 89109

2015 Meeting Agenda

Welcome and Introduction

Kevin R. Stone, MD

Presentations

Moderated by Stefano Zaffagnini, MD

Meniscus Transplantation Hot Topics.
Presented by Kevin R. Stone, MD

Arthroscopic Meniscal Allograft Transplantation without bone plugs: Survival analysis of 104 patients.
Presented by Stefano Zaffagnini, MD

Meniscal Allograft Transplantation: An analysis of a consecutive series of 114 transplants based on pre-operative articular cartilage grade.
Presented by Tim Spalding FRCS Orth

Combined autologous chondrocyte implantation and allogenic meniscus transplantation
A biological knee replacement.
Presented by James Richardson, MD

Combined Osteochondral Allograft and Meniscal Allograft Transplantation: A Survivorship Analysis.
Presented by Alan Getgood, MD

Meniscal Allograft Transplantation: How Should We Be Doing It? A Systematic Review.
Presented by Peter Myers, MBBS, FRACS, FAOrthA

The Emerging Biological Role of the Meniscus in Osteoarthritis: Implications for Meniscal Restoration.
Presented by Ian D. Hutchinson, MD

Targeted Growth Factor Delivery to Augment Early Meniscus-Scaffold Interface Development.
Presented by Ian D. Hutchinson, MD

Function of the medial meniscus in force transmission and stability.
Presented by Peter S Walker, PhD

Meniscal Allograft Transplantation: Effect of Fixation on Medial and Lateral Compartment Biomechanics.
Presented by Russell F Warren, MD

Knee contact mechanics before and after meniscus allograft transplantation. A preliminary *in vivo* study.
Presented by Scott Rodeo, MD

The new approach to medial meniscus transplantation based on cadaveric study of 37 human fresh cadaveric knees.
Presented by Robert Smigielski, MD

The new approach to lateral meniscus transplantation based on cadaveric study of 37 human fresh cadaveric knees.
Presented by Robert Smigielski, MD

Open Discussion

The group is encouraged to participate in an open discussion of issues in meniscus transplantation

Arthroscopic Meniscal Allograft Transplantation without bone plugs: Survival analysis of 104 patients

Zaffagnini Stefano, Grassi Alberto, Marcheggiani Muccioli Giulio Maria, Benzi Andrea, Serra Margherita, Giunchi Dario, Raggi Federico, Roberti di Sarsina Tommaso, Maurilio Marcacci
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Background
Few medium-term or long-term reports on meniscal allograft transplantation (MAT) are available.

Purpose
To present the results of a survival analysis of our first 104 arthroscopic MAT procedures.

Level of evidence and Study Design
Therapeutic study, Level IV; retrospective case series of prospectively collected data.

Material and methods
104 patients (78 males; 26 females) underwent arthroscopic MAT without bone plugs (55 medial MAT, 49 lateral MAT). [1] They were retrospectively reviewed at a mean of 4.2±2.2 (range 2.0-10.4) years follow-up. Mean age at surgery was 40.7±10.6 (range 15.5-60.7) years; 53 patients (51%) underwent combined procedures (anterior cruciate ligament reconstruction, high tibial osteotomy, distal femoral osteotomy or cartilage treatment). Survival analysis was performed using two endpoints: surgical failure (revision procedure with direct relation to MAT) and clinical failure (revision procedure or Lysholm score =poor" <65).

Results
There was a significant ($P < .05$) and clinically relevant decrease in the VAS and increase in KOOS and Lysholm from preoperative mean score to postoperative mean score.
Six (6%) patients (2 medial, 4 lateral) experienced surgical failure (5 meniscetomies, 1 unicompartmental knee arthroplasty). The mean overall survial rate at 2, 4 and 6 years was 95%, while survival time was 9.6 years.
Nineteen (18%) patients (8 medial, 11 lateral) were considered clinical failures. The mean overall survival rate at 2, 4 and 6 years was 93%, 85% and 80%, while survival time was 7.8 years . No statistical differences in failures and survival rate were present between medial and lateral MAT, isolated or combined MAT, patients >50 or <50 years old and patients with body mass index <25 or >25.

Conclusions
Arthroscopic transplantation of a fresh-frozen meniscal allograft without bone plugs can significantly relieve pain and improve function of the knee joint. Survival analysis showed that this beneficial effect remained in approximately 80% of the patients at six years. Our mid-term results are encouraging and are in agreement with the data reported by Verdonk et al [2] in the long-run.

References:

1) Marcacci M, Zaffagnini S, Marcheggiani Muccioli GM, Grassi A, Bonanzinga T, Nitri M, Bondi A, Molinari M, Rimondi E. Meniscal allograft transplantation without bone plugs: a 3-year minimum follow-up study. Am J Sports Med. 2012;40(2):395-403.
2) Verdonk PC, Demurie A, Almqvist KF, Veys EM, Verbruggen G, Verdonk R. Transplantation of viable meniscal allograft. Survivorship analysis and clinical outcome of one hundred cases. J Bone Joint Surg Am. 2005;87(4):715-724.

