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Clinical and Demographic Predictors of Short-term Recovery From Arthroscopic Partial Meniscectomy

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CLINICAL AND DEMOGRAPHIC PREDICTORS OF SHORT-TERM RECOVERY FROM ARTHROSCOPIC PARTIAL MENISCECTOMY

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CLINICAL AND DEMOGRAPHIC PREDICTORS OF SHORT-TERM RECOVERY FROM ARTHROSCOPIC PARTIAL MENISCECTOMY.

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Patients undergoing orthopaedic surgery are concerned with returning to activities of daily living (*recovery*) in addition to the long-term result of their surgery (*end result*). As evidence of predictors of rate of short-term recovery is limited to date, this study seeks to determine which patient clinical and demographic factors can serve as prognostic indicators for rate of short-term recovery from arthroscopic partial meniscectomy in the year following surgery and how they may differ from previously published associations with long-term outcome.

Clinical (depth of meniscal excision, involvement of one or both menisci, extent of meniscal tear, extent of osteoarthritis) and demographic (age, gender, and BMI) measurements were obtained pre- and intraoperatively. Mixed model repeated measures analyses were used longitudinally to identify independent predictors of rate of recovery, measured by prospectively assessing knee pain, knee function, and overall physical knee status pre-operatively and at regular intervals throughout postoperative recovery out to one year.

Of the clinical variables, only greater extent of osteoarthritis was associated with slower rate of recovery over all three recovery measures. Greater depth of meniscal excision

was associated only with poorer overall physical knee status, but not postoperative knee pain or function. Of the demographic predictor variables, female gender was associated with poorer scores over all three recovery variables over time, while age and body mass index (BMI) had no association with rate of recovery.

Factors affecting short-term rate of recovery are different than associations with long-term outcome. Previous research has shown poorer long-term outcome with advanced age, greater BMI, and greater amount of meniscal tissue excision. This research indicates that female gender and worse osteoarthritis at the time of surgery are associated with a slower rate of short-term recovery from arthroscopic partial meniscectomy, while age, obesity, and amount of meniscal tear/resection show no association with recovery scores over time throughout the first year postoperatively.

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INTRODUCTION

The medial and lateral menisci are two C-shaped fibrocartilaginous structures attached anteriorly and posteriorly to the tibial plateau (Figures 1 - 4). The anatomy of the menisci has been studied for over 100 years; historically, the meniscus was thought to be a vestigial tissue, and was first described by Bland-Sutton in 1897 as “the functionless remnants of intra-articular leg muscles.” (1) However now it is known that the menisci provide mechanical support and secondary stabilization, localized pressure distribution and load sharing, lubrication and proprioception to the knee joint.(2, 3) The menisci transmit at least 50%-75% of the axial load in knee extension, and up to 85% with the knee in ninety degrees of flexion. (4) This concept is illustrated in (Figures 5a - 5d) – as meniscal tissue is removed, as with partial or total meniscectomy, the contact area of the knee joints (both ipsi- and contralateral) decreases thereby increasing localized pressure on the surface of the articular cartilage. (5) Increased pressure on the articular surface causes local cartilage damage, leading to accelerated osteoarthritis. (Figure 4) anatomically shows the effects of meniscal deficiency on bone and the formation of subchondral sclerosis and osteoarthritis.

By dry weight, the menisci are comprised of mostly type I collagen (60%-70%), with a small amount of elastin (<1%) and other proteins (8%-13%). (6) Histologically, collagen fibers are arranged circumferentially (in order to disperse compressive loads) with some radial fibers as well (to resist longitudinal tearing). At the surface, collagen fibers are arranged randomly in order to disperse shear stresses associated with flexion and extension of the knee joint, as can be seen in (Figure 6). (2) The blood supply of the menisci originates at the periphery in the perimeniscal capillary plexus (Figure 7), and in the adult meniscus, only the outer 10%-25% is vascular. (7) Once the meniscus reaches maturity, the tissue receives nutrients from the synovial fluid via passive diffusion which is aided by motion of the knee joint. The avascularity of the inner two-thirds of the menisci results in an inability for tears in this region to spontaneously heal.

Tears of the minisci (both acute and chronic) are very common orthopaedic injuries, affecting patients of various ages and activity levels. Meniscal injury often causes great pain and physical impairment; once clinical symptoms such as catching, locking, and decreased range of motion are present, surgical intervention is required for relief. Their treatment has adapted over the course of several decades with both technological and intellectual advances in orthopaedic surgery; since 1936 when total meniscectomy was the treatment of choice,(8) abundant research has led to the understanding that meniscal tissue should be retained whenever feasible. (9, 10) Over time, measures have been taken to try to preserve as much meniscus as possible as treatment evolved from open total meniscectomy to open partial meniscectomy, and finally to arthroscopic partial meniscectomy or repair. Arthroscopic treatment of meniscal injuries has become one of the most common surgical procedures in the United States. The American Academy of Orthopedic Surgeons estimates that arthroscopy procedures of the knee total 636,000 cases per year in the United States as of 1999. (11) A large number of these procedures are arthroscopic partial meniscectomies, which represent up to 10% to 20% of all surgical cases at some centers. (12) Excision of meniscal tissue is the fifth most common ambulatory procedure in the United States, and is the third largest when excluding categories lumping several procedures together (Table 1).

Patients are often greatly concerned with their short-term recovery in the days and weeks following surgery in addition to how they will fare in the vague future years ahead. Although there is a new growing interest in short-term recovery from orthopaedic surgery,(13, 14) the literature to date has stressed the importance of the *end result* of meniscectomy in the long-term(15-27); there appears to be limited empirical evidence regarding immediate *recovery* following surgical intervention. Surgeons must be able to discuss evidence-based literature with surgical candidates that describe specific factors influencing short-term recovery over time. Currently, physicians are forced to advise patients regarding their short-term recovery based on anecdotal evidence from their own experience, including intuitions about how patients will recover based on their age, weight, incentive to recover, amount of tissue resected, and amount of physical therapy they receive, rather than being able to refer to published studies.

The variables that affect long-term knee status are not necessarily what will affect the patient over the immediate postoperative interval. Because initial return to function following arthroscopic partial meniscectomy does not require several years, it is vital to identify clinical factors associated with patient recovery in the short-term.

Long-term data are plentiful regarding the impact of surgical and demographic variables on the end result of meniscectomy. While most have contended that extensive meniscal resection predicts worse radiographic and functional long-term status, (15, 16, 18, 21, 25) some researchers report no impact of greater removal.(27) Many have supported an association between osteoarthritis at the time of surgery and poor surgical outcome, (17, 19, 25, 26) though one study (21) advocates that there is no difference. Data regarding medial vs. lateral arthroscopic partial meniscectomy are mixed: although in vitro computer modeling postulates that lateral partial meniscectomy is more dangerous than medial partial meniscectomy, (28) in vivo studies have shown no significant clinical differences. (17) Long-term success of meniscal repair appears to depend on the stability of the knee at the time of surgery,(22) and traumatic meniscal tears have better 6-year functional results than do degenerative meniscal tears.(24, 27) It has been reported in the literature that younger patient age predicts a better long-term prognosis after meniscectomy,(17, 26) while obesity is associated with a worse result.(19, 20) Regarding gender differences, analysis of outcome at 8.5 to 14.5 years after surgery shows no difference in surgical outcome between men and women, (21, 29, 30) while the 15 to 22 year follow up data indicates that symptoms and functional limitations are worse in women who have undergone meniscectomy when compared to men,(26) and women tend to develop more osteoarthritis.(19)

These studies, however, have only analyzed the *end result* of surgical intervention, that is the effect after several years - long after initial recovery from surgery was completed (Table 2).

Few studies have investigated short-term *recovery* from orthopaedic surgical procedures. Most recently, data from the spine patient outcomes research trial (SPORT) was published in an effort to determine symptomatic improvement through two years postoperatively from lumbar disk herniation with operative vs. conservative treatment.(13, 14) This study was limited in that it used specific timepoints throughout the first two years postoperatively, rather than using longitudinal analysis to determine effect of intervention over the entire recovery phase. Additionally there were methodological challenges surrounding patient randomization and treatment groups. Despite its limitations, however, this clearly indicates a growing interest in short-term rate of recovery from orthopaedic intervention. Concerning arthroscopic meniscectomy, no similar study of patient recovery exists. While one previous study reported general information concerning when patients could return to work, school, or daily activity to show that arthroscopy is reliable and cost effective with rapid return of good knee function,(31) it did not discuss specific factors that would influence patient recovery time and/or return to everyday activities. Similarly, some describe the effectiveness of supervised physical therapy for recovery from arthroscopic partial meniscectomy,(32) while others have asserted that postoperative recovery with supervised physical therapy was no better than independent home physical therapy.(23) There exists no study to date, however, that has reported patient surgical, demographic, and clinical factors influencing postoperative rate of recovery and return to activities of daily living following surgical intervention.

Although it may appear depth of meniscal excision, involvement of both menisci, extent of meniscal tear, and degradation of the articular joint surface would adversely affect rate of recovery immediately after surgical intervention as it does in the long-term, there is limited empirical evidence in the literature to support these clinical beliefs. Nor is it known which of these variables is most strongly associated with recovery from surgery, and which show a weak or no association at all. This study evaluates what factors the surgeon can apply to patients' concerns regarding postoperative rate of recovery, and how they differ from factors associated with long-term outcome.

HYPOTHESIS

Based upon the aforementioned long-term surgical outcomes research and understanding of meniscal structure and biomechanics, it is hypothesized that greater depth of meniscal excision, involvement of both menisci, greater extent of meniscal tear, and degradation of the articular joint surface will all adversely affect postoperative rate of recovery (patients will experience greater knee pain, poorer knee function, and poorer overall physical knee status scores over time throughout the postoperative recovery period) after arthroscopic partial meniscectomy. Additionally, it is hypothesized that advanced age and greater body mass index (BMI) will be associated with delayed recovery, while gender will have no association.

METHODS

As part of a comprehensive NIH-funded study ("Project Recover") designed to determine various predictors of postoperative recovery after minor surgery, several hundred patients who had undergone arthroscopic procedures of the knee (i.e. arthroscopic partial meniscectomy, ligament reconstruction, debridement) by one of several surgeons at two major university medical centers were studied. Inclusion criteria for the study included: ages 16-80 years, no history of injury to either knee that required surgical intervention or produced pain, swelling, mechanical symptoms, and/or activity restriction for greater than six months, no major varus or valgus deformities by clinical examination, no chronic comorbidities that resulted in restricted physical activity (e.g., insulin-dependant diabetes mellitus, severe coronary obstructive pulmonary disease), and not requiring emergency surgery for their injury. In summary, these were otherwise healthy patients with previously healthy knees who experienced relatively recent onset of mechanical knee symptoms caused by meniscal pathology.

In order to test the hypothesis presented here and minimize confounding factors, a subset of subjects who were patients of the lead surgeon-investigator were studied. All patients were given a preoperative diagnosis of 'torn medial meniscus' and/or 'torn lateral meniscus' by history, physical examination and confirmatory MRI (example seen in Figure 8) read by an attending diagnostic radiologist who specializes in musculoskeletal imaging. Additionally there was no history of ligamentous (i.e. ACL, PCL, LCL, MCL) injury per patient interview and confirmatory MRI. After meeting study inclusion criteria, 141 patients consented to participate. Fifteen patients (10.6%) were lost to follow-up, leaving 126 patients (89.4% retention) for analysis. This study therefore qualifies as a level I, high-quality prognostic prospective study (all patients were enrolled at the same point in their disease with >80% follow-up of enrolled patients). All procedures were performed and prospective data were collected between August 2000 and August 2005. Demographic characteristics of patient sample are displayed in (Table 3).

Ad hoc power calculations based on pilot study data (differences in knee flexion at postoperative weeks 3 and 8) confirmed an adequate number of subjects to detect significant differences at a power of 80% with $P < .05$. Additionally, our statistical methods (mixed model repeated measures analysis, as described below) used a 'within-subject' design which inherently has greater statistical power than a 'between-subject' design. (33)

Patients were typically identified 2 to 6 weeks before their scheduled surgery, and were screened and recruited by phone once identified by clinical staff as needing arthroscopy for a torn meniscus. All patients underwent arthroscopic partial meniscectomy on one knee. Approval for all procedures was obtained from the University Human Investigations Committee (Appendix C). Participation in this study was completely voluntary, and did not affect delivery of health care in any way.

Patient demographic and historical data were collected by physicians and trained research staff during the preoperative interview, including age, gender, BMI and past medical history. Surgical data were collected by the surgeon at the time of surgery; recovery variable data was collected 3-10 days preoperatively, and at 1, 3, 8, 16, 24, and 48 weeks postoperatively by the physician and trained research staff. Example intraoperative arthroscopic images are displayed in (Figure 9); sample data collection forms are displayed in (Appendix C).

Surgical notes and charts were reviewed and data collected for the four surgical variables of interest: depth of meniscal excision, involvement of one or both menisci, extent of meniscal tear, and extent of osteoarthritis. Involvement of one or both (lateral and medial) menisci was recorded. In addition, to determine depth of meniscal excision and extent of meniscal tear, the menisci were divided into six clinically significant divisions ("zones"): the anterior horn, body, and posterior horn of each of the lateral and medial menisci (Figure 10). Depth of meniscal excision was determined as the greatest amount of meniscus removed from any zone. Extent of meniscal tear was designated as the total number of zones involved in the meniscal tear on the worst side (medial or lateral), maximum of three zones. Extent of osteoarthritis was assessed using the Modified Outerbridge articular surface grading (ASG) scale as described in (Figure 11). (34) A score for each of the medial, lateral, and patellar joint surfaces was recorded by the surgeon at the time of surgery. The ASG scale score of the most arthritic of the three joint surfaces was used as the final score.

