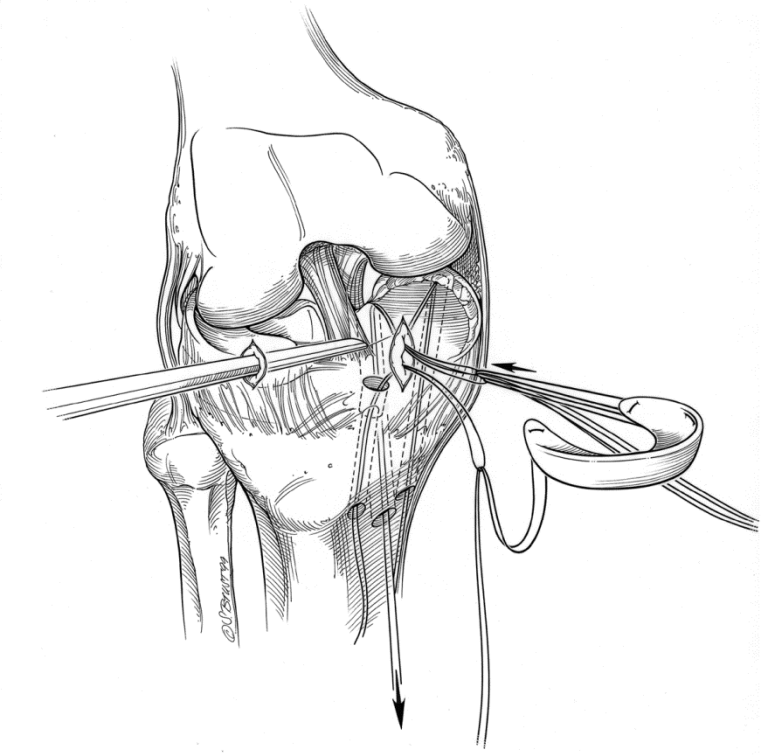
2013 Meeting of the Meniscus Transplantation Study Group

Thursday March 21, 2013
1:00pm – 3:30pm

Hyatt Regency McCormick Place
Regency Ballroom E
2233 S. Martin Luther King Drive
Chicago, Illinois 60616



Meeting Agenda

Welcome and Introduction

Kevin R. Stone, MD

Presentations

Moderated by David Caborn, MD

All presentations will be 6 minutes followed by a 2 minute discussion

Meniscus wrapping technique
Presented by Roland P. Jakob, MD

The effect of medial compartment meniscal allograft transplant fixation techniques on contact mechanics during simulated physiological gait
Presented by Ian Hutchinson, MD

In-vivo loading to define contact mechanics in patients undergoing meniscus allograft transplantation
Presented by Hongsheng Wang, MD

Meniscus allograft transplantation: an all inside anatomic soft tissue technique with suture anchor aperture horn fixation and tensioning. A 3 year follow-up study
Presented by David Caborn, MD

Transplantation of meniscal allografts. Survival analysis of 217 cases
Presented by Peter Verdonk, MD, PhD

Comparative study of immediate and delayed meniscus allograft transplantation: focus on clinical results and cartilage protection
Presented by Jia-Kuo Yu, MD, PhD

Meniscal allograft transplantation in isolated and combined surgery
Presented by Hui Zhang, MD

Meniscus allograft transplantation allows return to sporting activities
Presented by Kevin R. Stone, MD

Meniscal allograft transplantation in professional soccer players
Presented by Stefano Zaffagnini, MD

Synthetic scaffold for meniscal regeneration: prospective clinical study at 3 years follow-up
Presented by Elizaveta Kon, MD

Treatment of post-meniscectomy syndrome with a free-floating meniscus implant: a prospective, open label, single-arm trial
Presented by Peter Verdonk, MD, PhD

Arthritis self-efficacy scale pain and other symptom subscale scores in knee osteoarthritis: a systematic review and meta-analysis comparing arthritis self management education with or without exercise
Presented by Emily Brand-Monroe, MD

Industry Session

Led by Kevin R. Stone, MD

Meniscus wrapping technique

RP Jakob, M. Jacobi, Th. Piontek, K. Ciemniewska

[1]*University of Louisville, Louisville, KY*

Introduction: Meniscus wrapping technique is based on the experience of the senior author. Wrapping the meniscus with a collagen membrane might create kind of bioreactor within the knee, guiding cell ingrowth and improving stability of the suture. Following meniscal pathologies were included:

- Tears in the red-white or white-white zone
- Complex tears
- Delayed traumatic tears with degenerative aspects
- Repeat sutures

30 patients have been treated with this technique from 2003-2007. Baseline data is presented in table 1.

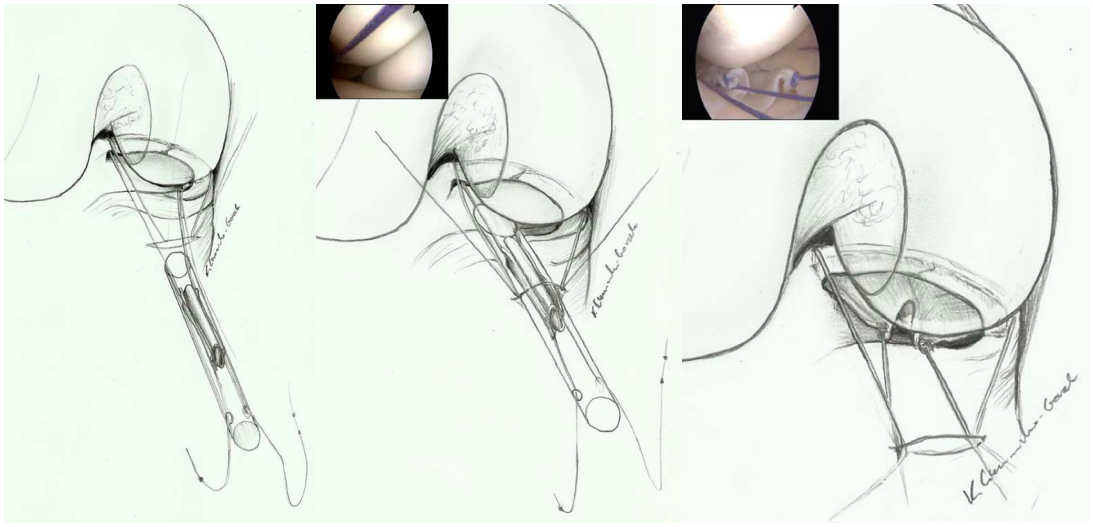
Technique: The meniscus is reduced and mechanically sutured with classical inside-out sutures. Then, the collagen I/III membrane (Chondro-Gide or Bio-Gide, Geistlich, Biomaterials, Switzerland) is prepared outside the knee with two holding sutures on the inferior corners and a holding suture for potential retrieval in the middle of the matrix. This is then pulled inside the knee through a cannula and placed on the meniscus, first fixed underneath and then flipped on the upper surface and fixed with multiple sutures stabilizing the membrane on the meniscus plus adding stability to the suture of the meniscal tear. After treatment is no different from an ordinary meniscal repair.