Meniscal Allograft Transplantation
An analysis of a consecutive series of 114 transplants based on pre-operative articular cartilage grade

Tim Spalding FRCS Orth, Nick Smith, Ben Parkinson, Laura Asplin, Alan Getgood
University Hospital Coventry and Warwickshire NHS Trust, UK

Introduction

The ideal candidate for meniscal allograft transplantation (MAT) is a patient with a symptomatic meniscal deficiency and preserved articular cartilage. It is not known whether patients with severe articular cartilage loss can benefit from MAT. This study analyses a large consecutive series based on articular cartilage status.

Methods

Patients undergoing MAT between May 2005 and October 2013 with a minimum of 12 months follow-up were grouped according to cartilage status: group 1 (articular cartilage ICRS grade 1-3a), group 2 (grade 3b or greater on either tibia or femur) and group 3 (grade 3b or greater on both tibia and femur). Baseline demographics, patient reported outcome measures (PROMs) and failures were prospectively collected and compared across the groups. Osteotomy, ligament reconstruction and cartilage repair surgery was performed concomitantly as appropriate. Failure was defined as conversion to arthroplasty or graft removal.

Results

All 114 transplants (group 1 n=64, group 2 n=24, group 3 n=26) performed during this period were included for analysis. The mean age was 31.6 (range 16-49) years and mean follow-up was 25 (range 12-110) months. Baseline PROMs were not significantly different across the groups. The overall failure rate was 10.5% (12 cases); group 1 - 1.6%, group 2 - 8.3% and group 3 - 34.6% ($p<0.05$).
There was a significant improvement in all PROMs but they were not significantly different across the groups. The Failure rate significantly varied according to the tissue bank provider with 75% coming from one particular tissue bank.

Discussion

In this series incorporating biological resurfacing principles, MAT has high patient satisfaction and improvement in function. Graft source was in independent predictor of failure.
The ideal candidate for MAT remains a patient with symptomatic meniscal deficiency and preserved articular cartilage. Failure in this group was very low, but was significantly higher in the presence of joint surface damage. However, in the absence of other viable treatments such as arthroplasty, young patients with poorly preserved articular cartilage can still benefit from MAT, especially when the technique is combined with additional techniques of ligament stabilisation, osteotomy and articular cartilage repair techniques. These patients with bare bone should be counselled as to the higher potential failure rate.
Of particular note, when the graft survived the patient reported outcome scores (PROMs) were not significantly different to scores in patients with optimal indications.

Combined autologous chondrocyte implantation and allogenic meniscus transplantation
A biological knee replacement

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The use of autologous Chondrocyte Implantation (ACI) has provided a new dimension to the treatment of chondral defects in the knee, with 85% long term good to excellent results. Patient with meniscus deficient knees are known to develop early osteoarthritic changes, however ACI is contraindicated in meniscus deficient knees.Allogenic Meniscus Transplantation (AMT) gives good symptomatic relief in meniscus deficient knees, with a reported success rate of 89%, however it is contraindicated in cases of advanced cartilage degeneration. It is hypothesized that the combination of the two procedures might be a good solution for bone on bone arthritis in young individuals.

We studied a consecutive series of 13 patients, with mean age of 51.2(Range 35-70) years, presenting with large kissing chondral defects, secondary to the previous meniscectomy. All the patients were treated with a combination of ACI and AMT. Mean pre-operative Lysholm score was 54.32 (Range 17-83), which rose to mean of 70.191 (Range 26-100) at 1 year, an average increase by 15.87 points. 8 patients showed significant improvement at one year. MRI scans showed good integration of the menisci with the capsule, without any rejection. Histology confirmed the integration. All the patients could lead an active life-style. 8 patients maintained their improvement at a mean follow-up of 6.9 years with a mean post-operative Lysholm follow-up score at last visit of 68.9. Two patients were converted to total knee replacement. We could not find any deleterious effects of the combination of these two techniques. A combination of chondrocyte implantation and meniscal transplantation provides hope for a biological knee reconstruction.

Combined Osteochondral Allograft and Meniscal Allograft Transplantation – A Survivorship Analysis

Alan Getgood[1], [2]Jonathon Gelber, [3]Simon Gortz, [4]Alison DeYoung, [5]William Bugbee
[1]Fowler Kennedy Sport Medicine Clinic, London, Ontario, Canada; [2]Harbor-UCLA Medical Center Torrance, CA; [3]University of California, San Diego, CA; [4]Lucile Packard Children's Hospital Palo Alto, CA; [5]Scripps Clinic, La Jolla, CA

Introduction

The efficacy of meniscal allograft transplantation (MAT) and osteochondral allografting (OCA) as individual treatment modalities for select applications is well established. However, few outcomes of concomitant MAT and OCA have been reported. This study is a retrospective review of patients that received simultaneous MAT and OCA at a single institution between 1983 and 2011.