Three measures of physician-rated recovery were obtained at each of the pre- and postoperative time points: knee pain, knee function, and overall physical knee status. Physicians rated both knee pain and function on a standardized 0 – 10 scale with higher scores reflecting more severe pain and higher knee function; this scale has been used extensively to assess both pain and function in a variety of surgical settings, including knee arthroscopy.(35-42) Additionally, it has been shown that physician ratings better predict postoperative knee pain and function scores than did patients' ratings.(39) Overall physical knee status included ratings of effusion, extension, flexion, gait, and general progress as determined by the physician at each office visit. Presence of effusion was determined by physical examination. Prone extension (heel height difference between affected and contralateral legs, in millimeters) and supine flexion were measured in degrees using a goniometer. Normal vs. abnormal gait and general progress were subjective measures determined by the surgeon at each follow-up visit. The five physical status variables were assessed individually as described above. In order to illustrate a general idea of patient status at each follow-up visit, a dichotomized score of normal/abnormal was generated for each variable, and a summary score was calculated, with 0 indicating normal ratings across all five variables and 5 indicating abnormal ratings across all five. Examples of 'abnormal' ratings include presence of effusion, difference in flexion/extension between affected and unaffected knees, abnormal gait (i.e. observed limp and/or loss of range of motion that visibly interfered with gait) and poor general progress at the follow up appointment. This summation variable, in addition to the standardized variables of pain and function described above were used as the three postoperative recovery variables of interest.

The clinical and demographic variables recovered from patient charts were coded and entered into SPSS for analysis. The data was merged with previously entered recovery scores for each patient's postoperative visits out to one year. All data was attributed to each patient through a unique study identifier in order to protect the identity of all research subjects.

Statistical Methods

Pearson correlations were calculated to determine what relationship, if any, exists between the surgical predictor variables.

Three mixed model repeated measures analyses were run to identify independent surgical predictors of recovery. This analytic approach allows use of all available data from all patients, and is able to analyze several independent variables separately (while controlling for all other independent variables) over an entire window of time rather than at a single specific endpoint. It also accounts for the trend toward recovery over time, that is to say that pain decreases and function increases over the recovery period and therefore scores are not random at any given timepoint.

The variables included in each analysis were as follows: the four surgical variables (depth of meniscal excision, involvement of one or both menisci, extent of meniscal tear and extent of osteoarthritis) and the three demographic variables (age, gender, and BMI). The three physician-rated recovery variables of knee pain, knee function, and overall physical knee status were included, respectively, as the dependent variables.

RESULTS

Surgical Predictors

Tear characteristics, including incidence of one vs. both menisci, number of zones involved, and depth of meniscal excision are shown in (Table 4). Distribution of Modified Outerbridge scores are shown in (Table 5); intercorrelations between the four surgical predictor variables are displayed in (Table 6).

Results of the mixed model repeated measures analyses are shown in (Table 7).

The first mixed model repeated measures analysis investigating the association of the surgical predictor variables with postoperative physician-rated *knee pain* revealed that extent of osteoarthritis was significantly associated with rate of recovery ($P = 0.01$). Depth of meniscal excision, involvement of one or both menisci, and extent of meniscal tear, however, were not associated with rate of recovery with regard to knee pain. For purposes of illustrating the impact of the extent of osteoarthritis on postoperative knee pain over the recovery period, high versus low ASG scores were determined by calculating median splits; pain scores stratified by high and low ASG score groups over time are displayed in (Figure 12a); average knee pain scores over the postoperative recovery period by ASG score are displayed in (Figure 12b).

The second mixed model repeated measures analysis analyzed the impact of the surgical predictor variables on physician-rated postoperative *knee function*. Again, this analysis revealed an overall main effect for extent of osteoarthritis (P = 0.01), supporting that greater osteoarthritis was associated with worse knee function postoperatively over time. Depth of meniscal excision, involvement of one or both menisci, and extent of meniscal tear were not associated with rate of improvement in knee function. To illustrate the impact of extent of osteoarthritis on knee function over the recovery period, high versus low ASG scores were determined by calculating median splits; knee function scores stratified by high and low ASG score groups over time are displayed in (Figure 13a); average knee function scores over the postoperative recovery period by ASG score are displayed in (Figure 13b).

Finally, the third mixed model repeated measures analysis investigating the influence of the surgical variables on *overall physical knee status* revealed that both extent of osteoarthritis (P = 0.02) and extent of meniscal tear (P = 0.04), were significantly associated with rate of improvement of overall physical knee status over the recovery period. Depth of meniscal excision and involvement of one or both menisci were not associated with rate of recovery with regard to patients' overall physical knee status score. To illustrate the impact of extent of osteoarthritis on physical knee status over the recovery period, high versus low ASG scores were determined by calculating median splits; physical knee status stratified by high and low ASG score groups over time are displayed in (Figure 14a); average overall physical knee status scores over the postoperative recovery period by ASG score are displayed in (Figure 14b).

Of note, time was also included in the model as a factor to confirm that recovery scores would improve linearly over time during recovery (*P* = .001 for all analyses).

Demographic Predictors

Results of mixed model repeated measures analyses for the demographic predictor variables showed that gender was predictive of worse postoperative recovery scores over time, with females having greater knee pain (*P* = 0.04) (Figure 15a), worse knee function (*P* = 0.01) (Figure 15b), and worse overall physical knee status (*P* = 0.01) (Figure 15c) over the recovery period when compared to men. Age and Body mass index were not predictive of any of the recovery scores in any of the three models (*P* > 0.05).

All results are summarized alongside previously mentioned long-term outcome data in (Table 8).

DISCUSSION

Surgical Predictors

Of the surgical predictor variables, only extent of osteoarthritis was predictive of recovery across all three recovery variables (knee pain, knee function, and overall physical knee status), with worse osteoarthritis negatively impacting the rate of recovery across all three recovery variables significantly. Interestingly, depth of meniscal excision and involvement of one or both menisci had no impact on any aspect of recovery, while the extent of meniscal tear affected only overall physical knee status, but not knee pain or function. This is contrasted by studies that have shown that increased meniscal tear and/or excision (e.g., greater meniscal injury) have resulted in poorer outcome. (15, 16, 18, 20) It is possible that these results may be explained by the aneural nature of meniscal tissue. Thus although greater extent of meniscal tear may impact overall physical knee status variables (such as flexion, extension, etc.) throughout the recovery period, knee pain and function are not impacted by extent of meniscal tear during the year after surgery. Variables that have been shown to affect long-term patient outcome are different than those that are associated with short-term rate of recovery and therefore cannot be generalized to implicate similar associations when considering short-term recovery from surgery.

The fact that extent of osteoarthritis as assessed by the Modified Outerbridge rating scale was predictive of how a patient would recover from arthroscopic partial meniscectomy is especially remarkable in that it is a standardized, validated measure of osteoarthritis. In a multirater, multicenter agreement study of articular cartilage grading, arthroscopic grading of articular cartilage was reliably assessed across surgeons and centers. (43) The present study supports that not only can osteoarthritis be reliably assessed, but that it has important implications for recovery: worse osteoarthritis as graded arthroscopically by the surgeon indicates delayed patient recovery from arthroscopic partial meniscectomy.

In a randomized control trial determining the effectiveness of treating osteoarthritis with arthroscopic debridement, arthroscopic lavage with or without debridement was no better than placebo for treatment of advanced osteoarthritis of the knee.(44) Our study attests that greater osteoarthritis is associated with worse recovery from arthroscopy, and substantiates that severe osteoarthritis may be a contraindication to surgery. Since patients with severe osteoarthritis already have extensive loss of cartilage and soft tissue, further soft tissue removal appears to have minimal impact on patient knee pain and regaining function in the short-term. Surgery would be justified only for mechanical symptoms (e.g. locking, catching, buckling, mechanical impingment), rather than for knee pain in any patient with a meniscal tear. In other words, knee pain and/or swelling without mechanical signs and symptoms is likely due to arthritic pain and will not be alleviated by arthroscopic partial meniscectomy; only mechanical symptoms and meniscal-based pain will improve.

Although using the Modified Outerbridge rating scale to determine the extent of osteoarthritis is valuable in predicting postoperative recovery from arthroscopic partial meniscectomy, one disadvantage is that it requires visualization of the knee joint by arthroscopy. Magnetic resonance imaging (MRI) is advantageous in evaluating the ligamentous and cartilaginous structures of the knee in multiple planes for preoperative planning in a non-invasively without ionizing radiation. The articular cartilage itself, however, is challenging to image owing to the fact that it is thin and has curved surfaces, which results in volume averaging and thus poor sensitivity for detecting small defects, fissures, and flaps. (45) Because of this poor sensitivity, MRI has been historically poor at imaging intraarticular cartilage and grading osteoarthritis, with poor intra- (46) and inter-observer (47) reliability. Additionally, preliminary retrospective data obtained during this study demonstrated that grading osteoarthritis by preoperative MRI was not predictive of postoperative recovery scores. Further prospective research is warranted to determine if preoperative evaluation and articular cartilage grading by newer cartilage-specific MRI sequences (45) might be able to better predict postoperative recovery in a noninvasive manner.

Demographic Predictors

Of the demographic variables included in our model, patient age and BMI were not associated with any postoperative recovery variable over time, although older patient age (17, 26) and obesity (19, 20) have been shown to be associated with a worse long-term result. In this study, women had greater preoperative knee pain, worse knee function, and poorer overall physical knee status than men. Postoperatively, these differences continued, with women continuing to show delayed recovery across all three recovery variables throughout the postoperative year, as previously illustrated in (Figures 14a - 14c). These findings contrast results indicating no differences in surgical outcome between men and women at 8.5 to 14.5 years after surgery, (21, 29, 30) but agree with results of previous research reporting worse long-term knee status in women after 15 years postoperatively. (19, 26). This indicates that women fare worse in the postoperative recovery period and past 15 years after surgery, but not at 8.5 to 14.5 years postoperatively. The reason for such gender differences are not known, but some research has shown gender differences in regards to knee kinematics, (48-50) hormone and immune factor milieu (51) and gait mechanics. (52)

Statistical Methods

One of the most important aspects of any study is to use statistical methods properly. As previously mentioned, the use of mixed model repeated measures allows use of all available data from all patients, is able to analyze several independent variables separately, and can examine data over an entire window of time rather than at a single specific timepoint by accounting for the trend toward recovery over time. Its organization as a 'within-subject' design inherently gives a greater statistical power than a 'between-subject' design. (33)

(Table 9) indicates proper statistical analyses for any given set of data. (53) It is important to select the proper statistical analysis in order ensure accurate significance and therefore appropriate applicability to the practice of evidence-based orthopaedics. As this data set compares several groups of data that are matched (scores over time are linked by patient), repeated measures analysis is vital to the integrity of the results.

Along the same line of reasoning, Pearson correlations were used to determine any correlation between surgical predictor variables (Table 6), as this is the proper statistical test for any such analysis. (53)

Strengths and Weaknesses

Notable strengths of this study are the prospective longitudinal design and gender balance, and that all patients were enrolled at the same time in their disease with fewer than 20% of subjects lost to follow-up. This classifies the data as meeting level I criteria (Table 10). Additionally, the recovery variables (knee pain, function, and overall physical knee status) are more understandable by the lay patient population rather than a measure conceived by orthopaedic surgeons (i.e. Lysholm score). In discussing this study with a potential surgery candidate, it is advantageous to be able to describe the results in terms the patient can understand (i.e. pain and function). Finally, mixed model repeated measures analyses were used to determine how the predictor variables were associated with recovery *over the entire recovery period*, rather than predicting knee status at a single specific timepoint.

One limitation of this study is that the recovery variables used differ from the outcome variables used in the previously mentioned studies, thus presenting a possible concern of confounding differences. The recovery variable of ‘overall physical knee status’ is not a standardized validated instrument. Although it is possible that the addition of a standardized validated instrument (i.e. Lysholm score) may add validity to this data, as mentioned previously no study to date has looked at postoperative recovery from surgery in the short-term. Rather, these instruments have been validated on, and used to describe, long-term surgical outcome. Therefore the degree to which these standardized validated instruments would add any reliability to the short-term recovery data is unknown.

Another limitation is that the study population, although representative of the university in which this study took place, is not representative of the average population. Patients were largely drawn from a university community; the population was not ethnically diverse (5% ethnic minorities) and included mostly a highly educated patient base (88% were educated through college or graduate/professional school).

Future Direction

Given that osteoarthritis at the time of surgery is the only variable shown to predict both long-term outcome and short-term postoperative recovery, it would be useful if we could measure and grade osteoarthritis preoperatively and noninvasively. This study and previous studies have graded osteoarthritis at the time of surgery by the Modified Outerbridge rating scale, which requires insertion of an arthroscope. With advances in radiographic imaging technology and the ability to better visualize articular cartilage, future research could be directed toward being able to predict long-term patient outcome and short-term postoperative recovery by preoperative MRI. In addition, this study opens the door for future research to determine what variables are associated with short-term recovery from orthopaedic procedures other than arthroscopic partial meniscectomy.

Conclusion

Variables that have previously been associated with poor long-term outcome are different than those associated with delayed short-term recovery, thus disproving part of our original hypothesis. Previous research has shown poorer long-term outcome with advanced age, greater BMI, and greater tissue excision, which were not seen here during the postoperative recovery period. This research has shown that female gender and worse osteoarthritis are associated with delayed short-term recovery from arthroscopic partial meniscectomy, while age, obesity, depth of meniscal excision, involvement of one or both menisci, and extent of meniscal tear showed no association over time throughout the first year postoperatively. On the whole, older and heavier patients are as likely to recover as capably as younger and leaner patients, however as previous literature has shown older and/or heavier patients may fare worse long-term.

Using these results, physicians can inform their patients that even though they are older or must have a large amount of tissue resected, this will not affect their rate of recovery when compared to other patients undergoing arthroscopic partial meniscectomy. Conversely, they can notify patients with significant osteoarthritis that even though they have a small meniscal tear, they may have poorer postoperative recovery than someone without significant osteoarthritis changes despite the small amount of tissue that needs to be resected, and may elect continuation of conservative (nonoperative) management.