Results: After a mean follow-up of 2.5 years (range 1-5) three patients had a symptomatic failure (10%). In two of them a partial meniscectomy was performed and in one case (a 20 year old female with second suture of a bucket handle tear) a third suture associated with an unloading osteotomy was performed which healed finally. All other cases 27 (90%) were asymptomatic. Additionally the following complications were noted: One arthrofibrosis which needed mobilisation under anaesthesia; One saphenus nerve entrapment, which needed revision and one ACL-rerupture after ACL-reconstruction and new trauma (the meniscus stayed intact).

Conclusions: This repair enhancement technique seems to improve healing chances also in unfavourable situations. Although evaluation was not done with a control arthroscopy the high percentage of 90% proved stable and asymptomatic after a mean follow-up of 2.5 years.

Meanwhile, from 2010-2013, the technique has been refined in a series of 90 patients by the Polish Authors going to All-Inside fixation and adding routinely marrow blood at the end of the procedure retrieved from the proximal tibia or the distal femur. Prospective data collection with adequate results allows future extension of the study.

Table 1: Baseline Data	
Men / Women	19 / 11
Associated injuries	10 ACL-Lesions (reconstruction) 1 medial meniscus (normal suture)
Medial / Lateral meniscus	23 / 7 all in the red-white or white-white zone
Complex tears	15
Bucket handle tears	11
Horizontal tears	4



The effect of medial compartment meniscal allograft transplant fixation techniques on contact mechanics during simulated physiological gait

Hutchinson, Gee, Wang, Chen, Stoner, Warren, Maher

Hospital for Special Surgery, 535 East 70th Street, New York

Introduction: The changes that occur in contact mechanics after meniscectomy have been implicated as the primary cause of early onset osteoarthritis[1, 2]. To restore normal joint contact stresses, Meniscus Allograft Transplants (MAT) have been used as substitutes for the native meniscus and function to redistribute loads on the operated compartment. Meniscal allografts are thought of as an ideal replacement as they recapitulate the viscoelastic anisotropic material properties of the native meniscus. Additionally, they have been shown to relieve the symptoms associated with meniscal injuries however, whether or not these grafts are able to restore normal joint contact stresses is yet unknown. Many variables have been identified for the success of MAT in restoring joint contact forces, of which, surgical fixation of the graft has been identified as one of the most crucial [3].

The fixation modalities most commonly utilized in the medial compartment are: (i) *trans-osseous suture fixation via bone plugs*, where bone plugs are prepared at the anterior and posterior horns of the graft and implanted into appropriately sized tibial bone tunnels, and (ii) *suture fixation at the meniscal horns*, where the sutures are drawn through tibial bone tunnels and tied over a bone-bridge. While finite element modeling has suggested that bone plug fixation may be advantageous, clinical outcome and in-vitro studies have not demonstrated significant differences between these fixation techniques[4,5,6].

The objective of this study was to quantify the dynamic contact mechanics associated with two commonly used graft fixation techniques in the medial compartment - *trans-osseous suture fixation via bone plugs* and *suture fixation at the meniscal horns*. Our hypotheses were that both methods would improve contact mechanics relative to the meniscectomized condition, but that only *trans-osseous suture fixation via bone plugs* would restore contact mechanics to that of the intact knee.

Methods: *The Model*: A Stanmore Knee Simulator (Middlesex, UK) was modified to accept cadaveric knees. This simulator was used to dynamically apply axial forces, anterior-posterior forces, internal-external torques, and flexion angles across human cadaveric knees (n=5) to mimic the activity of gait [7] (Fig. 1). Contact forces across the tibial plateau were measured using an electronic sensor (Model 4010N, Tekscan Inc, MA) consisting of an array of sensing elements (sensels) spread across the sensor at 2mm intervals. The sensor was placed on the tibial plateau, under the medial meniscus, and data was recorded at a frequency of 100 Hz. The knees were first tested intact after which the medial meniscus was resected with the bone plugs en-bloc. The resected meniscus was used as a perfectly-sized allograft, congruent with the tibial surface thus controlling for other confounding factors.

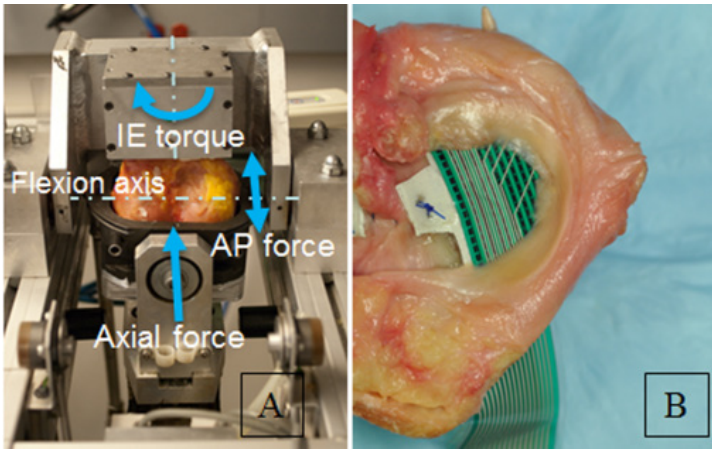


Fig. 1 (A) Cadaveric knee was placed into the knee simulator (B) Pressure sensor was placed under the medial meniscus.

Procedure: Each knee was tested under the following sequential conditions: (i) intact, (ii) trans-osseous suture fixation via bone plugs (BPC) - fixation of the same meniscus with sutures and bone cement to simulate the mechanical consequences of bone ingrowth, (iii) bone tunnel suture fixation at the meniscal horns (BTS) - the bone plugs were removed from the meniscus and fixation of the meniscus at the horns with suture-only through bone tunnels, and (iv) medial meniscectomy. Twenty gait cycles were collected from each condition at a frequency of 0.5 Hz.

Outcome Measures: For each time point in the stance phase of the gait cycle (3 – 55% of gait), the following data was computed using customized Matlab programs (r2008a, MathWorks Inc., Natick, MA): peak contact stress, contact area, and the weighted center of stress (CoS). The differences between conditions were determined using a Two-way ANOVA with a = 0.05.

Results: The peak contact stresses in the meniscectomized condition were significantly higher than that of the intact condition during the early phase of stance (10-25%). BTS fixation failed to reduce the excessive peak stresses associated with meniscectomy, while BPC fixation significantly decreased the peak stresses, to levels similar to that of the intact condition

(Fig. 2A). Interestingly, the maximum contact stresses were significantly increased at the first peak of applied axial force, which occurs at 14% of the gait cycle while no differences were found at the second peak of applied axial force, which occurs at 45% of gait cycle.

After meniscectomy, the cartilage-cartilage contact in the medial compartment was significantly reduced during early-to-mid stance (5–32%) (Fig. 2B). Both fixation techniques led to a significant increase in contact area relative to the meniscectomized condition, but did not restore contact area to that of the intact condition.