Materials/Methods

48 (29 male: 19 female) patients with an average age of 35.2 (15 – 66) years received combined MAT and OCA procedures between 1983 and 2011. 43 patients had received previous surgery with a mean of 3.3 procedures (1 – 11) indicating the complex nature of the patient cohort. The underlying diagnosis was trauma (tibial plateau fracture) in 33% with osteoarthritis predominating at 54.2% of cases. 31 patients received a lateral meniscus, 16 received a medial meniscus, and one patient received bilateral MAT. The average number of OCAs was 1.8 per patient, with an average graft area of 16.3 cm^2. There were 21 unipolar, 24 bipolar, and 3 multifocal lesions. 36 MAT constituted a compound tibial plateau OCA with native meniscus attached. The mean clinical follow up was 6.8 years (1.7 – 17.1), with patients completing a modified D'Aubigne and Postel scale, Knee Society Function Score, subjective IKDC score and satisfaction, pain, and function questionnaires.

Results

26 of 48 patients required reoperation but only 11 patients were noted to have failed (27.9%); 10 MAT and 11 OCA. The mean time to failure was 3.2 years (1.5 – 4.9 95% CI) and 2.7 years (1.2 – 4.1) for MAT and OCA respectively. The 5 year survivorship was 78% and 73% for MAT and OCA respectively and 69% and 68% at 10 years. Six of the failures were in the OA cases and one was an OCD lesion where bipolar grafts were utilized. The OCD case had a revision OCA and remains intact. The others were converted to knee arthroplasty. One case failed due to early deep infection. Of those with grafts still intact, statistically significant improvements in all outcome scores were noted between baseline and latest follow up. 90% of those responding would have the surgery again and 78% were either extremely satisfied or satisfied with the outcome.

Conclusion

The overall success rate of concomitant MAT and OCA was comparable with reported results for either procedure in isolation. Patients requiring combined MAT and OCA may be categorized in terms of their clinical presentation as either unipolar traumatic injury (treated mostly with enbloc meniscus and tibial plateau allograft) or salvage surgery secondary to OA (treated with MAT + unipolar or bipolar OCA). Firm conclusions regarding failure mechanism are difficult to determine due to the relatively small number of failures in this cohort of rare cases. However, a trend toward worsening outcome being associated with bipolar tibiofemoral grafts (7/11) in the setting of OA is observed. The comparatively better results in less advanced, unipolar disease could suggest that there is a chondroprotective benefit to early intervention that might merit a lower treatment threshold for combined MAT and OCA.

Meniscal Allograft Transplantation: How Should We Be Doing It? A Systematic Review

Peter Myers, Francois Tudor

Introduction

The details of the surgical technique of Meniscus Allograft Transplantation (MAT) are not well publicised. Most authors report reasonable mid to long term outcome results but all report different techniques of surgery and numerous associated surgeries. We chose to focus on issues which are undecided in MAT surgery and to undertake a systematic review of the literature to determine if some consensus with satisfactory outcome data could be found.

Methods

Following PRISMA guidelines a search was completed for PubMed, EMBASE and Cochrane databases with references review and with predetermined inclusion and exclusion criteria.

Results

The searches returned 629 results with 41 meeting the inclusion criteria. There were no randomised or controlled studies and no prospective cases series. Follow-up ranged from 24 months to 14 years (4.8 years).
Indications: all articles report pain after previous menisectomy as the primary indication for MAT. Malalignment and instability of the knee are no longer contraindications if correctable. The amount of chondral damage accepted varies widely as does the maximum patient age.

Graft Type: most authors are now reporting using non-irradiated fresh frozen grafts although some report irradiated, cryopreserved and viable grafts. Half of the reports used the Pollard technique of graft sizing. Some used anthropometric parameters and one each reported MRI and CT scanning techniques. Nine articles did not report a sizing method.

Surgical Techniques: 37 authors reported using an arthroscopically assisted technique while others used an open technique. Medially bone plug fixation was used by 21 authors with 15 using soft tissue only. On the lateral side, a single bone block was used by 20 authors whereas 15 used soft tissue fixation. One study compared fixation types and found a non-significant higher rate of menisectomy in the suture only fixation group. Another study found a significantly higher rate of extrusion with suture only fixation. All inside suturing was reported in only 10 studies.

Associated Surgical Procedures: only 11 articles reported results of MAT alone. Anterior cruciate ligament surgery was performed in 28 articles, chondral surgery in 17 and osteotomy in 12 with many patients receiving multiple associated surgeries. No differences in outcomes have been reported.

Rehabilitation: all but 5 articles reported a rehabilitation program. Most authors allowed their patients to be fully weight bearing with 90° of movement by 6 weeks from surgery. However the programs differed significantly.