Because patients are interested in the practical aspects of short-term recovery, that is, when will they be pain-free and thus able to return to work, sports, leisure time activities, and activities of daily living, identifying the surgical and demographic variables associated with rate of short-term recovery has great practical significance for the orthopaedic surgeon. In addition, entities other than the patient including employers, athletic teams, and insurance carriers are greatly interested in patient recovery and return to normal activity. Each requires data to be able to accurately predict the likely amount of time the patient will be expected to be out of work, off the playing field, or gaining disability benefits. By allowing the patient to be able to better know and understand their likely timeline for recovery from arthroscopic partial meniscectomy, “the process of shared medical decision making between patient and clinician becomes much more informed, educated, and confident." (54)

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Appendix A: Figures

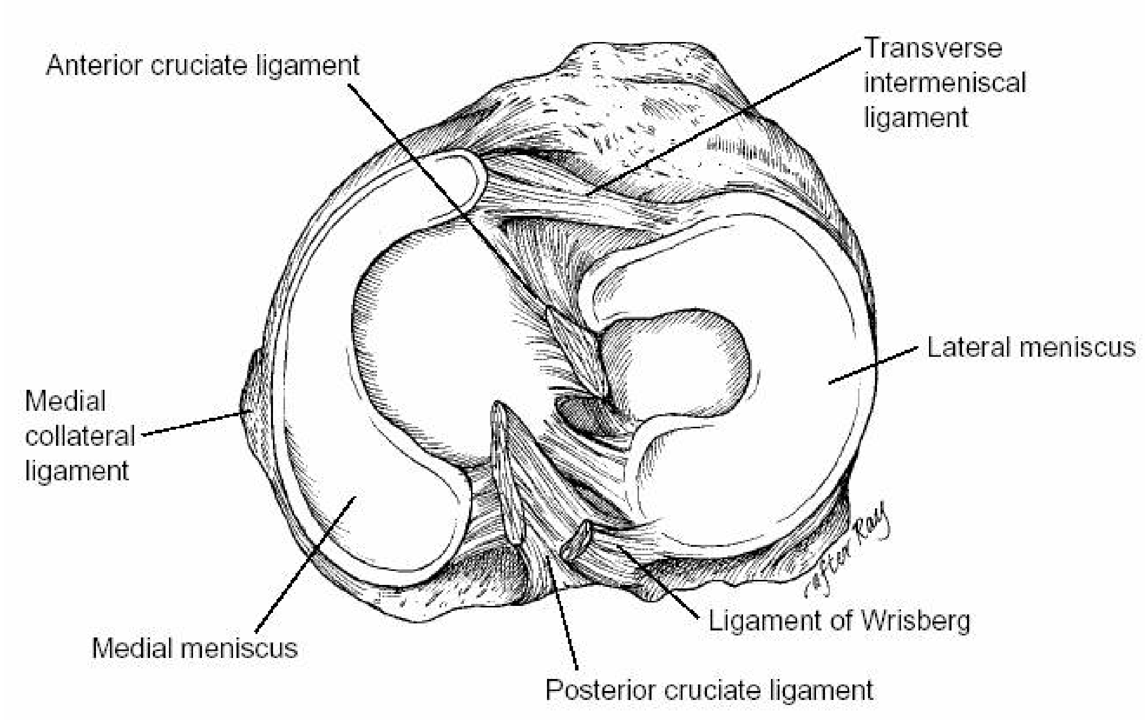

Figure 1. Gross anatomy of the menisci as viewed superiorly in the axial plane.

Pagnani MJ, Warren RF, Arnoczky SP, Wickiewicz TL: Anatomy of the knee, in Nicholas JA, Hershman EB [eds]: *The Lower Extremity and Spine in Sports Medicine*, ed 2. St Louis, MO: Mosby, 1995, pp 581-614.

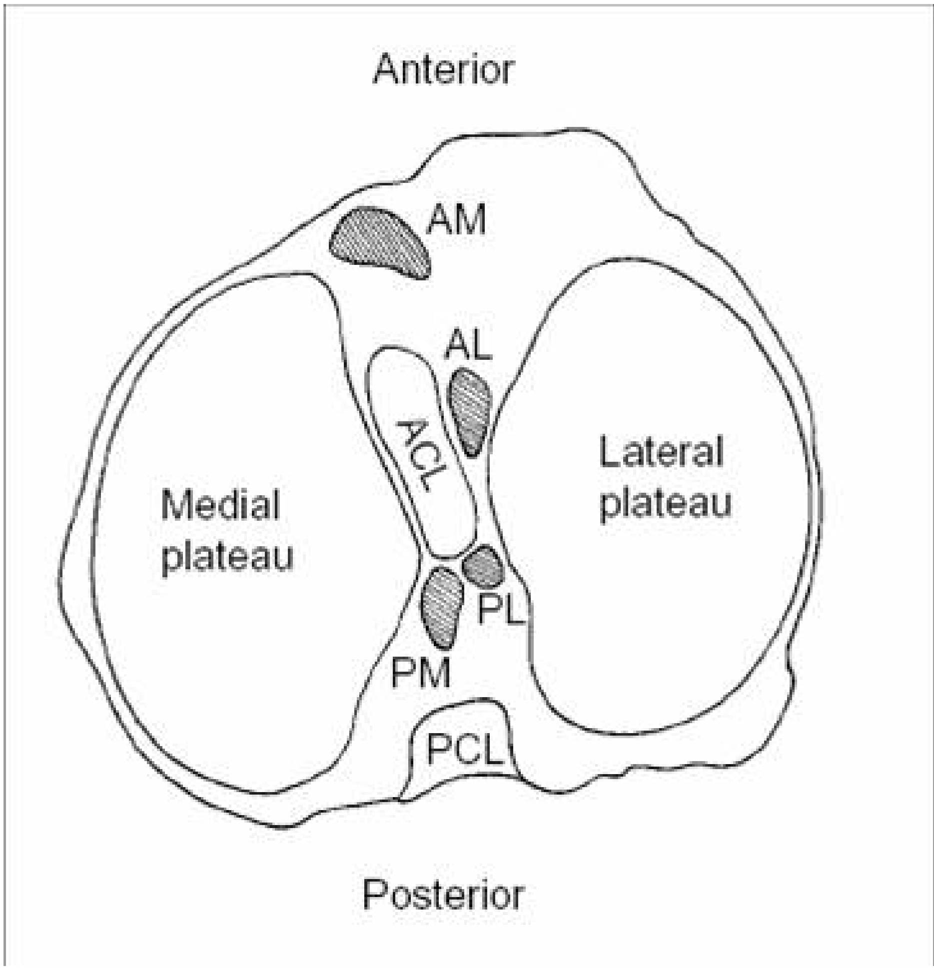

Figure 2. Attachments of the menisci and ligamentous structures on the tibial plateau as viewed superiorly in the axial plane.
AM: Anterior attachment of the medial meniscus; **PM:** Posterior attachment of the medial meniscus; **AL:** Anterior attachment of the lateral meniscus; **PL:** posterior attachment of the lateral meniscus; **ACL:** Anterior Cruciate Ligament; **PCL:** Posterior Cruciate Ligament

Johnson DL, Swenson TM, Livesay GA, Aizawa H, Fu FH, Harner CD: Insertion-site anatomy of the human menisci: Gross, arthroscopic, and topographical anatomy as a basis for meniscal transplantation. *Arthroscopy* 1995;11:386-394.

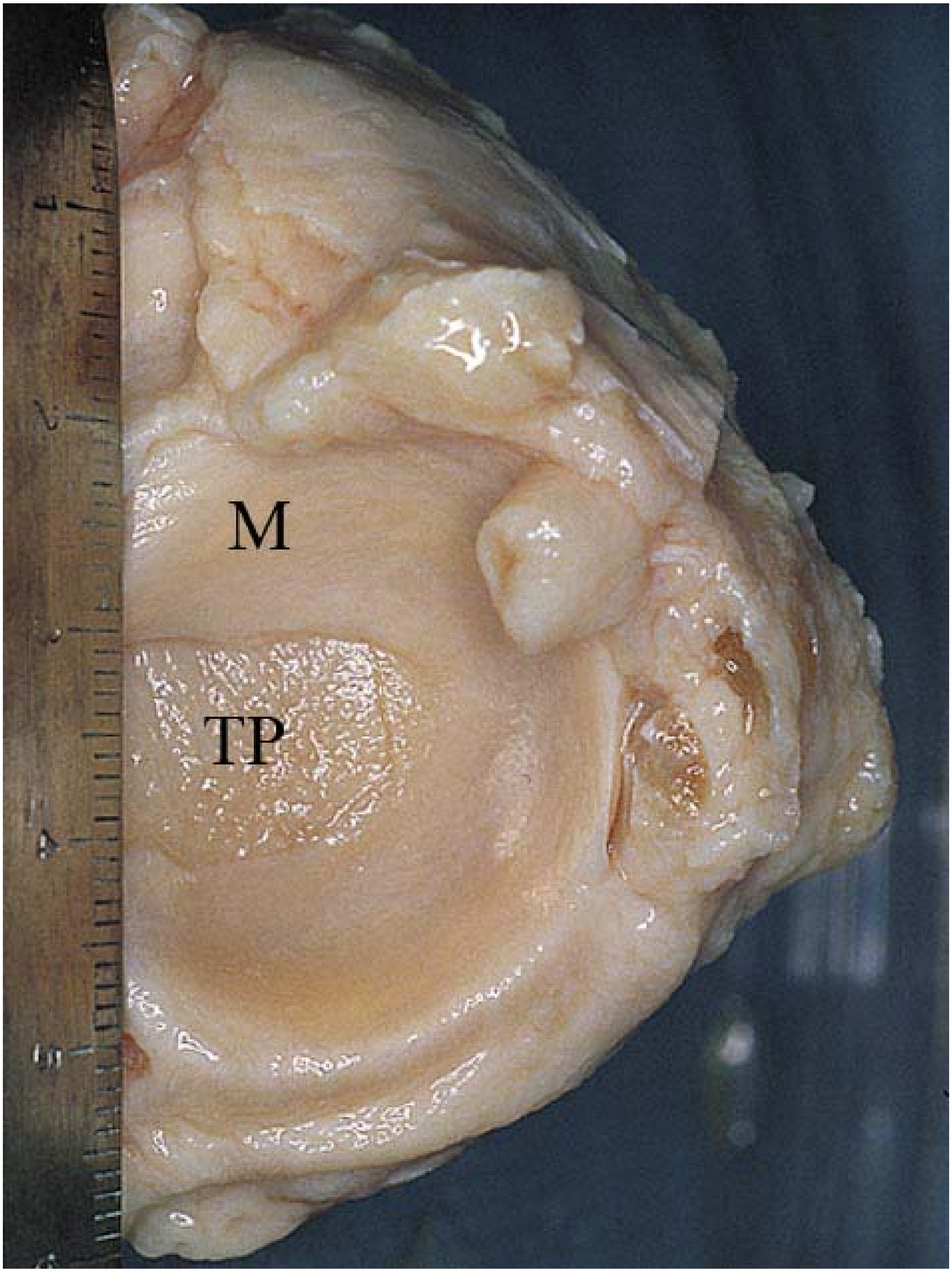

Figure 3. The lateral tibial plateau (TP) is largely covered by the lateral meniscus (M), a flexible fibrocartilage structure that plays an important role in load distribution in the knee. This meniscus has a normal appearance.

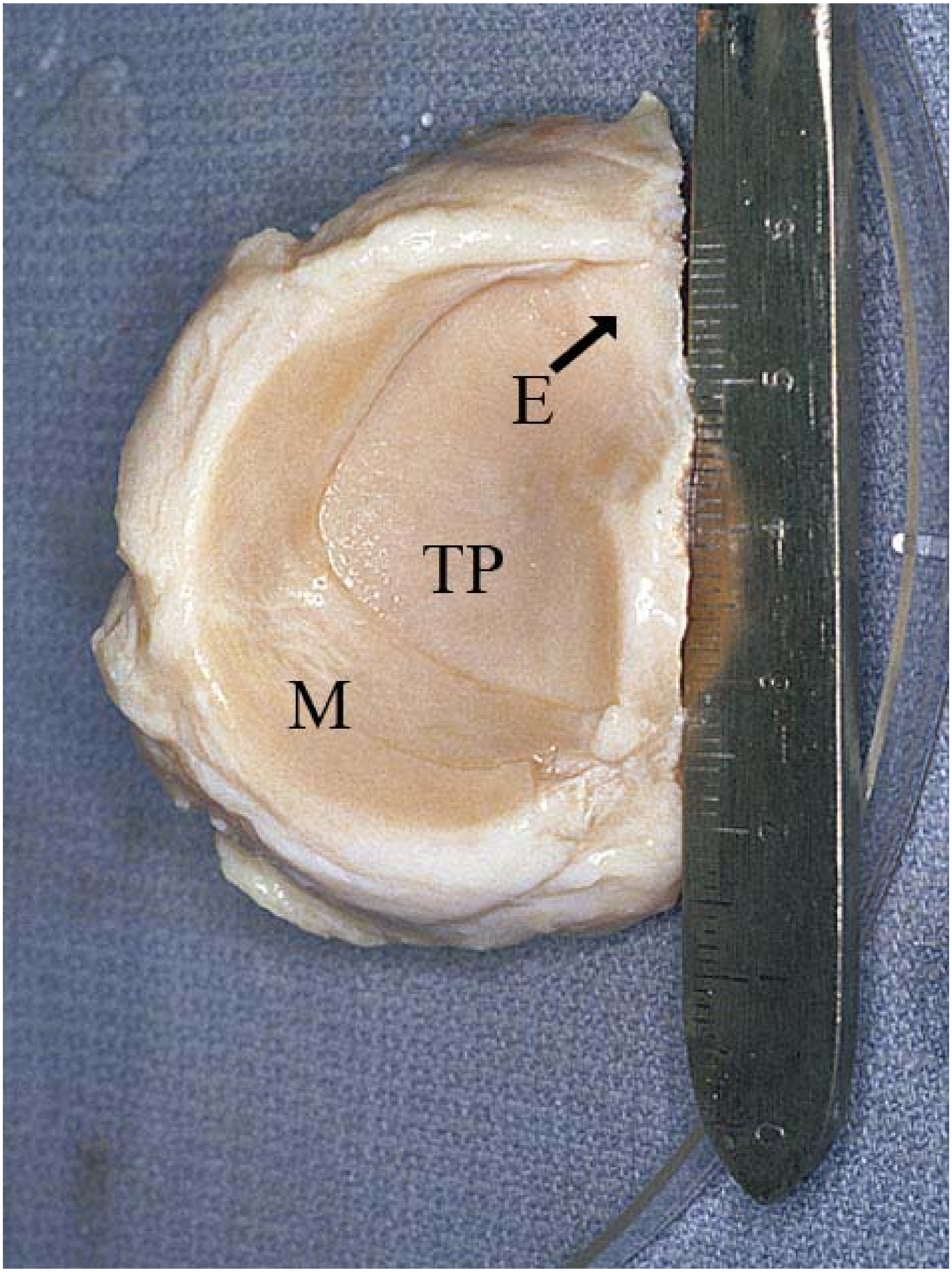

Figure 4. The medial meniscus (M) covers less of the articular surface of the adjacent tibial plateau (TP) than the lateral meniscus. A small erosion (E) of the articular surface is seen near the thinned posterior horn of the meniscus.