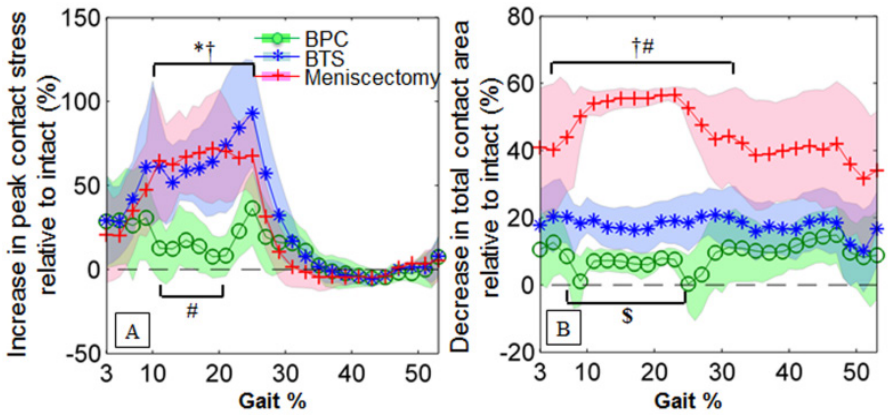


Fig. 2 The change in (A) peak contact stress (Mean +/- sem) and (B) contact area normalized by the intact values (in percentage) during the stance phase of gait. †p<0.05 Meniscectomy vs. Intact, * BTS vs. Intact, # BPC vs. Meniscectomy, $ BTS vs. Meniscectomy.

In meniscectomized knees, the CoS trajectories (weighted center of stress) shifted to the anterior and peripheral regions of medial tibial plateau relative to the intact knees (Fig. 3B-C). Neither BPC nor BTS restored the anterior-posterior location of the CoS to that of the intact condition (Fig. 3B). However, BPC exhibited improved correction of the peripheral-central location of the CoS compared to that achieved by BTS (Fig. 3C).

Conclusions: Contact mechanics of the knee joint were significantly affected by method of meniscal allograft fixation. Contact area, peak contact stresses and center of stress trajectory were improved relative to the meniscectomized condition for both fixation methods. However, BPC fixation more closely restored contact mechanics to that of the intact condition, thus supporting our hypotheses. Our study also suggests that the locations of contact stresses are significantly altered after total meniscectomy. Since the tibial cartilage is relatively thinner on the peripheral sites[8, 9], the peripheral shifting of the contact stresses may accelerate cartilage degeneration. The differences in peak contact stress as well as in the contact area mainly occurred during the first half of the stance phase, suggesting that the meniscus is functionally active mainly during the early phase of stance. In conclusion, our study suggests that trans-osseous fixation via bone plugs provides superior contact mechanics than suture fixation.

References: [1] McDermott et al. *JBJS Br* 2009. [2] McCann et al. *Osteoarthr Cartilage* 2009. [3] Matava, Clin Orthop Relat Res. 2007. [4] Brophy, Matava *J Am Acad Orthop Surg* 2012. [5] Hunt et al, *Bull NYU Hosp Jt Dis*. 2008. [6] Haut Donohue et al, *J. Biomech*, 2003. [7] Bedi et al. *JBJS* 2010. [8] Andriacchi et al. *JBJS* 2009. [9] Chaudhari et al. *Med Sci Sports Exerc* 2008.

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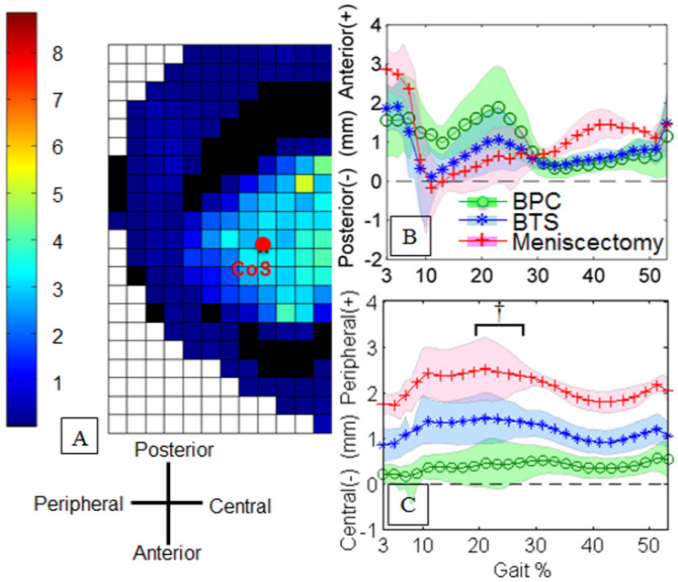

Fig. 3 (A) The center of stress on medial tibial plateau (Mean +/- sem), the dislocation in (B) anterior-posterior direction and (C) central-peripheral direction relative to the intact values during the stance phase of gait. †p<0.05 Meniscectomy vs. Intact.

In-vivo loading to define contact mechanics in patients undergoing meniscus allograft transplantation

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Introduction: Complete meniscectomy often leads to pain and early-onset of osteoarthritis[1, 2]. Changes in contact mechanics in the meniscus deficient compartment have been implicated for the rapid progression of osteoarthritis, although the exact mechanism is unknown. In addition to providing symptomatic relief, meniscus allograft transplantation (MAT) may offer a degree of chondroprotection by restoring the native meniscal contact mechanics. However, currently there is no objective measure of the ability of MAT to approximate the native meniscal contact mechanics.

The purpose of this study was to investigate the differences in peak pressure, contact area and load sharing between intact, meniscectomized, and allograft conditions at various physiological loads and flexion angles. This information will be used to define parameters that can be measured in the OR and used to quantitatively determine the ability of a MAT to provide symptomatic relief and restore compartmental contact mechanics. Our overall goal is to develop techniques to measure contact mechanics intra-operatively in patients undergoing MAT.

Methods: A modified load controlled, multidirectional knee simulator (Stanmore, Middlesex, UK) was used to apply axial forces (approximate 1/2, 1, 3/2 of body weight) at different flexion angles (0°, 10°, 20°) across two human cadaveric knees. Contact forces across the tibial plateau were measured using an electronic sensor (Model 4010N, Tekscan Inc, MA). Three conditions were reproduced: intact meniscus, MAT-bone plug suture (BPS) and meniscectomy. The medial meniscus was resected with bone plugs en-bloc and reduced and fixed to serve as the allograft condition. Applied axial load was maintained for forty seconds for each condition. For each trial, peak contact stress, medial load share (percentage of the total load carried by the medial compartment) and contact area were recorded as a function of both flexion angle and load.

Results: The peak contact pressure in the meniscectomized condition was higher than the peak contact pressures measured in the intact condition at 10° and 20° of flexion. Meniscal allograft (BPS) partially restored the peak pressures compared to the meniscectomized condition and is most pronounced at ½ BW and 20° of flexion. After meniscectomy, the medial compartment contact area was significantly reduced. Meniscal allograft led to an increase in contact area relative to the meniscectomized condition, but did not restore contact area to that of the intact condition (Fig. 1).