Outcome: overall 10 different scoring systems were used to assess outcome with the Lysholm score being the commonest. All studies reported improvements in pain and function but some did not show improvement in activity level by Tegner scoring.

Failures and complications: 7 authors did not report failures. Of the 1,849 MAT's identified, 140 (7.55%) subsequently required menisectomy, 13 (0.07%) a revision MAT and 39 (2.1%) required refixation. Some degree of complication through to complete failure was reported in 26.3% of patients.

Discussion

Overall MAT appears to be a worthwhile procedure in well selected patients. There is no data to support either bony or soft tissue fixation and there is no consistent recognised rehabilitation program. A uniform definition of failure and use of consistent outcome scores would aid future reporting and analysis.

The Emerging Biological Role of the Meniscus in Osteoarthritis: Implications for Meniscal Restoration.

Austin V. Stone MD PhD[¥1], **Ian D. Hutchinson MD**[¥1], Justin Hicks, B.S, Scott A. Rodeo, MD[2], Cristin M. Ferguson, MD[1].
[1]*Wake Forest Baptist Health, North Carolina, USA;* [2]*Hospital for Special Surgery, New York, USA.*
¥ (both authors contributed equally)

Introduction

The biomechanical role of the meniscus in delivering joint congruity and normal loading of the articular cartilage are well accepted. Meniscal deficiency, including meniscal tears, partial and total meniscectomy, disposes the articular surfaces to altered loading and is associated with joint degeneration. However, recent evidence suggests that the meniscus (and meniscal injury) may also have an active biological role in osteoarthritis (OA) pathogenesis. The purpose of this review is to highlight recent developments in the literature with a particular emphasis on investigating: i) the metabolic status of injured meniscal tissue as a local healing environment and with respect to other joint tissues and ii) the implications of transplanting viable meniscal tissue on joint homeostasis and potential osteoarthritis risk.

Methods

A literature search was conducted to identify all articles related to the biological role of the meniscus in osteoarthritis using a **narrative approach**. The following databases were searched; Medline, CINAHL, Cochrane, and Pubmed. Controlled vocabulary was used when available and reference tracking was performed for any articles potentially missed throughout the search. The articles were then reviewed and included based on inclusion criteria: original research articles that investigate the biological role of the meniscus (and meniscal fibrochondrocytes) in osteoarthritis development and progression.

Results

(1) Obesity (BMI>30kg/m^2) is associated with dysregulation of anabolic gene expression in partial meniscectomy tissue and up regulation of Ca^{2+} ion binding, associated with OA. (2) Age-related differential gene expression is demonstrated in patients >40 years, impairing the meniscal healing potential. (3) Age-related alterations in cytokine and chemokine secretion may accelerate joint tissue degradation. (4) Pro-inflammatory stimulation of meniscal cells isolated from healthy menisci results in increased matrix metalloprotinase (MMP) secretion and enhanced catabolic gene expression implicated in osteoarthritis pathogenesis. (5) In younger patients (<40 years) an upregulation of catabolic mediators was demonstrated in resected partial meniscectomy tissue; resected meniscal tissue in patients with concomitant ACL injury showed further catabolic shifts. (6) Current interpretation of *ex-vivo* meniscal tear studies is hampered by tissue analysis only of the injured, resected meniscal tissue in the absence of synovial fluid and joint tissue assessment.

Discussion

The meniscus is a biologically active tissue that not only responds to factors produced by pathologically altered cartilage and synovium, but also actively produces catabolic factors that may contribute to joint degeneration. Further exploration of the pathobiology manifesting in injured meniscal tissue will enable the clinical and basic science pursuit of meniscal restoration and whole joint health. The potential of symptomatic, injured meniscal tissue to act as a catabolic nidus within the knee joint (particularly of younger patients) is becoming recognized. In addition, the pre-arthritic nature of non-traumatic isolated meniscal tears in middle-aged patients has been described. In addition to the biomechanical benefits of MAT, further studies should investigate the biologic ramifications of viable meniscal allografts to actively contribute to joint homeostasis following implantation. In this regard, it is possible that unfavorable viable meniscal tissue may accelerate osteoarthritic changes through pre-arthritic biologic activity and active interaction with the other joint tissues (cartilage and synovium). In conclusion, consideration of the meniscus as a metabolically active tissue that actively interacts with the other joint tissues will compliment contemporary surgical approaches to MAT and meniscal restoration, particularly with respect to offsetting the significant risk of premature joint degeneration.