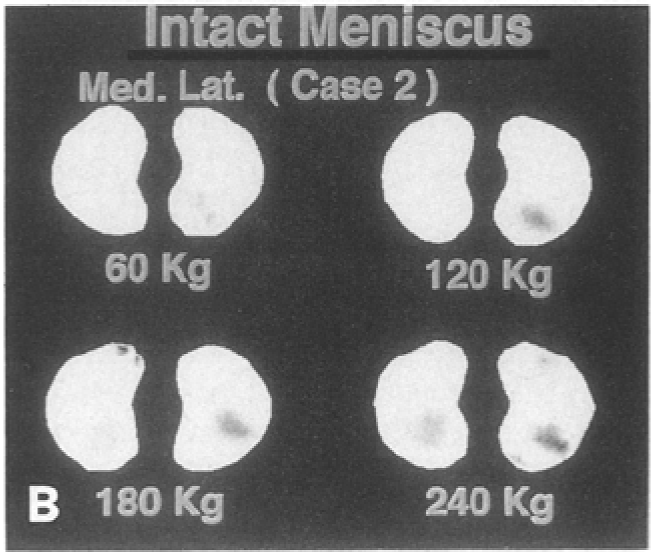

Figure 5a. Pressure-sensitive contact film showing pressure distribution over intact medial and lateral menisci.
Darker exposure = more pressure.

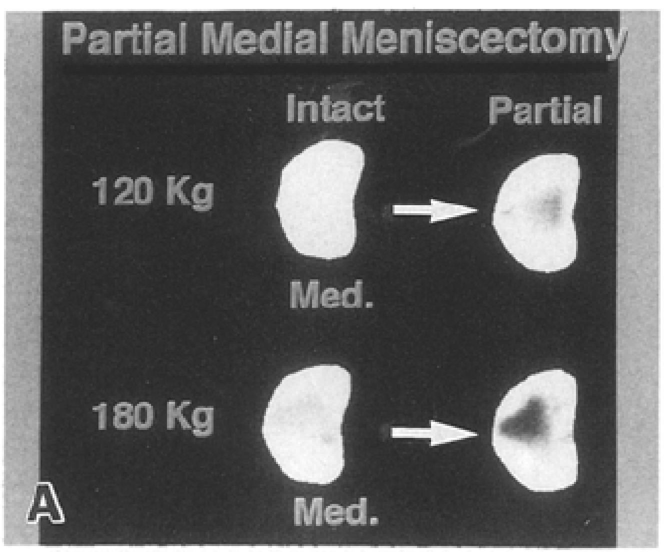

Figure 5b. Pressure-sensitive contact film showing pressure distribution over medial tibial plateau after partial medial meniscectomy.
Darker exposure = more pressure.

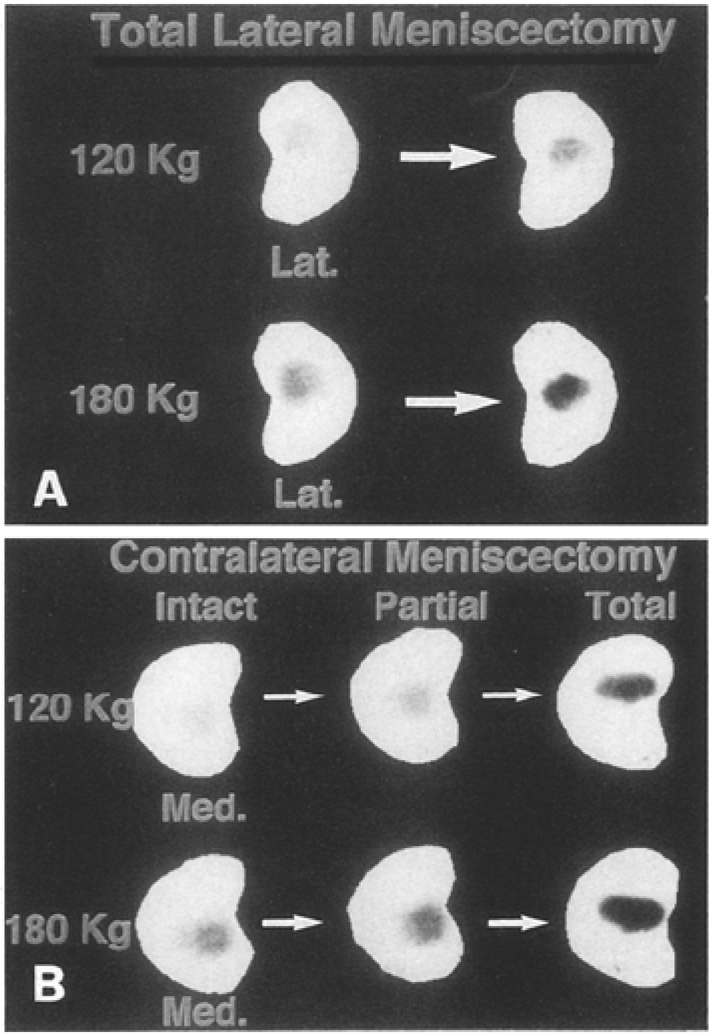

Figure 5c. Pressure-sensitive contact film showing pressure distribution after total lateral meniscectomy over the ipsilateral lateral tibial plateau (A) and the contralateral medial tibial plateau (B) after partial and total meniscectomy.
Darker exposure = more pressure.

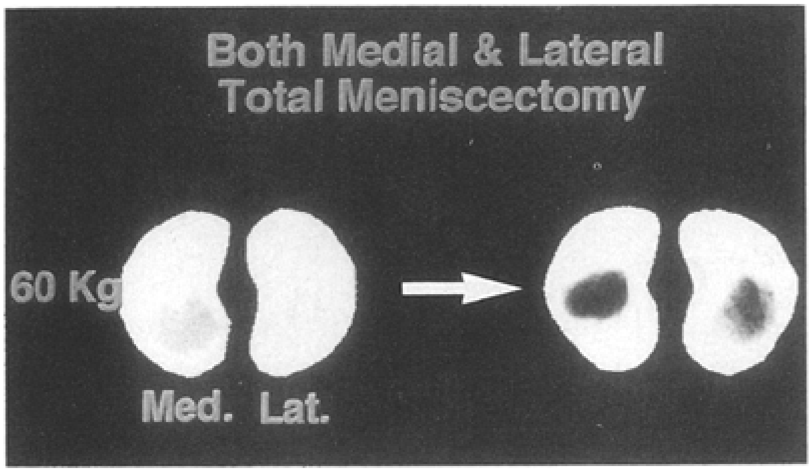

Figure 5d. Pressure-sensitive contact film showing pressure distribution over tibial plateau after total meniscectomy. Note the extreme pressures and small contact surface area with a 60Kg load.
Darker exposure = more pressure.

Ihn, J., Kim, S.J., and Park, I.H. 1993. In vitro study of contact area and pressure distribution in the human knee after partial and total meniscectomy. *International Orthopaedics* 17:214-218.

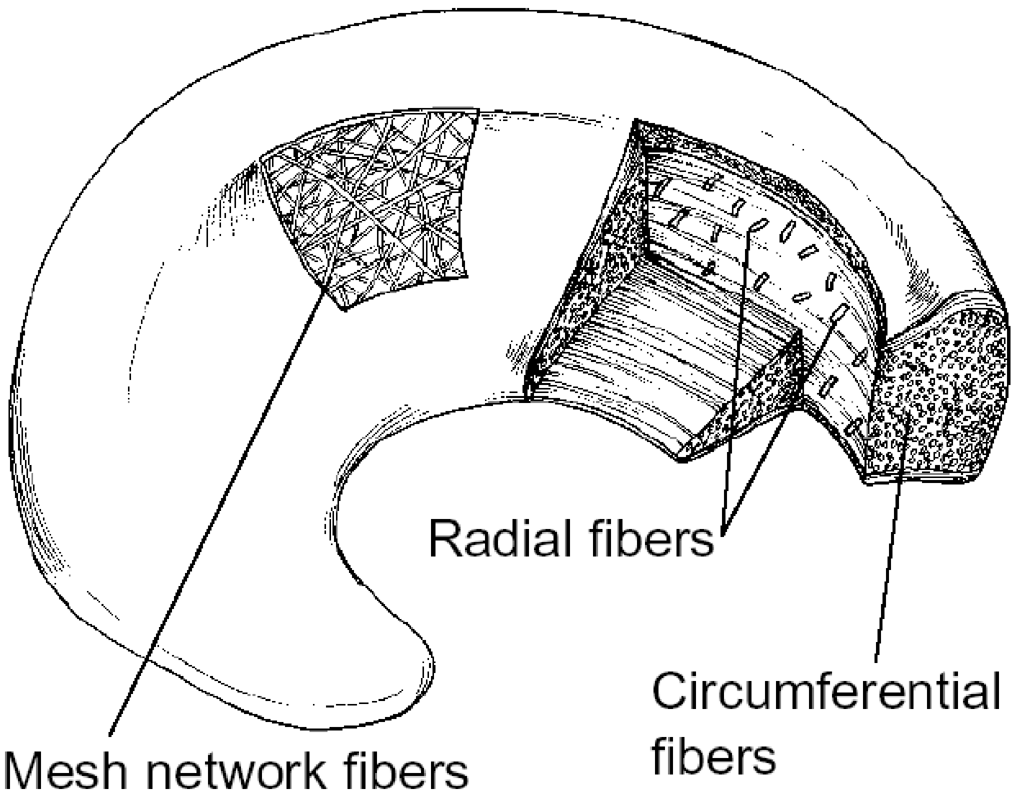

Figure 6. Organization of collagen fibrils in the meniscus.

Bullough PG, Munuera L, Murphy J, Weinstein AM: The strength of the menisci of the knee as it relates to their fine structure. *J Bone Joint Surg Br* 1970;52:564-567.

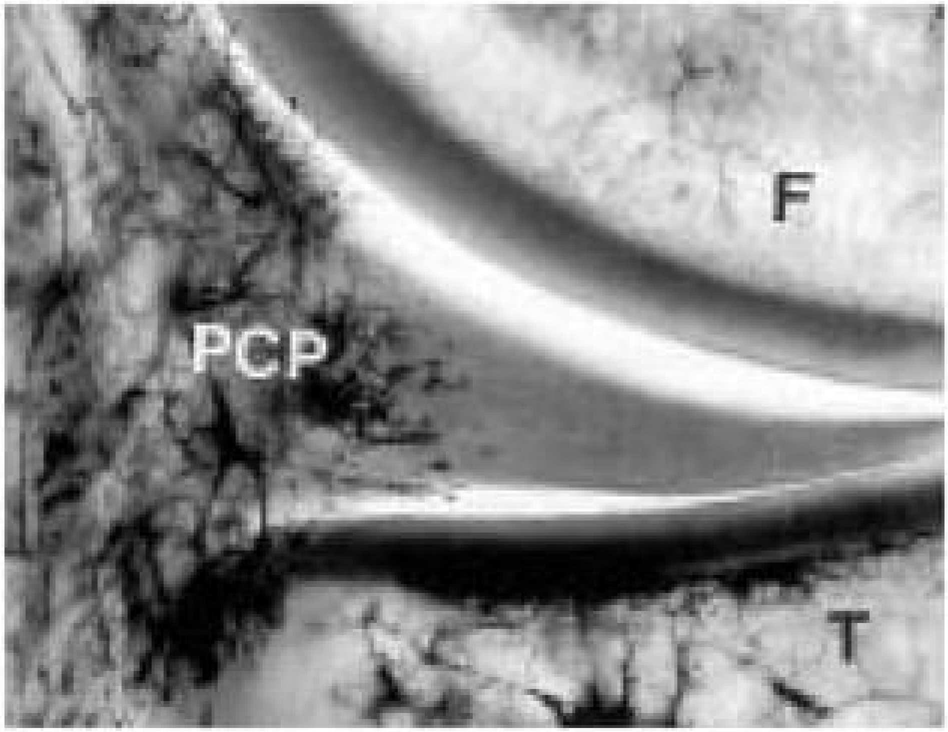

Figure 7: Blood supply in the adult meniscus.
F: Femoral condyle; **T:** Tibial plateau; **PCP:** Perimeniscal capillary plexus

Arnoczky S, Warren RF: Microvasculature of the human meniscus. *Am J Sports Med*, (10): 90-95, 1982.