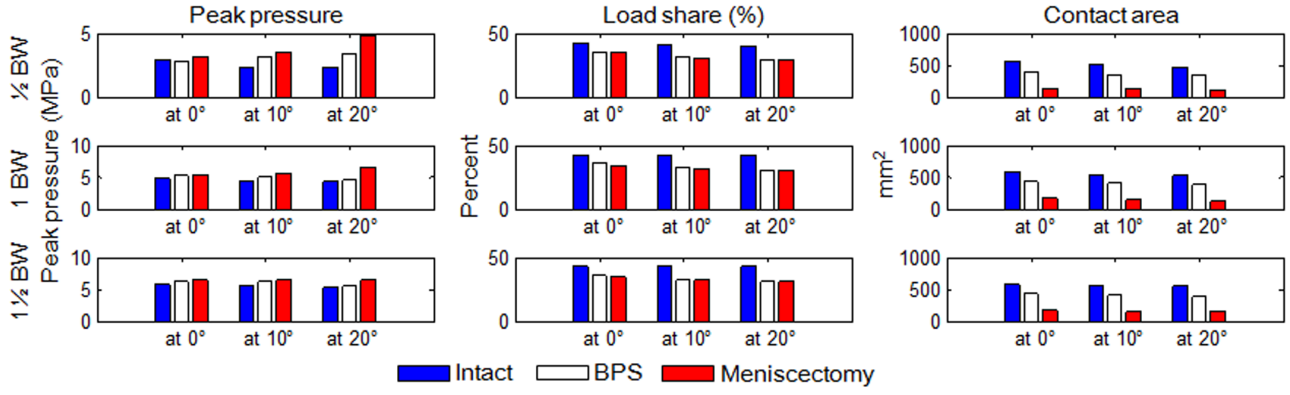

Figure 1. The peak pressure, load share and contact area on the medial tibial compartment at different axial loads approximating 1/2, 1 and 3/2 body weight respectively.

Conclusions: Our early results confirm the feasibility of analyzing load sharing, contact area and maximum contact pressure measurements *in vivo* in the human knee within the constraints of the O.R. The variation in contact mechanics suggest that the medial meniscus does, in fact, have a role in contact mechanics at 20° flexion and this is congruent with findings from a physiologic dynamic model for medial MAT fixation in our lab (unpublished data). It is expected that the contact mechanics would be affected even more at higher flexion angles. We measured these parameters at lower flexion angles as our ultimate goal is to correlate this data with MR images of the knee under axial load. This data may be linked to quantitative MRI of articular cartilage before and after MAT to evaluate its role as a surrogate for mechanical measures peri-operatively as part of the selection process for patients undergoing MAT.

Meniscus allograft transplantation: an all inside anatomic soft tissue technique with suture anchor aperture horn fixation and tensioning. A 3 year follow-up study

David Caborn, MD

[1]*University of Louisville, Louisville, KY*

Introduction: The meniscus is an integral structure for the biomechanical and biological well being of the joint. Prior results have demonsrated it to be a viable treatment option for the subtotally and totally meniscectomized knee. The difficulty and invasiveness of the surgical procedure has deterred many surgeons thus potentially compromising the longevity of the joint. The use of an all inside anatomic soft tissue meniscus transplantation technique will reduce pain and improve knee function at a 3 year follow up.

Methods: Twenty-four patients underwent meniscus transplantation (16 medial and 8 lateral) 15 male, 9 female and average age 32yrs. Transplantation technique involved a soft tissue procedure with modified Mason Allen high tensile suture in the horns and anatomic horn restoration using an accessory posterior portal and suture anchor aperture fixation with subsequent tensioning . Bucket handle stabilization then performed with an all inside meniscus repair technique. Patients were evaluated with IKDC, KOOS, Lysholm and Tegner scales.

Results: Clinical evaluation showed a mean IKDC score of 76 (SD 16), KOOS 74 (SD 17), Lysholm 79 (SD 13) and Tegner 7 (5-10). Of the 24 patients 5 required further surgery. 3 concomitant OW HTO's went on to medial UKA, 1 concomitant ACL, microfracture required partial meniscectomy and 1 concomitant ACL required adhesiolysis.

Conclusions: This small retrospective early series showed improvement in preoperative pain and function without increasing morbidity and decreasing invasiveness. This may be particularly important when complex combined procedures are contemplated.

Transplantation of meniscal allografts. Survival analysis of 217 cases

Sofie Herregods, Arnoud de Kock, Rene Verdonk and Peter Verdonk

Departments of Orthopaedic Surgery, Monica Hospitals Antwerp, Belgium and Ghent University, Belgium

Introduction: Few long-term report on meniscal allograft transplantations are available. In this study, we present the results of a survival analysis of the clinical outcomes of 217 procedures involving transplantation of viable medial and lateral meniscal allografts.

Methods: 126 lateral and 91 medial meniscal allografts were evaluated after a mean of 9.37 years (SE 6.865 years, range 0 to 24 years). Survival analysis was based on a specific cilinical end point, with failure of the allograft defined as progression to a total or unicompartimental knee replacement. Overall meniscal allograft survival was analysed by the Kaplan-Meir method with 95% confidence interval. Multivariate analysis using Cox's proportional hazards model was carried out to assess the effects of covariates on allograft survival. The level of significance was set at $p<0.05$.

Results: Overall 24 (19%) of the 126 lateral allografts and 17 (18.7%) of the 91 medial allografts failed. Cox's proportional hazards model showed a non-signifcicant hazard for allografts in men versus woman ($p=0.31$), right versus left allografts ($p=0.299$) and lateral versus medial allografts ($p=0.864$). The age of the patient at the time of allograft transplantation ($p=0.014$) and the intra-operatively determined Outerbridge cartilage degeneration grade ($p<0.001$) were significant factors on the relative odds of allograft failure.

Conclusions: This study showed no difference in allograft survival between lateral and medial allografts and between men and women. Our study suggests that the age of the patient at the time of allograft transplantation and the degree of the articular cartilage damage are significant predictive factors on the relative odds of allograft failure. Repair of the articular cartilage in patients with a high degree of cartilage damage may have a significant effect on the outcome of the allograft transplantation. A prospective study, over a longer period of time, comparing patients after meniscus allograft transplantation with similar articular cartilage damage and treated with and without articular cartilage repair, will be necessary to investigate further this interesting topic.

Comparative study of immediate and delayed meniscus allograft transplantation: focus on clinical results and cartilage protection

Jia-Kuo Yu, MD, PhD

Institute of Sports Medicine of Peking University 3rd Hospital, China

Introduction: Meniscus allograft transplantation (MAT) is generally for the symptomatic postmeniscectomy patients. However, immediate MAT after meniscectomy has not been studied in clinical use. Compared to the conventional delayed MAT, immediate MAT might provide better clinical results and less joint degeneration.