Targeted Growth Factor Delivery to Augment Early Meniscus-Scaffold Interface Development

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Introduction

Scaffold-meniscal tissue integration is critical to the long term clinical success of restorative surgery. Clinically, interface development is facilitated by post-operative restrictions in weight bearing and range of motion, but gaps at the scaffold-meniscal tissue interface still occur[1,2]. To address this issue, the use of growth factors as a stimulus for cell migration and matrix deposition have been investigated in vitro [3,4,5]. The in vitro models are typically designed to allow for growth factor supplementation through addition to the media. Such non-directional supplementation elicits a response from all cells, and not the intended target cells at the interface. Furthermore, degradable scaffolds are typically used; the morphology and mechanics of which change with time. In such a continually changing environment, the growth factor effect cannot be effectively isolated and studied.

The goal of this study was to investigate the ability of targeted growth factor delivery to improve meniscus-scaffold integration. To achieve this goal, a non-degradable scaffold was augmented with growth factor-seeded microparticles. The response of the interface to the following factors was tested using an in vitro tissue-scaffold annulus model: Insulin-like Growth Factor (IGF-1), TGF-β3, BFGF, Platelet Derived Growth Factor (PDGF).

Methods

A non-degradable, macroporous interconnected polyvinyl alcohol (PVA powder, Sigma Aldrich, St. Louis, MO) scaffold was augmented with Chitosan (Sigma Aldrich, St. Louis, MO). Growth factor laden alginate microparticles were manufactured using an oil-in-emulsion technique then cross-linked PVA-Chitosan scaffolds. Meniscal explants were cored out from red-white zone mature bovine meniscus (8mm diameter; 2.5mm depth). A biopsy punch was used to create a circular defect through the center of the explant (3.5mm) into which the scaffold was press-fit. The following groups were tested: FITC-Dextran (control), BFGF, PDGF, TGF- β3, and IGF-1 for n=6 in all groups. All samples were cultured in media containing 10% fetal bovine serum but devoid of specific growth factor augmentation for 28 days. In the control group, the FITC dextran matched the average molecular size (20kDa) of the growth factors. Outcome measures included interface strength (pushout test) and histology. Histological analysis was undertaken using the untested scaffold–meniscus explants. These were fixed in neutral buffered formalin + 0.5% cetylpyridinium chloride, cryoprotected in a 30% sucrose solution and embedded in the gelatin–sucrose medium. Blocks were cryotomed for histological analysis of i) interfacial GAG deposition using Safarin-O/Fast Green histological stains cellular infiltration using , ii) interfacial collagen deposition using Picrosirius Red using 8 µm sections.

Results

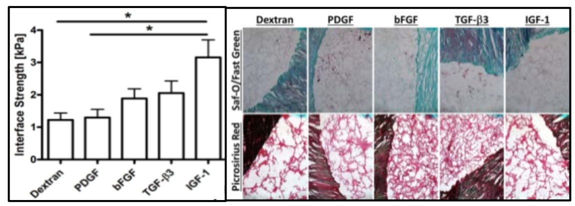


Fig. 1 (left) Pushout strength of the scaffold groups. Fig. 2 (right) Histology of the early meniscus scaffold interface.

Delivery of IGF-1 to the meniscus scaffold interface resulted in significant increase in interface strength (fig.1) (n=15, $P<0.05$). All growth factor groups demonstrated histological evidence of integration with increased collagen and glycosaminoglycan deposition at the meniscus-scaffold interface, compared to the control (fig.2).

Discussion

In conclusion, using a meniscal scaffold capable of delivering growth factors directly to the interface, IGF-1 resulted in a significantly stronger interface at the early 28 day time-point. IGF-1 has previously been identified as a candidate growth factor to enhance meniscal healing and meniscal scaffold regeneration[6,7]. However, to fully understand and appreciate the tissue effects of specific growth factor gradient exposures at the interface requires the development of a computationally-augmented platform (modelling growth factor pharmacokinetics and meniscal tissue exposure). Currently underway in our laboratory, this integrated approach will be used to identify the exact nature if the optimal biological stimulus and cellular behaviors required to augment interfacial development may be more accurately elicited guiding the use of biologics and tissue engineered technologies.

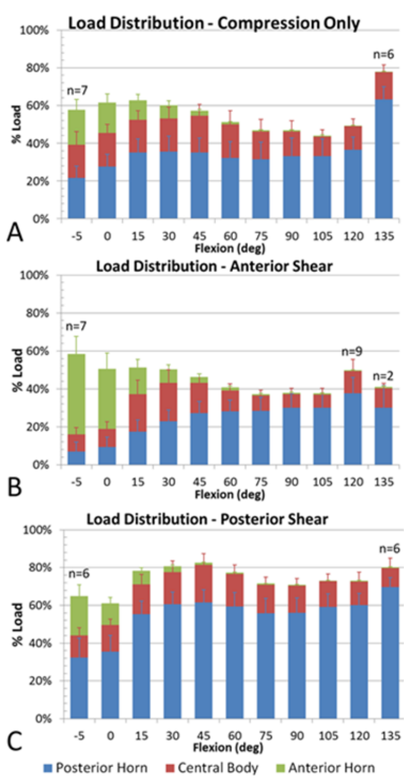
References

1) Spencer, *Knee* 2012; 2) Moran, Int Orthop 2014; 3) Ionescu, *Acta Biomater*. 2012; 4) Ionescu, *Tissue Eng Part (A)*, 2011; 5) McNulty, Biorheology, 2008; 6) Zhang, *CORR*, 2009; 7) Puetzer, *Tissue Eng Part (A)*, 2013.