Figure 8. Sagittal magnetic resonance image (MRI) showing a tear in the anterior horn of the medial meniscus (arrow).

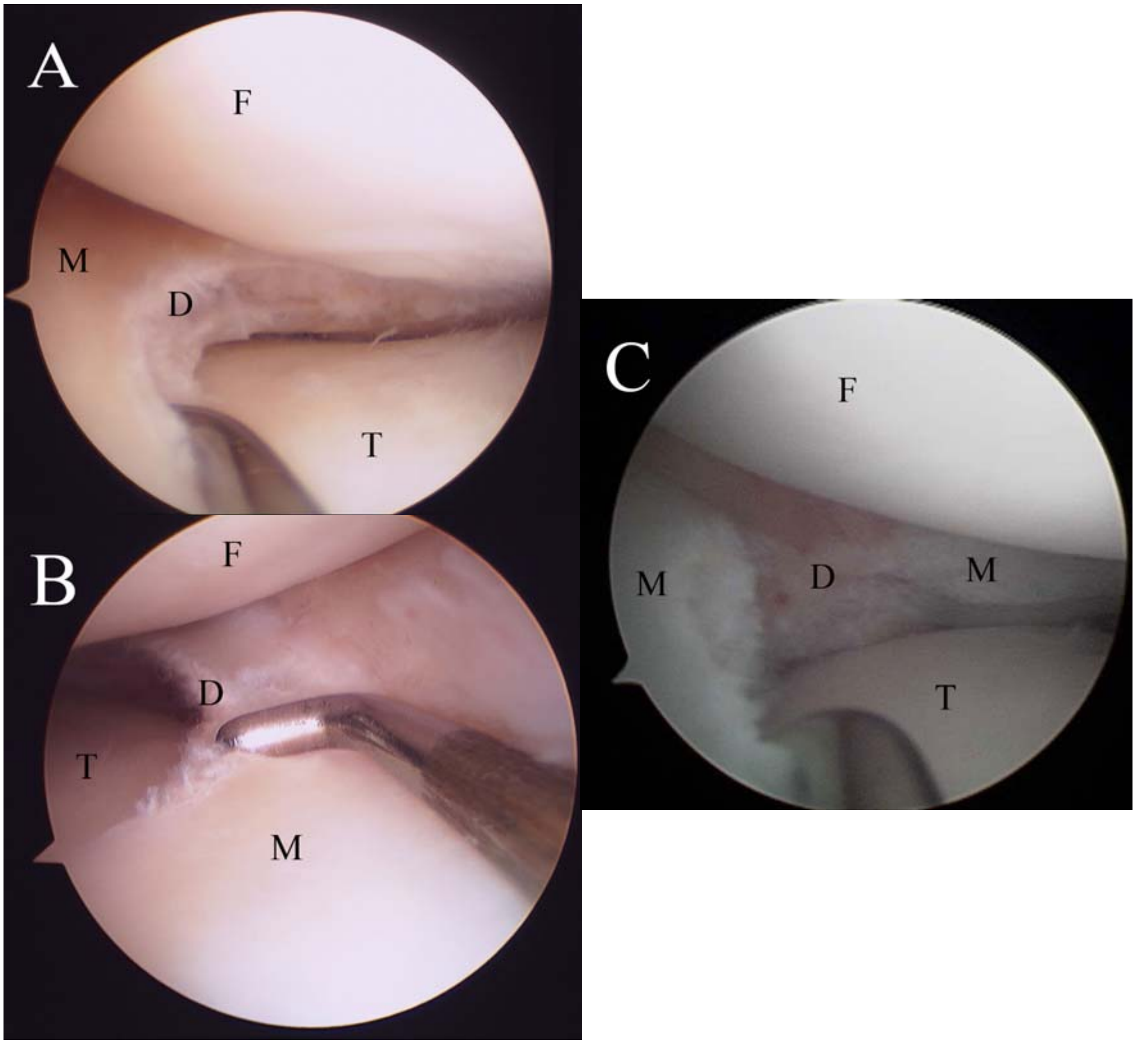

Figure 9. Example intraoperative arthroscopic images showing 25% (A), 50% (B), and 100% (C) meniscal width excision. For orientation, femur (F), tibia (T), meniscal tissue (M) and area of meniscal debridement (D) are noted. In the case of 100% meniscal width excision, only a small rim of tissue (a few millimeters) remains. For scale, the instrument seen here is a 5mm probe.

Images provided courtesy of Dr. Michael Medvecky
Yale University School of Medicine Department of Orthopaedics and Rehabilitation

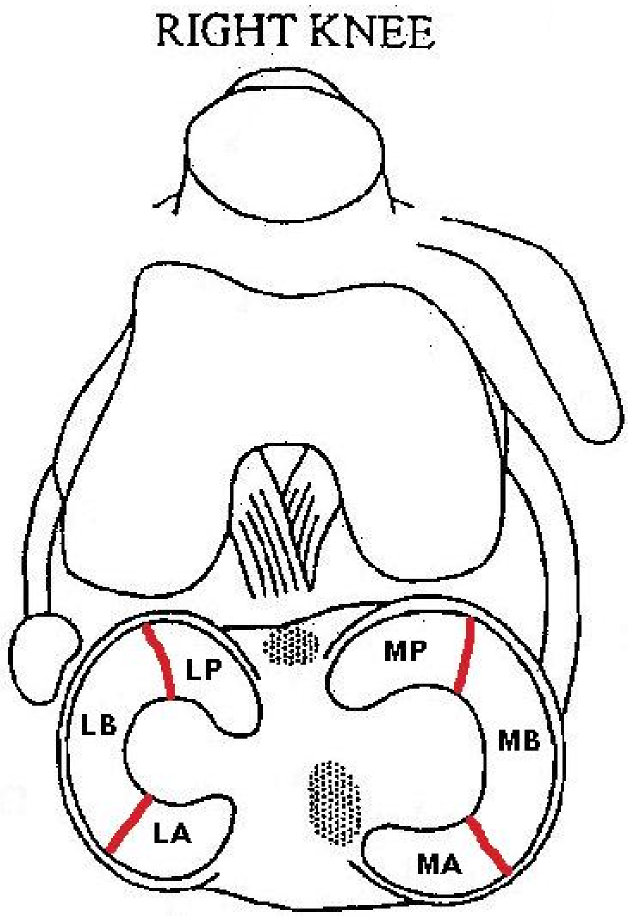

Figure 10. The six meniscal zones as shown in the right knee.
LP: Lateral Meniscus, Posterior Horn; **LB:** Lateral Meniscus, Body; **LA:** Lateral Meniscus, Anterior Horn; **MP:** Medial Meniscus, Posterior Horn; **MB:** Medial Meniscus, Body; **MA:** Medial Meniscus, Anterior Horn.

1	Articular cartilage softening
2	Chondral fissures or fibrillation <1.25cm in diameter
3	Chondral Fibrillation >1.25cm in diameter
4	Exposed subchondral bone

Figure 11. Modified Outerbridge articular surface grading (ASG) Scale

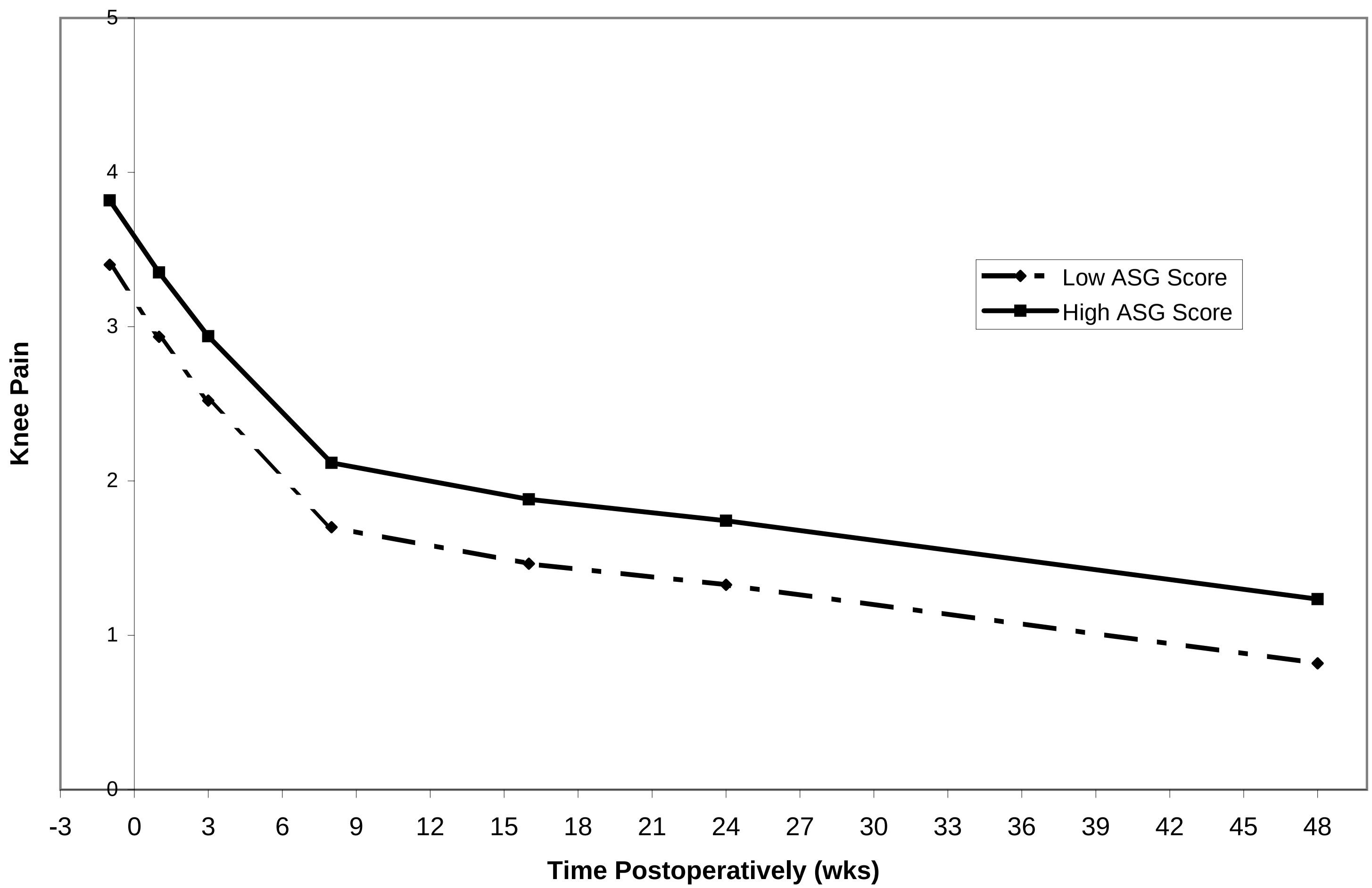

Figure 12a. Influence of Cartilage Damage on Knee Pain Over Time. Patients with greater cartilage damage report more knee pain over time. Groups reflect patients with high vs. low ASG score (median split).

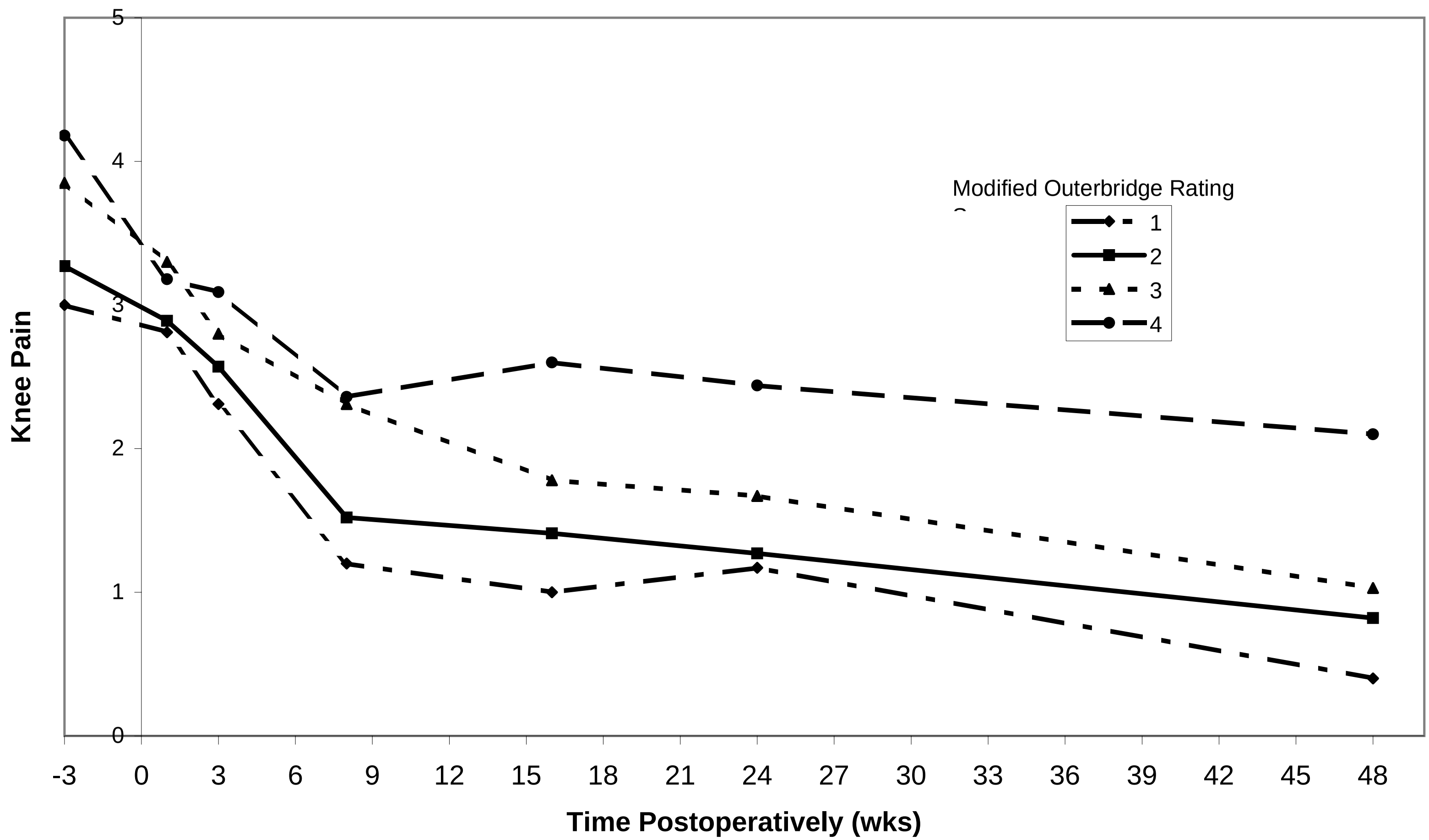

Figure 12b. Influence of articular surface grading score on knee pain over time.