Methods: The study was performed with 18 transplanted menisci (6 medial and 12 lateral) of 16 patients. 8 menisci were transplanted immediately after meniscectomy (Group IM) and 10 menisci were delayed transplanted for the patients who complained of knee symptoms at mean 15 (9-60) months after meniscectomy (Group DE). Degenerative changes of knee joints were evaluated by plain X-ray and conventional magnetic resonance imaging (MRI). The allograft extrusion and relative percentage of extrusion (RPE) was measured on both conventional MRI and 3-D MRI. Other outcome assessments included IKDC, Tegner, Lysholm and VAS scores, range of motion (ROM) and isokinetic muscle strength evaluation.

Results: The average length of follow-up was 50.8 (44-62) months for the group IM and 60 (44-94) months for the group DE respectively. A statistically significant difference in favor of the group IM was found with the VAS score, the IKDC score and the muscle strength ($P < 0.05$). The group IM showed significant less cartilage degeneration in MRI when compared to the group DE. Some degree of extrusion of the allograft was observed in all patients. No significant difference was found in terms of the Lysholm score, the Tegner score, joint narrowing and meniscus extrusion in conventional MRI and 3-D MRI ($P>0.05$).

Conclusions: Compared to the delayed MAT, the immediate MAT led to more satisfied subjective results, less joint degeneration and less muscle strength deficit. The 3-D MRI could be an alternative to evaluate the postoperative meniscus extrusion.

Meniscal allograft transplantation in isolated and combined surgery

Hui Zhang, MD[1]; Xin Liu MD[1]; Yi Wei, MD[1]; Lei Hong, MD[1]; Xiang-Su Geng, MD[1]; Xue-Song Wang, MD[1]; Jin Zhang, MD[1]; Ke-bin Cheng, MD[2]; Hua Feng, MD[1]

[1]Sports Medicine Service, Beijing Jishuitan Hospital, Beijing, China; [2]Department of Radiology, Beijing Jishuitan Hospital, Beijing, China

Introduction: The purpose of this study was to report the initial results of meniscus allograft transplantation after a 2-year follow-up period with second-look arthroscopy of 18 patients.

Methods: Seven medial and 11 lateral meniscus allografts were evaluated with a median follow-up of 24.9 months (range, 18-41 months). The clinical outcome and failure rate was evaluated by use of second-look arthroscopy in all patients, magnetic resonance imaging (MRI) analysis in 17 patients and standardized outcome scores assessment, including Lysholm score, Knee Injury and Osteoarthritis Outcome Score (KOOS), visual analog scale (VAS) on pain and satisfaction and International Knee Documentation Committee (IKDC) objective ratings in all patients. Patients were grouped into medial and lateral subgroups as well as those with isolated or combined procedures.

Results: For the second-look arthroscopic findings, 6 meniscus transplants (33%) had normal characteristics, 10 (56%) had altered characteristics, and 2 (11%) failed. On MRI, two grafts had grade III signals and 11 showed partially extruded. Patients demonstrated statistically significant improvements in standardized outcome scores and VAS pain scales. Overall, 67% of the patients reported that they were completely or mostly satisfied with the procedure. There were no significant differences in the medial and lateral subgroups and no significant differences were noted in the isolated and combined subgroups.

Conclusions: Arthroscopic meniscus transplantation can achieve satisfying subjective and objective clinical outcomes, with a failure rate of 11% after 1-3 years of follow-up, as documented by second-look arthroscopy.

Meniscus allograft transplantation allows return to sporting activities

KR Stone, MD[1,2]; JR Pelsis, MHS[1]; ST Surrette, BS[1]; AW Stavely, BS[1,2,] AW Walgenbach, MSN, FNP[1,2]

[1]Stone Research Foundation, San Francisco, CA;[2]The Stone Clinic, San Francisco, CA

Introduction: Loss of a significant portion of the meniscus can lead to osteoarthritis (OA) due to the increased contact pressure between the femur and tibia. OA is devastating for the athletic patient due to intense pain and discomfort when participating in sporting activities. Meniscus allograft transplantation has been reported to reduce pain and improve function; however, current recommendations state that the procedure is contraindicated in patients with OA and discourage return to high level sports. The purpose of this study was to evaluate the effect of meniscus allograft transplantation on clinical outcome and return to sports independent of the degree of arthritis. We hypothesized that the procedure would allow previously high-level athletes to again participate in sporting activities, and improve subjective measures of pain and function without adversely affecting the survival of the meniscus allograft.

Methods: Athletes with a pre-injury Tegner level of 8 or higher (competitive sports with moderate to high levels of running, jumping, and cutting) with the following indications were included: knee joint line pain with irreparable damage or loss of a minimum of 50% of the meniscus. Prior to surgery, patients underwent an informed consent process by an independent Institutional Review Board. Subjective clinical outcomes were determined from the analysis of International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC) and Western Ontario and McMasters Osteoarthritis Index (WOMAC) scores. Patients' activity levels were determined using the Tegner activity index. Patients with Outerbridge (OB) scores of I-IV were included. Exclusion criteria were less than one year of postoperative follow-up or health issues not related to the knee joint that would inhibit return to sporting activities. Using these criteria, 67 patients were included in the final study population, 52 (77.6%) were male and 15 (22.4%) were female. Eight (11.8%) patients were lost to follow-up. The mean time from surgery to the most recent follow-up was 6.1 ± 4.2 years (range: 0.9 to 14.5 years). The mean estimated survival of the meniscus allograft was calculated using Kaplan-Meier (KM) product analysis. For the survival analysis, procedure failure was defined as removal of the meniscus allograft without replacement or progression to unicondylar or total knee replacement. Cox proportional hazards model was calculated to evaluate the combined effects of clinically relevant factors (age, sex, operative compartment arthritis, highest postoperative Tegner score) on allograft survival. Preoperative and most recent follow-up subjective outcome scores were compared using the Mann-Whitney U test for non-parametric data. Continuous variables are presented as mean ± standard deviation; categorical variables as number and percentage; and non-normally distributed variables as median and inter-quartile range [IQR]. Significance level was set at $p = 0.05$ for all tests.