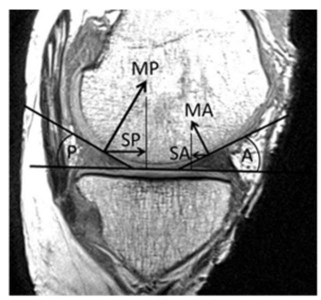
FUNCTION OF THE MEDIAL MENISCUS IN FORCE TRANSMISSION AND STABILITY

Peter S Walker PhD, Sally Arno PhD, Christopher Bell MSc, Gaia Salvatore BSc, Ilya Borukhov BSc
Laboratory for Orthopaedic Implant Design, New York University – Hospital for Joint Diseases

There is still uncertainty concerning the role of the menisci in distributing load and providing stability. In this paper, we focus on the medial meniscus because the medial side is most often affected in osteoarthritis. MRI scans were taken of ten knee specimens to determine the geometry of the structures, and the absence of abnormal pathology. The knees were loaded in combinations of compressive and shear loading over a full flexion range. Tekscan sensors were used to measure the pressure distribution across the joint as the knee was flexed continuously through a full range. A digital camera was used to track the motion, from which femoral-tibial contacts were determined by computer modelling. Load transmission was determined from the Tekscan for the anterior horn, central body, posterior horn, and the uncovered cartilage in the center of the meniscus. For the three types of loading; compression only, compression and anterior shear, compression and posterior shear; between 40-80% of the total load was transmitted through the meniscus, the overall average being 58%. The remaining 42% was transmitted directly through the uncovered cartilage. The anterior horn was loaded only up to 30 degrees flexion, and played a role in controlling anterior femoral displacement. The central body was loaded 10-20% and would provide some restraint to medial femoral subluxation. Overall the posterior horn carried the highest percentage of the shear load, especially after 30 degrees flexion when a posterior shear force was applied, for which the meniscus was estimated to carry 50% of the shear force. This study added new insights into meniscal function during weight bearing conditions, particularly in early flexion, and in transmitting shear forces.

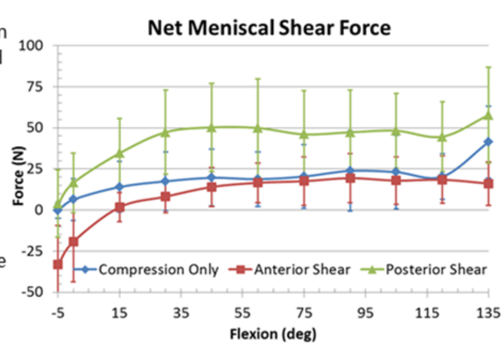


Left: The average percentages of the forces on the 3 meniscal zones at the different flexion angles for the 10 knees tested. 2a, vertical compression; 2b, compression and anterior shear, 2c, compression and posterior shear. The remaining force (up to 100%) was carried on the uncovered cartilage on the center of the tibial plateau.



Above right: Analysis for estimation of shear forces between the meniscus and the femur, based on a mid-medial sagittal MRI section. MP= resultant force at posterior horn; SP = shear component = NP sin P; MA = resultant force at anterior horn; SA = shear component = MA. sin A; Net anterior shear force = SP-SA.

Right: Calculated shear forces (Newton) between the medial meniscus and the femur, for a total of 500N compressive load and 100N shear load applied to the kneeThe vertical axis also represents % of the applied shear force which was 100N. Positive values indicate an anterior force of the meniscus on the femur.



Meniscal Allograft Transplantation: Effect of Fixation on Medial and Lateral Compartment Biomechanics

<u>Russell F Warren MD</u>, Caroline Brial, MS, Moira McCarthy, MD, Hongsheng Wang, PhD, Albert Gee, MD,
Kirsten Stoner, MS, Ian Hutchinson, MD, Tony Chen, PhD, Suzanne A Maher PhD
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Introduction

While many factors can effect the functional characteristics of meniscal allograft transplantation (MAT), the method of fixation is directly under the control of the surgeon. In the medial compartment, *transosseous suture fixation via bone plugs* and *suture-only* fixation at the mensical horns are typically used. While in the lateral comparment, a *keyhole fixation* method (anterior and posterior meniscal horns attached to a single bone block) and a *bone plug fixation* method *(*two separate bone segments) are used. The objective of this study was to quantify the effect of meniscectomy and MAT as a function of fixation method, in both the medial and lateral compartment of the knee joint during gait.