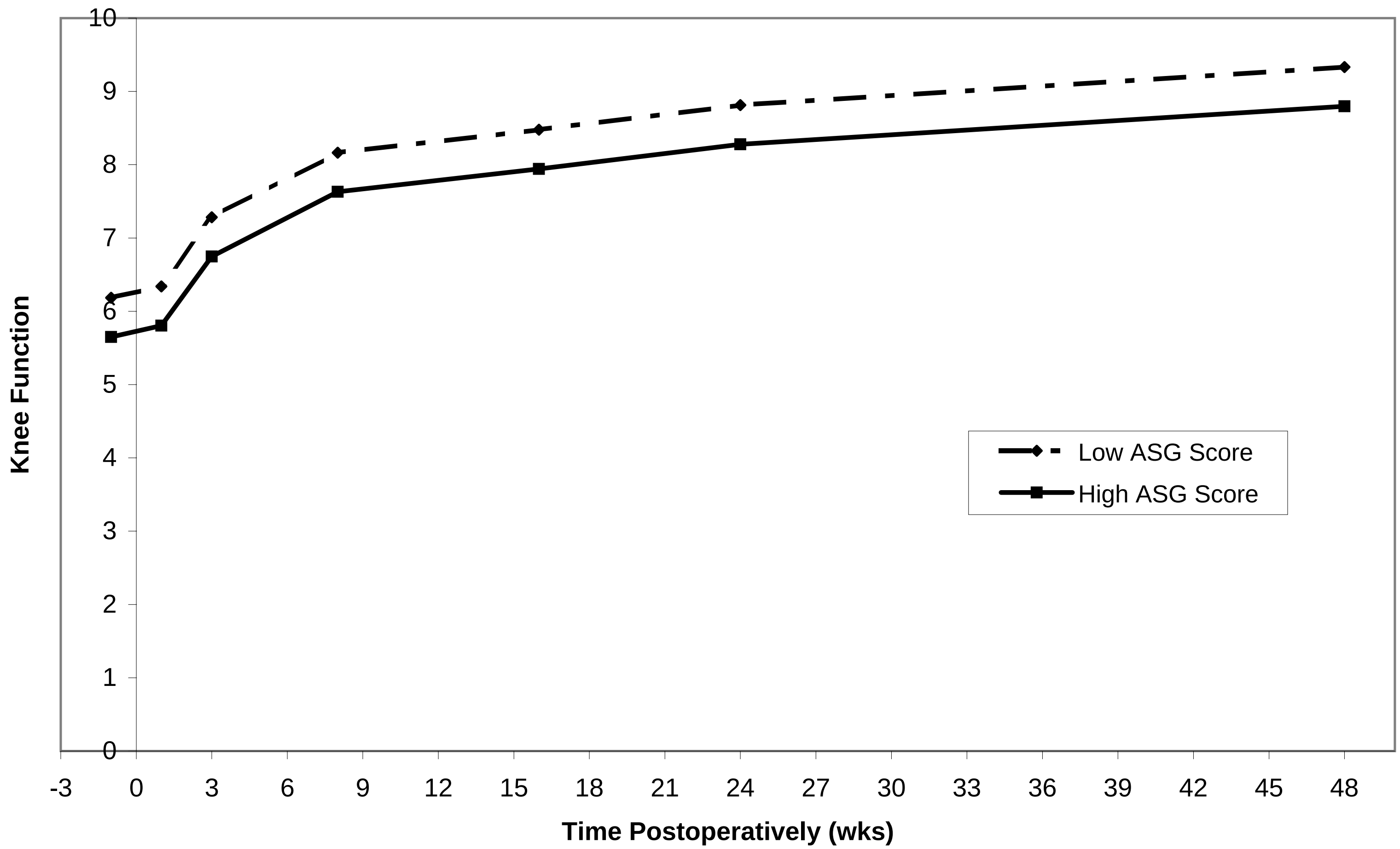

Figure 13a. Influence of Cartilage Damage on Knee Function Over Time. Patients with less cartilage damage report greater knee function over time. Groups reflect patients with high vs. low ASG score (median split).

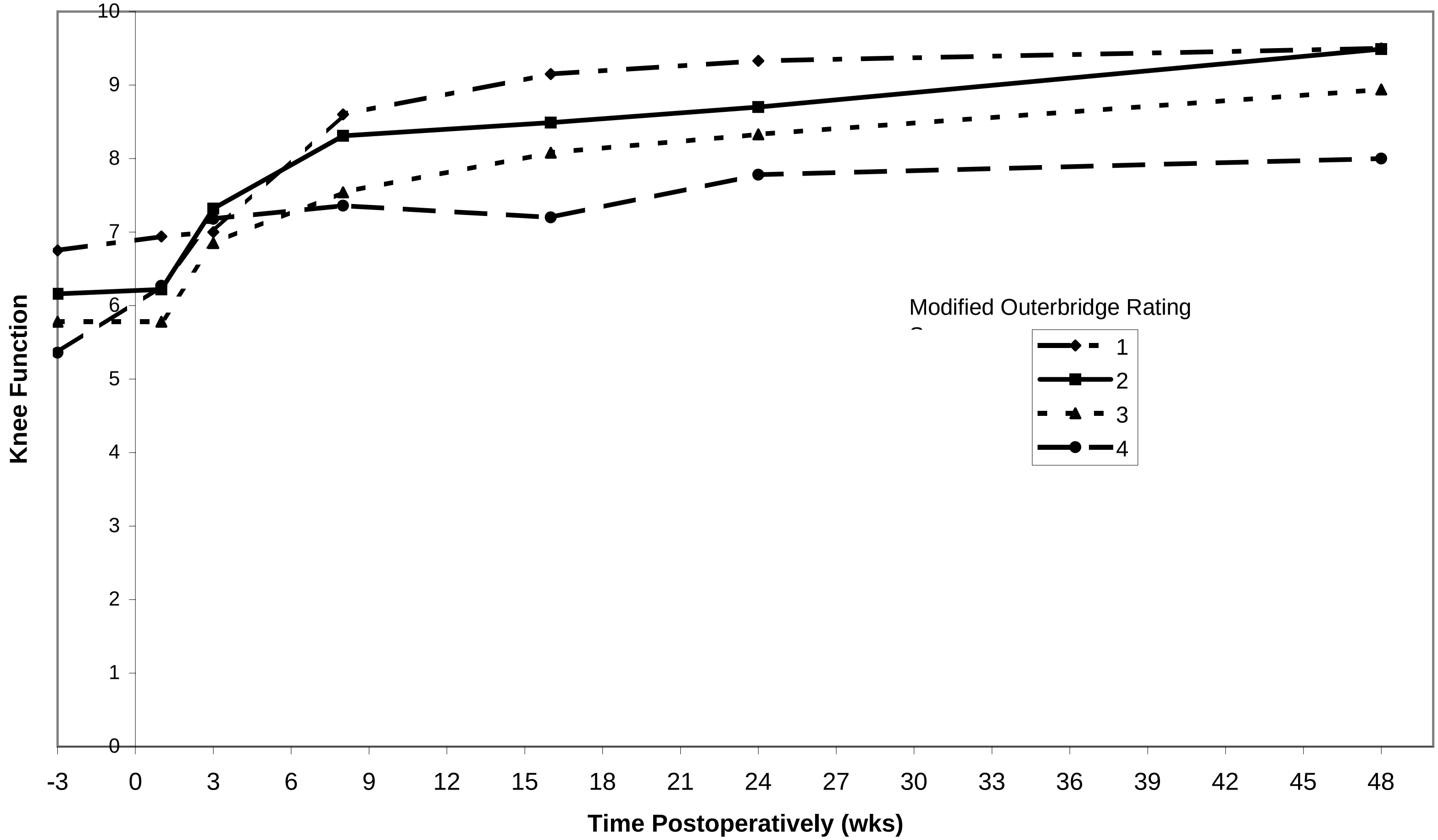

Figure 13b. Influence of articular surface grading score on knee function over time.

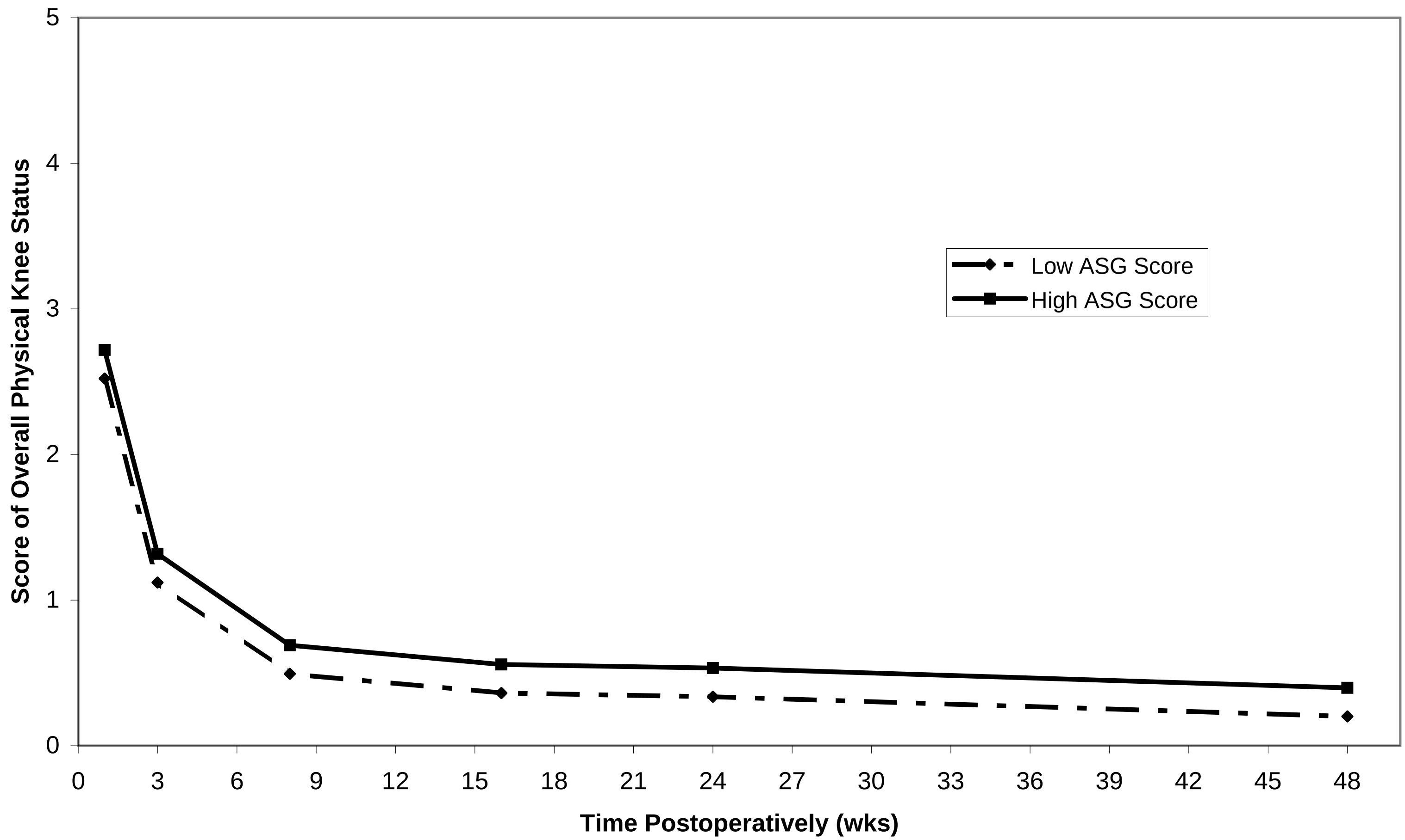

Figure 14a. Influence of Cartilage Damage on Overall Physical Knee Status Score Over Time. Patients with greater cartilage damage report worse overall physical knee status (higher numerical scores) over time. Groups reflect patients with high vs. low ASG score (median split).