Results: Medial meniscus transplantation was performed on 46 (68.7%) of the 67 patients and lateral meniscus transplantation on the other 21 (31.3%) patients. Three (4.5%) patients had OB grade I; 5 (7.5%) patients had grade II; 11 (16.4%) patients had grade III; and 48 (71.6%) patients had grade IV at the time of initial meniscus allograft transplantation. Concomitant procedures most commonly included a combination of debridement, chondroplasty, microfracture, and articular cartilage paste grafting. Patients underwent an average of 3.0 concomitant procedures (range, 0 – 7 procedures). Sixteen (23.9%) patients required at least one subsequent, non-failure related, surgery. Median IKDC scores improved from 50.7 [34.1, 61.3] pre-operatively to 70.1 [57.5, 81.0] at most recent follow-up ($p < 0.001$); WOMAC scores improved from 24.0 [13.0, 38.0] to 8.0 [1.0, 17.0] ($p < 0.001$); and Tegner Scores improved from 3.0 [2.0, 5.0] pre-operatively to 5.0 [3.0, 6.0] ($p = 0.003$). Median pre-injury Tegner score was 9.0 [8.0, 9.0] and the median highest Tegner score that these patients returned to was 6.0 [4.0, 7.0]. Cox proportional hazard model revealed no significant effect by the clinical factors tested on the survival of the meniscus allograft including patients' highest postoperative Tegner score ($p = 0.105$) or the number of surgeries subsequent to the original meniscus allograft surgery ($p = 0.329$). Eight (11.9%) patients experienced graft failure over the follow-up period: 7 medial and 1 lateral. KM estimated mean survival time was 12.8 ± .6 years (95% CI: 11.6 – 14.0 years).

Conclusions: This study shows that meniscus allograft transplantation can relieve pain and allow increased function and activity in patients who participated in high-level sporting activities prior to injury. Median subjective outcome scores showed significant improvement at most recent follow-up from pre-surgery in all three measures analyzed. Additionally, patients were able to return to sporting activities after the procedure without significantly affecting procedure survival time or the number of surgeries subsequent to the original meniscus allograft surgery. This suggests that patients with high pre-injury activity levels can return to sporting activities following meniscus transplantation surgery. This study shows promising long-term clinical results and estimated survival of meniscus allograft transplantation in an athletic population.

Meniscal allograft transplantation in professional soccer players

S. Zaffagnini; G. M. Marcheggiani Muccioli; A. Grassi; T. Bonanzinga; F. Raggi; G. Nanni; M. Ricci; K. Tzapralis; S. Della Villa; M. Marcacci

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Introduction: Meniscal allograft transplantation (MAT) is nowadays considered an effective terapeutic option to improve knee function and decrease pain in symptomatic patients after total/subtotal meniscectomy. Soccer players are a high-risk population **regarding** knee injuries, especially meniscal lesions and subsequent development of early onset osteoarthritis, therefore particular care should be used when dealing with such high-demand population. The purpose of this study is to assess clinical outcomes and the possibility to return to sport after MAT in professional soccer players.

Methods: Between 2008 and 2011, twelve male professional soccer players (Tegner level 10) were underwent arthroscopic MAT according to Marcacci et al [1] and followed by a specific rehabilitation protocol in the same center. Mean age at surgery was 24.5 ± 3.6 years (range 19-29). Transplantation involved medial meniscus in 6 patients (50%) and lateral meniscus in the remaining 6 patients (50%). The mean time from meniscectomy to surgery was 37 ± 31 months (range 2-82). Seven patients (58%) underwent concurrent procedures (2 anterior cruciate ligament (ACL) allograft reconstructions, 2 microfractures, 1 osteochondral scaffold, 1 posterolateral corner plasty, 1 distal femoral osteotomy).

All patients were evaluated at 12 and 36 months of follow-up. Evaluation was assessed with Tegner, Lysholm, Subjective and Objective IKDC, VAS for pain and WOMAC scales. The duration of rehabilitation, number of sessions, return to sport and return to official match were recorded as well.

Results: At 12-month follow-up, all score improved significantly from baseline. Tegner improved from 8 (IQR 3-10) to 10 (IQR 9-10) (P= .0391), Lysholm from 66 ± 16 to 92 ± 11 (P=.0021), Subjective IKDC form 61 ± 16 to 85 ± 10 (P=.0026), WOMAC from 77 ± 17 to 93 ± 8 (P=.0242), VAS from 62 ± 15 to 30 ± 25 (P=.0029) and Objective IKDC form 1A, 8B, 1C, 2D to 7A, 5B (P=.00765).

At 36-months follow-up patients slightly improved the outcomes compared to 12-moth follow-up evaluation (Tegner: 10, IQR 9-10, P=.5000; Lysholm: 93 ± 12, P=.576; Subjective IKDC: 91 ± 10, P=.1532; WOMAC: 94 ± 7, P=.0798; VAS: 16 ± 15, P=.1377; Objective IKDC: 8A, 4B, P=.2588).

The mean time from surgery to end of rehabilitation was 7.5 ± 2 months, whereas the mean time to official match was 10.5 ± 2.6 months. The mean number of rehabilitation session was 154 (95 gym, 35 pool, 24 field).

At 12-month follow-up 67% of patients presented the same activity level (Tegner 10) of pre-injury status. At 36-month follow-up, 9 patients (75%) are still playing as professional (Tegner value 10), whereas 2 patient (17%) are playing as semi-professional (Tegner value 9).

One patient developed knee infection after meniscal allograft transplantation plus ACL allograft reconstruction. This player was successfully treated with oral antibiotics and two arthroscopic lavages. He presented a Tegenr value of 3 at 36-month follow-up and was considered a failure (8%).

Conclusions: Although the high-demanding physical activity and the long rehabilitative protocol, MAT allowed 92% of professional soccer players to improve knee function and reduce pain, permitting to continue soccer career at 3 years after surgery. Our results are comparable to those published by Alentorn-Geli et al in term of failures, but we recalled an higher rate return to play soccer (92% instead of 85.7%). Moreover in our series all the players were professional football players (Tegner 10) and 75% of them are still playing at the same level 3 years after the surgery. Meniscal allograft transplantation does not seem to represent a career-threatening procedure in patients with high-demand physical activity.

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Synthetic scaffold for meniscal regeneration: prospective clinical study at 3 years follow-up

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Introduction: The possibility to reproduce both structure and function of the meniscus is highly attractive, aiming to restore knee biomechanics and to prevent the development of early osteoarthritis. Regenerative approaches have been advocated to improve the reparative processes of joint tissues, while good results have already been reported in literature. Recently, a new polyurethane scaffold has been introduced in clinical practice claiming better material properties to resist the high knee forces and therefore better chondroprotection.

Methods: We performed a prospective clinical evaluation of 19 patients (12 males, 7 females, mean age 45 yy) affected by a massive loss of meniscal substance either the medial or the lateral side of the knee (13 and 6, respectively), associated with intra-articular or global knee pain and/or swelling, and treated with meniscal scaffold implantation. Eleven patients underwent associated procedures involving cartilage treatment or osteotomies. Patients were evaluated clinically and with MRI up to 3 years of follow-up.

Results: Patients' evaluation showed good results, both from clinical and imaging point of view. One patient had a re-injury playing competitive soccer after the 12 months follow up and was excluded from the subsequent analysis. IKDC subjective score improved from 47.3±17.5 to 72.9±13.9 ($p<0,0005$) at 1 year, then increased to 75.1±15.2 ($p<0,0005$) at 2 years and 75.7±15.7 ($p<0,0005$) at 3 years of follow-up.