Methods

Twelve human cadaveric knees were subjected to multi-directional loads to mimic gait.[1] Contact stress across the tibial plateau was measured using a thin resistive sensor (Tekscan, Boston, MA) that was placed underneath the menisci and across either the lateral plateau or the medial plateau (n=6 knees per group). In each group of knees, intact, meniscectomized and MAT were simulated. In the lateral compartment, the meniscus was replaced first using the *keyhole* technique, and then using the *bone plug* technique. In the medial compartment, the meniscus was replaced, first using *transosseous fixation via bone plugs* and then using *suture only* fixation. The following outcomes were quantified: Contact area, peak contact stress, and weighted center of contact stress (a measure of contact location)[2]. Data was computed at two points in the gait cycle at which axial load peaked (14% and 45% of the gait cycle). A paired one-way repeated measures ANOVA with Tukey post-hoc test was used for statistical analysis, with $p<0.05$ representing significance.

Results

Effect of meniscectomy: Medial meniscectomy led to reduced contact area and increased contact stresses only at 14% of the gait cycle, while lateral meniscectomy significantly increased contact stress and decreased contact area at both 14% and 45% of the gait cycle. *Effect of method of fixation*, <u>lateral compartment</u>: *bone plug fixation* led to significantly higher peak contact stress compared to the intact condition at 14% and 45% of the gait cycle. There was no significant difference between intact and *keyhole* fixation; but contact area at 45% of the gait cycle was significantly lower for the *keyhole* fixation compared to intact. The center of contact shifted posteriorly after meniscectomy and was partially restored with both fixation methods. <u>Medial compartment</u> – *suture fixation* led to significantly higher peak contact stresses compared to the intact condition. There was no significant difference between intact and *transosseous fixation via bone plugs* for peak contact stress and contact area at 14% of the gait cycle. The center of contact shifted peripherally, and this offset was partially restored with the transosseous fixation via bone plugs.

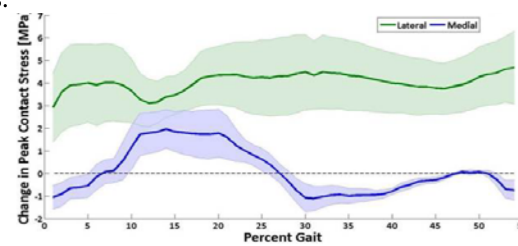

Figure 1: Average change in peak contact stress between intact and meniscectomy on the lateral and medial plateau throughout the stance phase of gait.

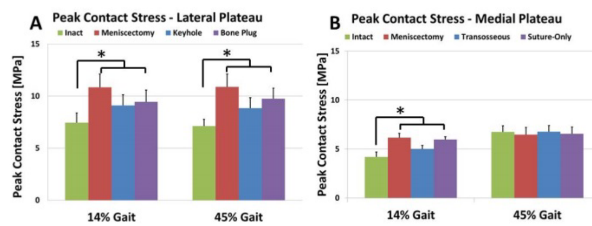

Figure 2: Peak contact stress on the [A] lateral plateau and [B] medial plateau at 14% and 45% of the gait cycle. * denotes significantly different from intact condition.

Discussion

By way of a cadaveric model which mimics gait, we demonstrated that the effect of meniscectomy and graft fixation on joint contact mechanics is sensitive to the phase of gait, the method of fixation and the compartment. Medial meniscectomy led to reduced contact area and increased contact stresses only in early stance, while lateral meniscectomy led to significant changes in early and late stance. This result may explain the differences between the response of the medial and lateral compartment to meniscectomy that have been observed clincially[3]. Contact mechanics were improved for both compartments relative to the meniscectomy condition with MAT. But the extent of restoration of intact mechanics was affected by the method of fixation. In the lateral compartment, the *keyhole* method was more successful in restoring the contact mechanics to that of an intact knee, while in the medial compartment, *transosseous suture fixation via bone plug* was preferred.

Acknowledgements: The Russell F. Warren, MD Chair in Tissue Engineering and NIH for funding this work. **References:** 1. Gilbert, Chen et al: *J Biomech*. 2013. 2. Wang et al: Am J Sports Med. 2014. 3. Nawabi et al: Am J Sports Med. 2014.

Knee contact mechanics before and after meniscus allograft transplantation
A preliminary in vivo study

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Introduction: Accelerated joint degeneration is well-documented following total meniscectomy, with more rapid degeneration and a higher incidence of degenerative changes after lateral meniscectomy compared to medial meniscectomy[1, 2]. A primary goal of meniscal allograft transplantation (MAT) is to delay the progression of cartilage degeneration in the meniscal deficient compartment, but clinical results have been variable[3]. Previous cadaveric studies showed that meniscal replacement increases the weight bearing area and decreases the magnitude of contact stress across the articular surfaces[4]. However, *in vivo* knee joint loading patterns in patients before and after meniscus graft placement has yet to be investigated. The objective of this study was to measure contact stress and weight bearing area on the articular surface in patients undergoing MAT.