Please Note: In the overall physical knee status scoring system, 0 = Most Normal, 5 = Most Abnormal

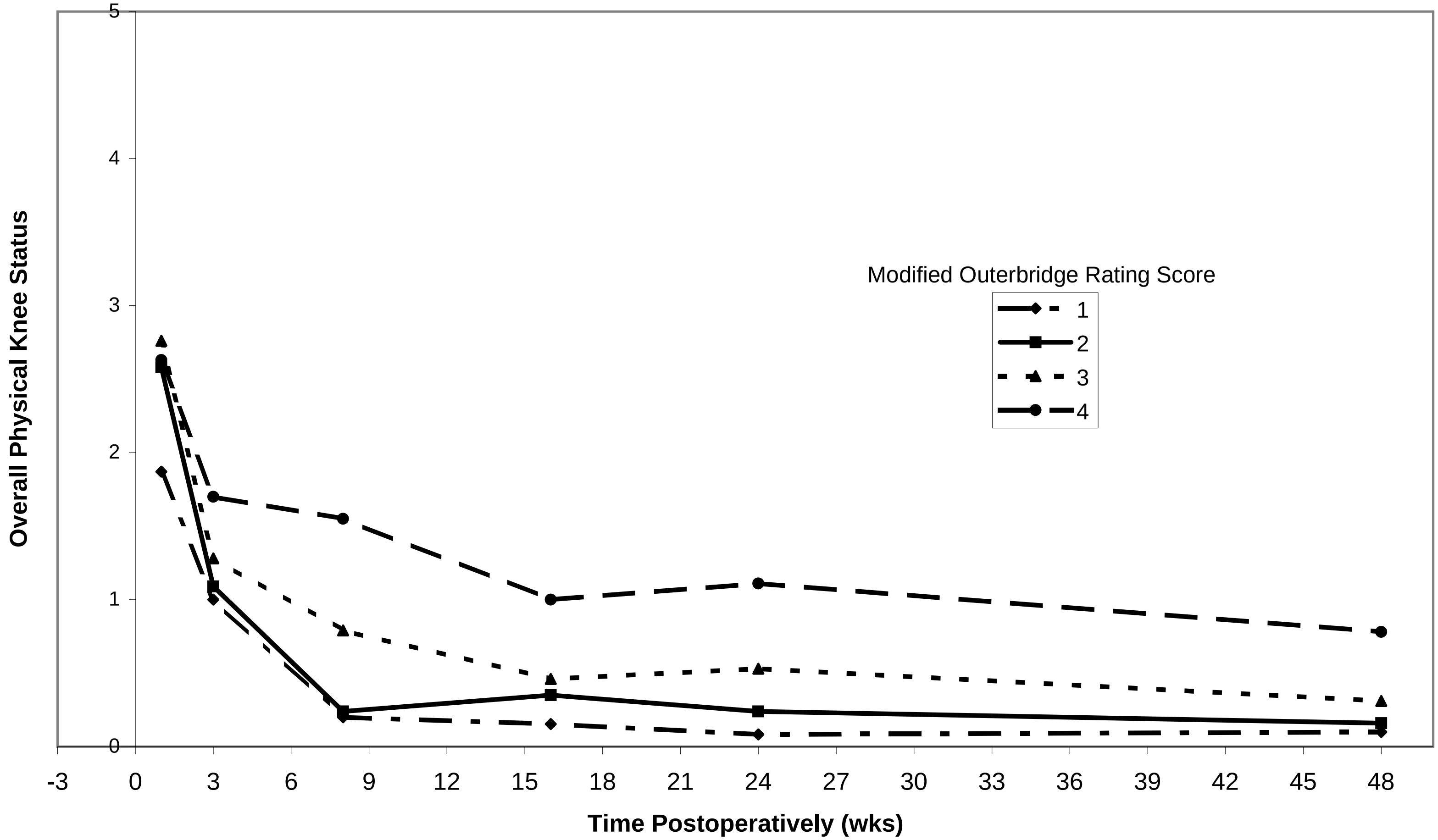

Figure 14b. Influence of articular surface grading score on overall physical knee status score over time.

Please Note: In the overall physical knee status scoring system, 0 = Most Normal, 5 = Most Abnormal

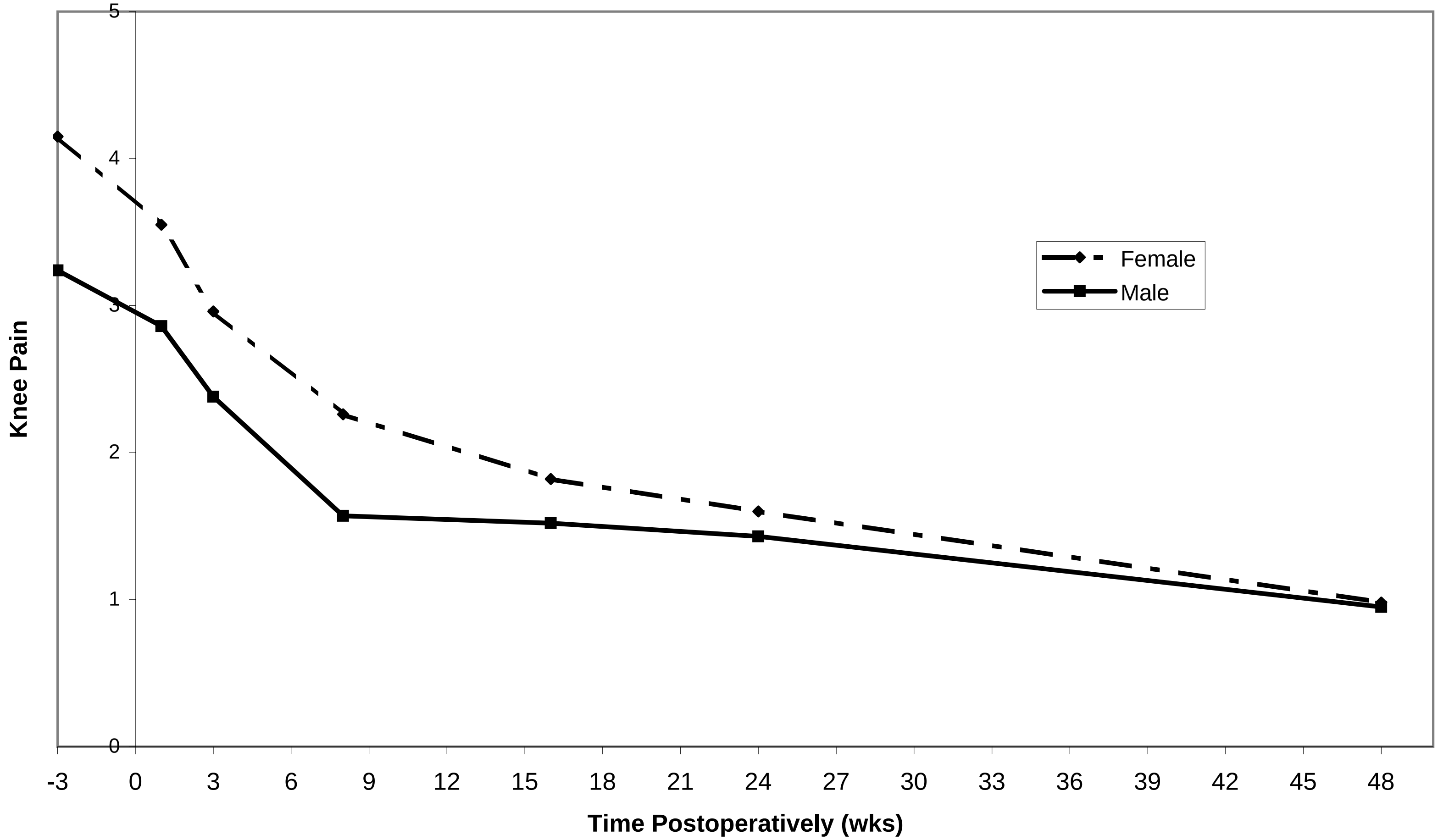

Figure 15a. Influence of gender on knee pain over time. Gender differences in preoperative knee pain continued postoperatively but became equal at the end of the recovery period.

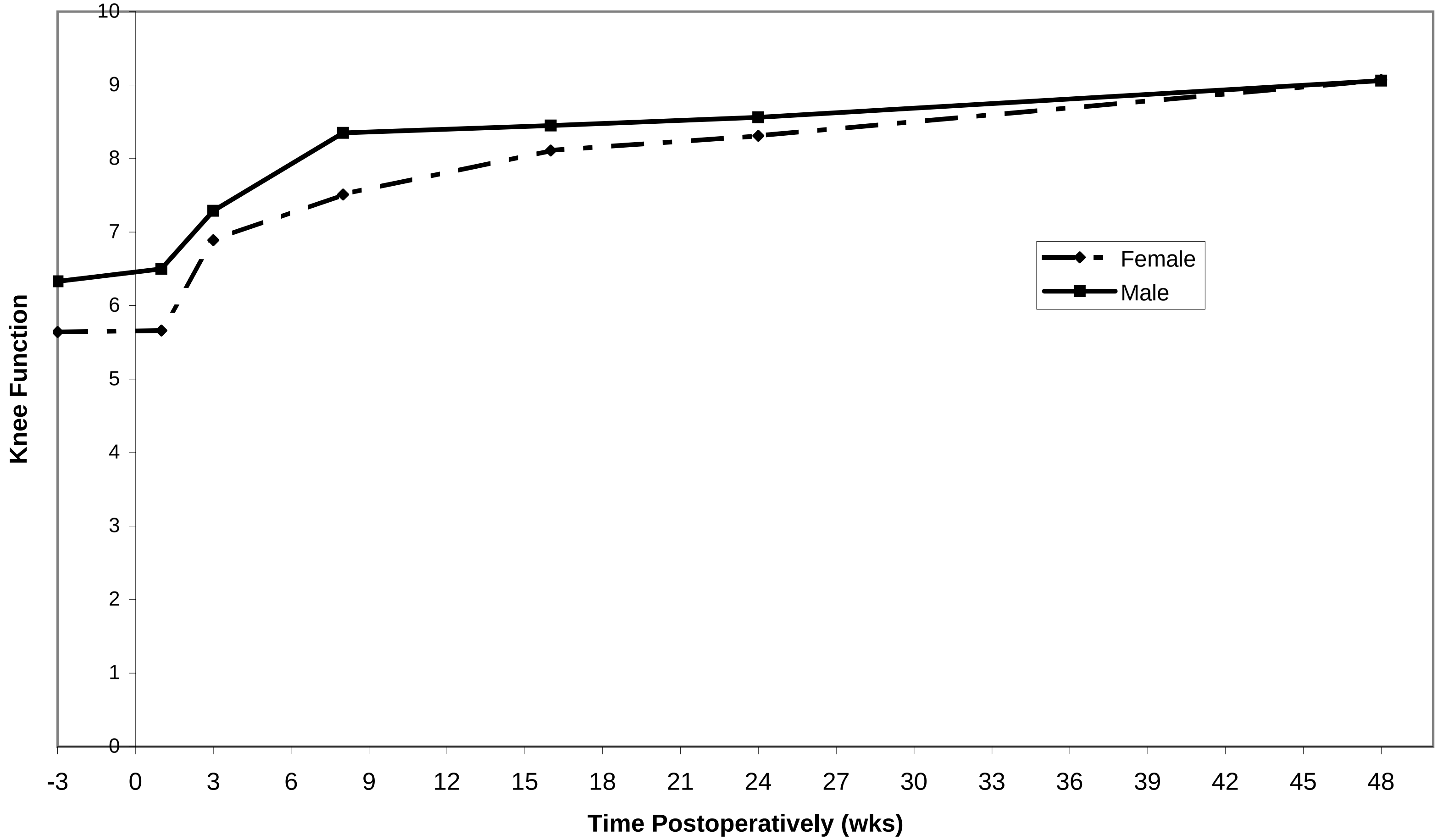

Figure 15b. Influence of gender on knee function over time. Gender differences in preoperative knee function continued postoperatively but became equal at the end of the recovery period.

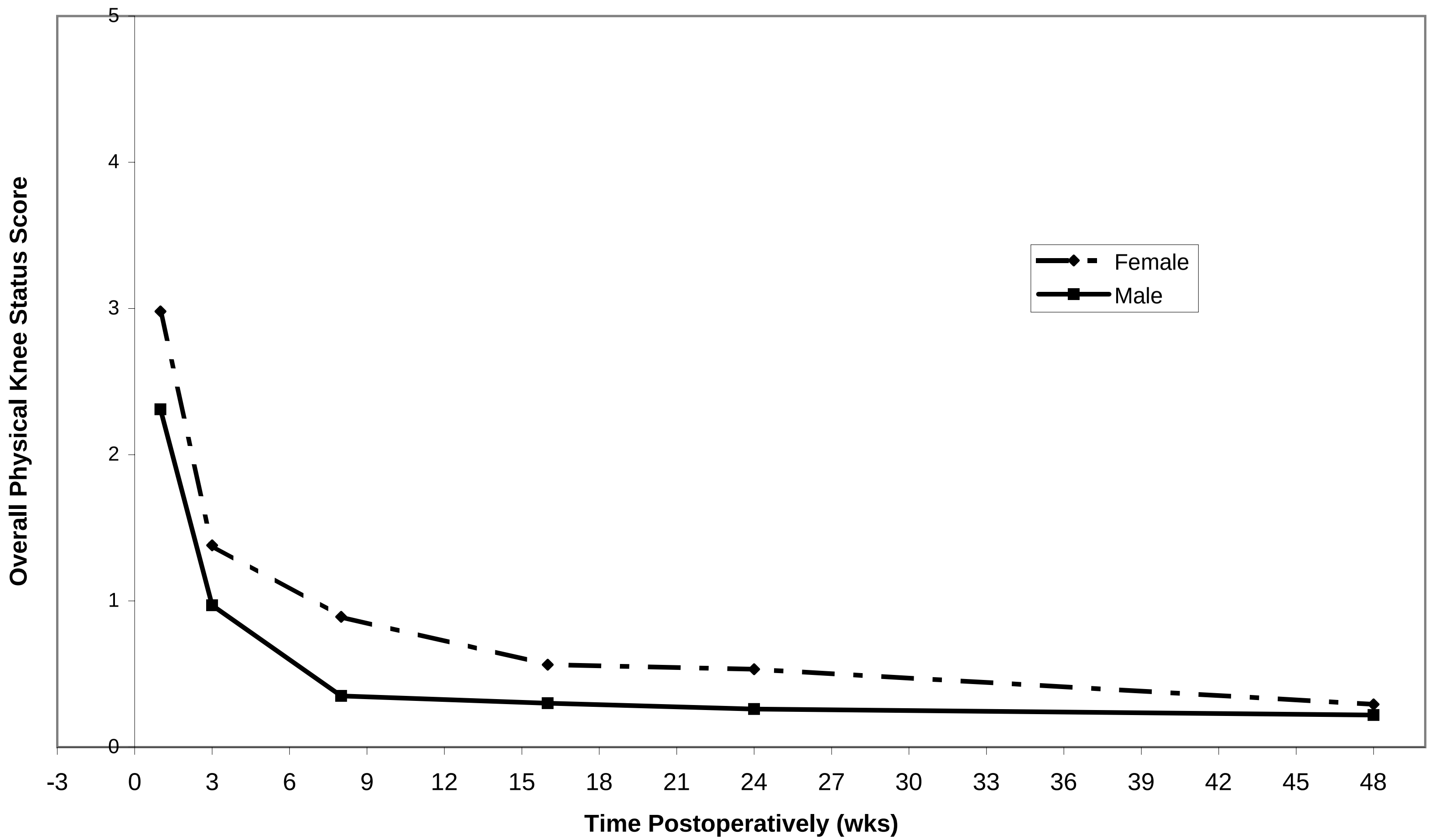

Figure 15c. Influence of gender on overall physical knee status score over time.