Conclusions: The obtained results are promising; they documented a significant clinical improvement treating partial meniscal lesions with scaffold implantation. Long-term randomized studies are needed to confirm if better structural properties of the meniscal scaffolds will also lead to better long-term clinical outcomes and joint protection from early osteoarthritis.

Treatment of post-meniscectomy syndrome with a free-floating meniscus implant: a prospective, open label, single-arm trial

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Introduction: Loss of meniscal tissue leads to increased pain and decreased clinical function and activity levels. We are currently evaluating the use of a polycarbonate-urethane, non-anchored, meniscus implant for the treatment of post-meniscectomy syndrome on the medial side.

Methods: From February 2011 to date, 33 subjects (16 women, 17 men) with a previous partial medial meniscectomy, treated by the author, have been enrolled in the study. The mean age was 47 years (range 30-60), the mean Body Mass Index is 26.4 (range 18.6-35.1), and 24 of the cases were left knees. Patients were asked to undergo four clinical follow-up examinations over two years, and complete validated outcomes questionnaires (KOOS, visual analogue pain scale, IKDC subjective knee assessment and EQ-5D). MR imaging is performed 1.5 months, 1 year and 2 years post implantation.

Results: The mean follow-up is 8.8 months (range 0-22). To date, 23 patients completed the 1.5 months visit, 16 completed the 6 month visit and 10 completed the 12 month visit. The KOOS Pain Score increased significantly by ~60%, from 40.3 preoperatively to 64.4 at 12 months ($p<0.05$). This reduction in pain is confirmed by the VAS pain score which decreased by ~55%, from 67.1 before surgery to 29.8 at 12 months. KOOS Quality of Life score increased by ~120%, from 21.3 before surgery to 46.9 at 12 months. MR-scans, analyzed 12 months post impantation, showed no change in the majority of operated joints, in terms of cartilage degradation and/or bone damage, with respect to baseline scans.

The overall secondary surgical intervention rate is 15.2%: Three dislocations (9.1%) and 2 removals for device-related problems (6.1%), and one case of skin infection (0.3%). All implants were removed and replaced with a new device. All affected patients are improving in terms of functionality and pain relief.

Conclusions: The treatment of post-meniscectomy pain and discomfort in middle-aged patients is still a controversial subject and far from having found an effective treatment of choice. This novel free-floating meniscus implant may provide long term pain relief and improved knee function to patients that are suffering from post-meniscectomy syndrome but are too young for a partial or total joint replacement and have contraindications to High Tibial Osteotomy. Longer term results are yet to be collected in order to confirm this initial promising outcomes.

Arthritis self-efficacy scale pain and other symptom subscale scores in knee osteoarthritis: a systematic review and meta-analysis comparing arthritis self management education with or without exercise

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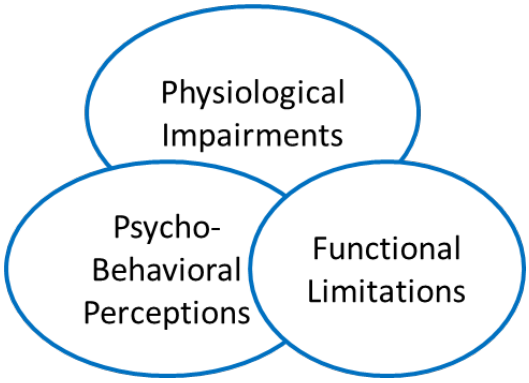
Introduction: Developing adequate self-efficacy to manage knee OA symptoms can increase the patients' ability to complete physical tasks. This factor becomes especially important following meniscal transplantation. The purpose of this study was to evaluate reports that used arthritis self-management education alone **(Group 1)** or with exercise **(Group 2)** to improve Arthritis Self-Efficacy Scale (ASES) pain and other symptom subscale scores of patients with knee osteoarthritis (OA).

Methods: Medline (1946-March 2012), CINAHL (1981-March 2012) and PsycINFO (1967-March 2012) databases were searched. Mann-Whitney "U" tests were used to compare group effect sizes. Studies that met the inclusion criteria were scored using the Methodological Quality Scale.

Results: Twenty-two studies including 2036 subjects (1598 women, 78.5%) of 65.9 ± 5.7 years of age met the systematic review inclusion criteria. A meta-analysis was performed of studies that had a treatment and control group that used the ASES pain (n = 14) or other symptom (n = 13) subscale. The arthritis self-management education alone group had a longer duration between study initiation and initial follow-up than the arthritis self-management education with exercise group (19.8 ± 6.4 weeks vs. 8.0 ± 2.5 weeks, $P < 0.0001$). The arthritis self-management education alone group displayed a slightly greater mean ASES pain subscale effect size (0.49 ± 0.49 vs. 0.26 ± 0.26) however this difference was not statistically significant ($P = 0.46$). The arthritis self-management education with exercise group had a slightly greater ASES other symptom subscale effect size (0.34 ± 0.26 vs. 0.30 ± 0.18) however this difference also was not statistically significant ($P = 0.88$). For both subscales an insignificant treatment effect was noted with the addition of exercise. Only 4.5% (1 of 22) of studies received a full Methodological Quality Scale score for follow-up timing, 31.8% (7 of 22) performed a blind assessment, 31.8% (7 of 22) used intention to treat analysis, 31.8% (7 of 22) did not describe a control or placebo group, and 27.3% (6 of 22) did not adequately describe subject drop-out management.



Conclusions: Similar improvements were observed with small-to-moderate effect sizes regardless if the arthritis self-management education program included an exercise component. Less generic, more prescriptive therapeutic exercise interventions based on patient-specific impairments and functional limitations and delivered in an active learning environment may help improve self-efficacy. Well-designed studies with longer follow-up timing, greater use of blinded outcome assessment, intention to treat analysis, more frequent use of control or placebo groups and better documentation of subject drop-out rates and reasons are needed.

Relationship between meniscal integrity and anterior-posterior laxity of the knee

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Introduction: The meniscus plays a primary role in distributing load and enhances stability in the knee. Furthermore, a number of studies have shown an association between knee osteoarthritis (OA) and meniscal damage. It is therefore hypothesized that for patients with OA, the meniscus would have degenerated, thereby having a decreased weight-bearing role and causing greater anterior-posterior (AP) displacements of the femur on the tibia. One method of measuring meniscal integrity is through the use of the T2/T2* MRI time constant, which is sensitive to slow molecular motions of water protons. As the T2/T2* relaxation times increase, it indicates a disruption in the collagen network of the meniscus and a decrease in water content, both indications of meniscal degeneration. Therefore, the purpose of this study was to use MRI to evaluate the integrity of the menisci of patients with OA as well as normal controls, using the T2/T2* MRI time constants. This data would then be compared with that obtained on the patients AP laxity, to determine if there is a correlation between meniscal integrity and AP laxity of the knee.