Methods: So far, four patients (3m/1f, age 24±9 year, weight 77±6 kg) who were to undergo lateral meniscal allograft transplantation surgery were enrolled. In addition to standard-of-care MRI, each patient underwent morphological (SPGR) and quantitative (T1rho and T2) MRI scans to assess cartilage thickness and composition at the time of transplantation. Images were acquired with no joint load and then under axial load (50% body weight). Thereby, changes in cartilage thickness (mechanical integrity) and T2 relaxation time (measure of collagen organization) in response to load were quantified.

During the surgery, contact stress on the tibial plateau was measured using a thin-electronic sensor (Tekscan Inc.). The sensor was calibrated and trimmed to accommodate to the shape of the tibiofemoral compartment (Fig. 1), then sterilized using ethylene oxide. The sensor was passed through a small arthrotomy from anterior to posterior by pulling the posterior tab via a passing suture placed through a posterolateral incision, and its position was adjusted arthroscopically to cover the whole tibial plateau. A custom designed device was used to apply a 50% body weight axial load to the foot with the knee in full extension, while the contact stress on the tibial plateau was synchronously recorded. Contact stress and weight bearing area were measured before and after meniscus allograft placement using bone-plugs (MAT).

Results & Discussion: Compared to the meniscectomy condition, a decrease in peak contact stress (3.0±1.2 MPa vs. 2.1±1.0 MPa) and increase in weight bearing area (209±14 mm^2 vs. 265±53 mm^2) was found in the MAT condition (Fig. 2 A-C). In addition, the weight bearing region shifted from peripheral to central tibial plateau. The location of peak contact stress was correlated with the location of cartilage deformation (Fig. 2D). There was a significant reduction in T2 relaxation time within the cartilage in the lateral compartment (35.8±10.9 ms vs. 30.5±12.6 ms, Fig. 2E) which may correlate with water exudation and increased collagen alignment after mechanical loading.

These patients will be followed up with postoperative MRI at 6 and 12 months. Evaluation of the changes in cartilage thickness, mechanical integrity, and biochemical composition will be quantified and compared to time-zero measurements. The unique imaging-mechanical data will help identify biomechanical predictors of early cartilage degeneration following MAT.

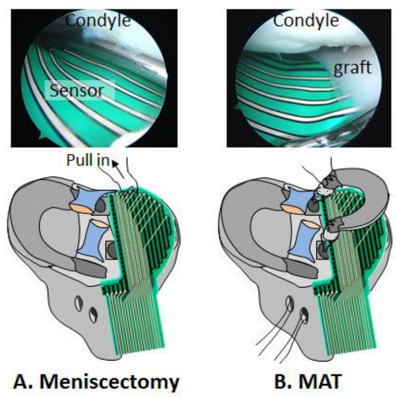

Figure 1: Arthroscopic photo (top) and illustration of sensor placement.

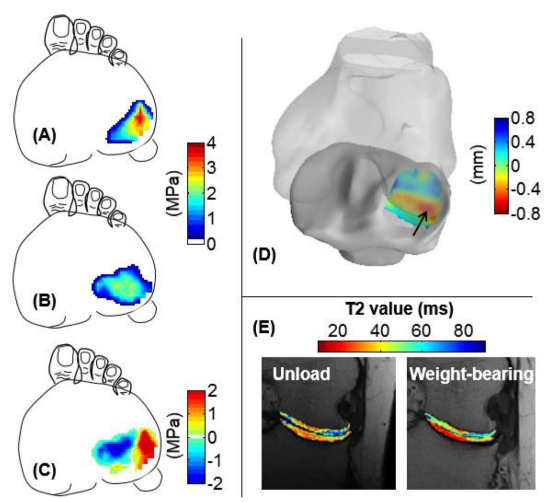

Figure 2: Contact stress of a representative patient at (A) meniscectomy, (B) MAT condition and (C) MAT *minus* meniscectomy. Decrease in (D) cartilage thickness and (E) T2 relaxation under loading.

Acknowledgements: American Orthopaedic Society for Sports Medicine. **References:** 1. Fairbank TJ: JBJS. 1948. 2. Nawabi et al: Am J Sports Med. 2014. 3. Lubowitz et al: *KSSTA*. 2007. 4. Wang et al: AJSM. 2014.

The new approach to medial meniscus transplantation based on cadaveric study of 37 human fresh cadaveric knees

R. Śmigielski, MD, U. Zdanowicz, MD

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37 fresh frozen cadaveric knees from 37 humans were used in this cadaveric study. Medial meniscus anatomy was carefully evaluated and reconfirmed with histology. Anatomy was documented on digital high resolution professional pictures. 5 uneven anatomical zones with different attachment structure were distinguish. Its potential influence on medial meniscus transplantation technique is discussed.

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