Please Note: In the overall physical knee status scoring system, 0 = Most Normal, 5 = Most Abnormal

Appendix B: Tables

Table 1. Top 10 All-Listed Ambulatory Procedures in the United States

Procedure:	**Total Number of Cases (Thousands):**	**% of Ambulatory Cases**
Lens and cataract procedures	431	8.7
Other theraputic muscle/tendon procedures	246	5.0
Tonsillectomy and/or Adenoidectomy	186	3.8
Other theraputic procedures on joints	166	3.4
Excision of semilunar cartilage of knee	159	3.2
Inguinal and femoral hernia repair	153	3.1
Cholecystectomy and common duct exploration	152	3.1
Lumpectomy, quadrantectomy of breast	151	3.1
Myringotomy (ear tube placement)	149	3.0
Diagnostic Dilation & Curettage	142	2.9

Source: Agency for Healthcare Research and Quality (2003)

Table 2. Predictors of Poor Recovery and Outcome - A Current Review of the Literature

Predictor Variable	Effects on Postoperative Recovery (0-2 years)	Effects on Long-Term Outcome (6-22 years)
	Study	Study
Depth of Meniscal Excision	No data to date, addressed in this study	Andersson-Molina 2002 Bonneux 2002 Englund 2003 Higuchi 2000 Meredith 2005
Involvement of One or Both Menisci	No data to date, addressed in this study	No data available
Extent of Meniscal Tear	No data to date, addressed in this study	No data available
Extent of Osteoarthritis	No data to date, addressed in this study	Chatain 2003 Englund 2004 Meredith 2005 Roos 2001
Age	No data to date, addressed in this study	Chatain 2003 Roos 2001
Obesity/BMI	No data to date, addressed in this study	Englund 2004 Harrison 2004
Female Gender	No data to date, addressed in this study	Englund 2004 Roos 2001
		Burks 1997 - No difference Fauno 1992 - No difference Higuchi 2000 - No difference

Table 3. Patient Characteristics of One Hundred Twenty Six Arthroscopic Partial Meniscectomy Candidates

Variable	Value
Gender	
Male	78
Female	48
Race	
White	120
Black	1
Hispanic	2
Other	3
Age (years)	49.3 ± 10.76 [23-78]
BMI	28.4 ± 5.5 [19.3-47.2]
Marital Status	
Never Married	19
Divorced or Widowed	13
Married	94
Education (years)	15.64 ± 1.72
High School	14
College	62
Professional School	50

Table 4. Frequency of Severity of Patient Knee Pathology and Depth of Meniscal Excision

One vs. Both Menisci	Number of Zones Involved (max 6)		Depth of Meniscal Excision (max 100%)
	1 Zone	76	
One Meniscus: 87	2 Zones	31	25% : 37
Both Menisci: 39	3 Zones	14	50% : 60
	4 Zones	3	75% : 27
	5 Zones	2	100% : 2
	6 Zones	0	
(126 Total)	(126 Total)		(126 Total)

Table 5. Distribution of Modified Outerbridge Scores

Score	Frequency
0	14
1	16
2	45
3	40
4	11
	(Total: 126)

Table 6. Intercorrelations Among Surgical Predictor Variables

	ASG	Depth of Meniscal Excision	One/Both Menisci
Depth of Meniscal Excision	0.042		
One or Both Menisci Involved	0.108	0.217*	
Extent of Meniscal Involvement	0.192*	0.471***	0.408***

Pearson correlation values demonstrating intercorrelations between each of the surgical predictor variables.
* $p \leq 0.05$, *** $p \leq 0.001$

Table 7. Summary of Mixed Model Repeated Measures Analyses Examining Influence of Predictor Variables on Recovery Over the Recovery Period

Predictor Variable	Recovery Variable					
	Pain		Function		Overall Physical Knee Status	
	Parameter Estimate	T Value	Parameter Estimate	T Value	Parameter Estimate	T Value
Modified Outerbridge ASG Score	0.29	2.64**	-0.32	-0.28 **	0.15	2.37*
Depth of Meniscal Excision	-0.08	-0.81	0.03	0.3	-0.25	-0.46
One vs. Both Menisci	-0.14	-0.75	0.04	0.19	0.10	0.94
Extent of Meniscal Tear	0.24	1.6	-0.25	-1.6	0.17	2.14*
Gender	0.38	2.13*	-0.49	-0.26**	0.25	2.59**
Age	0.00	0.37	0.00	-0.09	0.00	-0.51
Body Mass Index (BMI)	-0.01	-0.44	0.01	0.41	0.02	1.94
Time	-0.04	99.55***	0.05	17.73***	-0.02	-9.69***

* $p \leq 0.05$, **$p \leq 0.01$, *** $p \leq 0.001$

Table 8. Long and Short Term Predictors of Poor Outcome/Recovery

Predictor Variable	Effects on Postoperative Recovery (This Study)	Effects on Long-Term Outcome (Literature)
Depth of Meniscal Excision	No Association	Significant Predictor of Poor Outcome
Involvement of One or Both Menisci	No Association	No Literature Available at This Time
Extent of Meniscal Tear	No Association	No Literature Available at This Time
Extent of Osteoarthritis	Significant Predictor of Poor Recovery Scores	Significant Predictor of Poor Outcome
Age	No Association	Significant Predictor of Poor Outcome
Obesity/BMI	No Association	Significant Predictor of Poor Outcome
Female Gender	Significant Predictor of Poor Recovery Scores	Significant Predictor of Poor Outcome

Table 9. How to Choose a Statistical Test

Goal	Type of Data			
	Continuous Data	Ordinal Data	Binomial Data	Survival Time
Describe 1 Group	Mean, SD	Median, Quartiles	Proportion	Kaplan Meier Survival Curve
Compare 2 Unpaired Groups	Unpaired t-test	Mann-Whitney Test	Fisher's Exact Chi-square (large samples)	Log-Rank Test
Compare 2 Paired Groups	Paired t-test	Wilcoxon Test	McNemar's Test	
Compare 3 or More Unmatched Groups	One-way ANOVA	Kruskal-Wallis Test	Chi-square	
Compare 3 or More Matched Groups	**Repeated Measures ANOVA**	Friedman Test	Cochrane Q	
Association Between Two Variables	Pearson Correlation	Spearman Correlation	Contingency Coefficients	

A proper statistical test is chosen based on the goal of the analysis as well as the data it represents (and sample size, where appropriate).
In this study, repeated measures were used to compare matched data over time rather than at a single timepoint (highlighted).

Table 10: Levels of evidence for prognostic studies

Level of Evidence	Criteria
I	High-quality prospective study All patients enrolled at same point in their disease >80% followup of study participants Systematic review of level I studies
II	Retrospective Study Untreated controls from a randomized control trial Lesser-quality prospective study Patients enrolled at different points in their disease <80% followup of study participants Systematic review of level II studies
III	Case-control study
IV	Case series
V	Expert Opinion

Levels of evidence for prognostic studies (investigating the effect of a patient characteristic on the outcome of disease)

Appendix C: Forms

Yale University

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To:	Peter Fabricant
From:	Maurice Mahoney, Chair Chair Park for MJM
Date:	06/14/2005
HIC Protocol #:	0505027718
Study Title:	Clinical Factors Influencing Recovery from Meniscectomy (Medical Record Reveiw)
Committee Action:	**Expedited Approval**
HIC Action Date:	06/13/2005
Approval Date:	06/13/2005
Expiration Date:	06/12/2006
Submission Type:	Initial Protocol Application for Approval

Your request regarding the above-referenced protocol has been APPROVED following an expedited review by the Human Investigation Committee. The approval period for this protocol is noted above.

If you require institutional certification of this approval for some funding agency, please send to this office:

1) The form (if any) on which it is to be provided; and

2) HIC form #10 (completed).

__Reapproval:__ **It is the investigator's responsibility to apply for reapproval of ongoing research prior to one year from the date this protocol was reviewed by the full HIC or earlier if required by previous HIC approval. Therefore this protocol must be reapproved before the above-referenced expiration date.**

In compliance with federal regulations and current guidelines, the Human Investigation Committee ***requires*** that the Principal Investigator provide us with a *copy of* ***each grant application*****--for federal or other funding**--that is associated with the above-listed protocol. Please forward same as soon as possible.

__**Adverse Reactions:**__ If any untoward incidents or severe reactions should develop as a result of this study, you are required to notify the Chairperson of the HIC immediately; HIC Form #6 should be used for this purpose. If necessary, a member of the HIC will be assigned to look into the matter. If the problem is serious, approval may be withdrawn pending HIC review.

__**Amendments**__: If you wish to change any aspect of this study, such as the procedures, the consent forms, or the investigators, please communicate your requested changes in writing (in duplicate) to the HIC. All proposed changes to study documents, whether additions or deletions, will be required to be highlighted by underlining or other easily discerned marker method and must be specified in the submittal letter that references the proposed changes. The new procedure is not to be initiated until HIC approval has been given.

Please keep this memo with your copy of the approved protocol.

PROJECT RECOVER PHYSICIAN RATINGS – BASELINE

Patient Name:_______________________________ Date__ __/__ __/__ __ ID # ___ ___ ___

		Injured Knee	Contralateral Knee
1.	**Significant Effusion** *None=0, Mild=1, Moderate=2, Tense=3*	0 1 2 3	0 1 2 3
2.	**Aspiration** *No=0 Yes=1*	0 1	0 1
3.	**6-inch Straight Leg Raise** *No=0 Yes=1*	0 1	0 1
4.	**Prone Extension** *(heel height difference)*	mm	mm
5.	**Supine flexion** *(in degrees)*	○	○
6.	**Gait**	Normal no restrictions 0 / Normal w/ restrictions 1	Antelgic 2 / Assisted 3

7. Currently, how would you rate this patient's pain level? (*Please ask patient whether experiencing any pain and to describe pain. DO NOT ask the patient to rate pain using this scale. When rating pain, take into account both verbal reports of pain and nonverbal pain behaviors. Circle number below)*

0 1 2 3 4 5 6 7 8 9 10

No Pain **Unbearable pain**

8. Currently, how would you rate this patient's overall knee function? (*please circle)*

10 9 8 7 6 5 4 3 2 1 0

Excellent (*able to do any activity, Including sports,with no problems*)

Poor *(Significant limitations that affect daily activities)*

9. Physician Rater (*please circle*)

1= Jokl 2= Silver 3= Medvecky 4= Lynch 5= Mayor 6= Fulkerson 7= Dotson 8= Pelker 9=Other

PROJECT RECOVER PHYSICIAN RATINGS – POSTOPERATIVE WEEK _____

Date__ __/__ __/__ __   Patient ID # ___ ___ ___

		Injured Knee	Contralateral Knee
1.	**Significant Effusion** *None=0, Mild=1, Moderate=2, Tense=3*	0 1 2 3	0 1 2 3
2.	**Aspiration** *No=0 Yes=1*	0 1	0 1
3.	**6-inch Straight Leg Raise** *No=0 Yes=1*	0 1	0 1
4.	**Prone Extension** *(heel height difference)*	mm	mm
5.	**Supine flexion** *(in degrees)*	○	○
6.	**Gait**	Normal no restrictions 0 Normal w/ restrictions 1	Antelgic 2 Assisted 3

7. <u>Currently</u>, how would you rate this patient's <u>pain level</u>? (*Please ask patient whether experiencing any pain and to describe pain. DO NOT ask the patient to rate pain using this scale. When rating pain, take into account both verbal reports of pain and nonverbal pain behaviors. Circle number below)*

0 1 2 3 4 5 6 7 8 9 10

No Pain **Unbearable pain**

8. <u>Currently</u>, how would you rate this patient's <u>overall knee function</u>? (*please circle)*

10 9 8 7 6 5 4 3 2 1 0

Excellent
(*able to do any activity, Including sports,with no problems*)

Poor
(Significant limitations that affect daily activities)

9. Rate the current progress level of this patient in terms of rehab performance compared to other meniscectomy patients.

0 = Behind schedule 1 = On schedule 2 = Ahead of schedule

10. Has patient re-injured the knee in any way? (*since most recent surgery - please circle)*

0 = No 1 = Yes, minor 2 = Yes, needs re-surgery

11. Physician Rater (*please circle*)

1= Jokl 2= Silver 3= Medvecky 4= Lynch 5= Mayor 6= Fulkerson 7= Dotson 8= Pelker
9=Other

Meniscus Removal Data Sheet

Project Recover ID: ___________

Surgery Site: YALE TEMPLE

Knee: R L

Region:	Medial			Lateral		
	Anterior	Mid.	Posterior	Anterior	Mid.	Posterior
% Removed:	________	________	________	________	________	________
	0	0	0	0	0	0
	25	25	25	25	25	25
	50	50	50	50	50	50
	75	75	75	75	75	75
	100	100	100	100	100	100

Outerbridge Score: ________ Lateral ________ Medial ________ Patellar