Methods: In accordance with HIPAA regulations and IRB approval, eleven patients (6 male, average age 64 ± 11 years) with a Kellgren-Lawrence (KL) grade of 2 – 4 in their symptomatic knee and KL 0 – 1 in their contra-lateral control knee (11 knees per group) were recruited from the non-therapeutic R01 NIH study AR052873 cohort at our teaching hospital. All patients were placed supine in a plastic rig with the knee at 15 degrees of flexion and a compressive force of 222N was applied along the tibial long axis. A 3 Tesla (3T) Siemens Verio scanner was used with a 3D Proton density weighted (PDw) SPACE sequence with 0.5mm isotropic resolution. This was followed by a spin-echo 2D T2 sequence and a spin echo 3D T2* sequence. Upon completion of these scans, an internal tibial torque of 5Nm was applied in addition to the compression and a second 3D PDw SPACE scan obtained. Testing was performed for the symptomatic and the contralateral control knee.

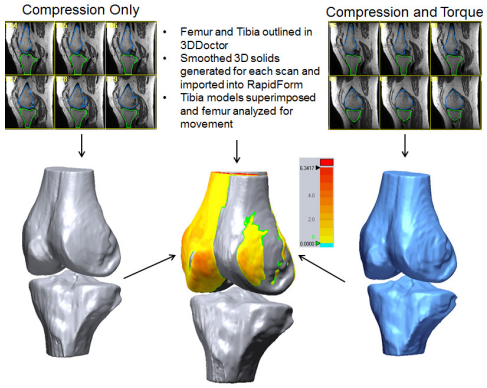

Figure 1. Tibia models were superimposed and a deviation analysis performed on the femur.

3D-Doctor software (Able Software Corp., Lexington, MA) was used to segment the femur, tibia and cartilage on each slice of the 3D SPACE scans from which smoothed 3D surface models were created. Rapidform (Inus Technology, Seoul, South Korea) was then used to determine the deviation of the femur with respect to the tibia, after the torque was applied. In order to determine this, the compression only tibia model and the compression and torque tibia model were superimposed. Using the same transformation matrix, the femur models were then shifted to align with the tibia models. A deviation analysis, represented as a color map, was then performed to determine the movement of the compression and torque femur model as compared to the compression only femur model (Figure 1). In addition to a color map, a histogram was provided from which the average displacement was determined. Thickness maps of the cartilage were also created in order to qualitatively determine if increased AP laxity was associated with thinner cartilage.

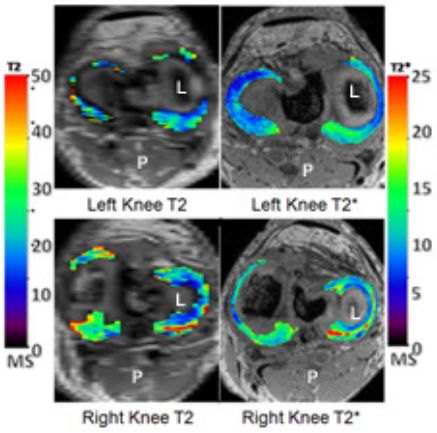

Figure 2. The T2 and T2* relaxation maps for patient 1 show there is a tear in the posterior horn of the lateral meniscus of the right knee. In addition, loss of the anterior horn of the medial meniscus can be seen.

The T2 weighted images were fitted by using a least squares fitting procedure for the T2 map using eight echoes and T2* using ten echoes respectively. The menisci were manually segmented and T2/T2* mapping was processed offline using custom developed software (FireVoxel) at our centre. The Students t-test was used with α=0.05, to evaluate significance between the deviations and T2/T2* relaxation times of the symptomatic and control knees. Spearman's rank correlation was then used to determine if there was an association between AP laxity and meniscal integrity.

Results: Comparing the T2/T2* relaxation times for the menisci of the symptomatic and control knees, the T2 times were not found to be statistically different, whereas the T2* relaxation times were found to be statistically significant (p=0.03) due to the higher resolution of the T2* relaxation maps. Figure 2 shows an example of the T2 and T2* maps indicating significantly

prolonged T2* times in the symptomatic knee compared to the control knee, suggesting meniscal degeneration.

In the control knee, relative to the tibia, the femur underwent an external rotation, such that the medial condyle had a small anterior displacement (0.88mm) and the lateral condyle had a larger posterior displacement (1.22mm). In the symptomatic knees, the average anterior medial translation was 0.85mm and the average lateral posterior translation was 1.69mm. There was a significant difference in the lateral posterior displacements of the femur between the symptomatic and control knees (p=0.04). In addition, the T2* relaxation times for the posterior horn of the lateral meniscus indicated a significant correlation with the displacement of the femur in the posterior lateral direction (spearman correlation coefficient r=0.46, p=0.03). The largest difference in AP displacement between the symptomatic and control knee was noted in patients with the thinnest cartilage (Figure 3).

Conclusions: A significant increase was found in the lateral posterior displacements of the symptomatic and controls knees. In addition, a significant increase in T2* relaxation times were found between the symptomatic and control knees, which was correlated with the increased displacements. This suggests that a deficient meniscus may have a decreased weight-bearing role allowing greater anterior-posterior laxity of the femur, which could accelerate cartilage degeneration.

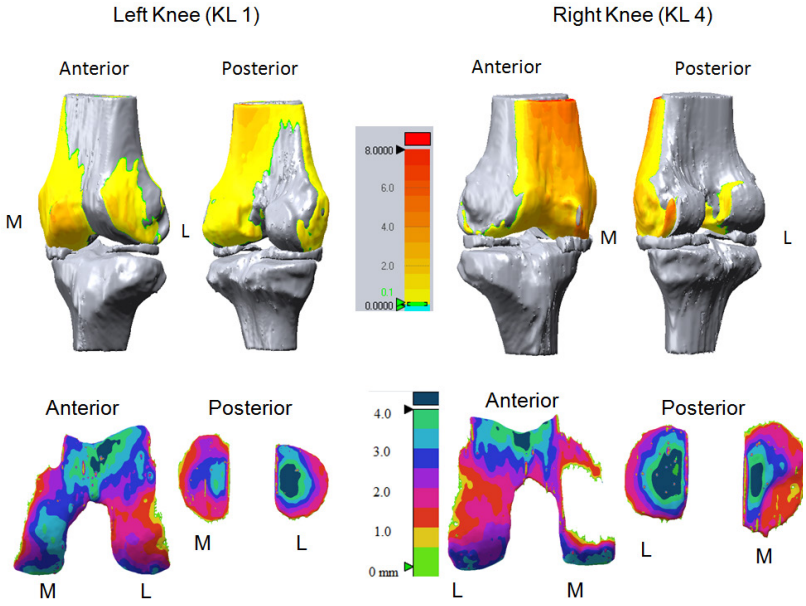

Figure 3. Top Row: The deviation maps for the symptomatic and control knee of patient 1. It can be seen that this patient exhibited significantly more anterior translation in the symptomatic knee compared to the control. Bottom Row: The cartilage thickness maps for the symptomatic and control knee for patient 1. The increased anterior translation of the right knee was associated with thinner cartilage, in addition to the lack of the anterior horn of the medial meniscus, seen in Figure 2.