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Biomechanical Effects of a Partial Undersurface Medial Meniscal Tear

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Abstract

Numerous studies have shown the biomechanical properties of the meniscus can be restored with repair. The aim of this study is to evaluate if partial undersurface tears of the medial meniscus encountered at the time of arthroscopy have any biomechanical impact on the contact area and peak pressure of the knee.

Methods: Nine unmatched cadaveric knees were harvested. The knees were inspected for prior disease and then prepared for loading on an MTS hydraulic machine at 1800N at 0 degrees of flexion. A 1.5cm, 50% partial undersurface tear of the medial meniscus was simulated, starting posterior to the deep medial collateral ligament (MCL) and continuing towards the posterior horn. After the simulated tear the specimens were trialed at 1800N on the MTS machine. Contact area and peak pressure were recorded.

Results: There was no difference in the contact area before or after the simulated tear on the medial meniscus. Medial contact area in mm^2 was 286.2 in the control group *vs*. 294.7 in the tear group (p=0.441). Lateral contact area in mm^2 was 400.3 in the control group, compared to 383.6 in the tear group (p=0.139).No difference in peak pressure before or after the simulated medial meniscus tear on the medial or lateral meniscus was demonstrated. Peak pressure on the medial meniscus was 3678.7KPa in the controls and 3545.8 in the tear group, with p=201. Peak pressure laterally was 5893.2KPa in controls *vs*. 5721.0 in tears with a p=953.

Conclusion: Statistical analysis demonstrates no biomechanical difference in contact area or peak pressure when a medial undersurface partial meniscal tear is encountered during arthroscopy. It may be extrapolated from this data that is safe for a surgeon who encounters this type of tear to treat it non-surgically or without repair at the time of surgery.

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Clinical Relevance

There is little in the current literature concerning the treatment of partial undersurface medial meniscal tears, however there is a long history of significant data demonstrating that full-thickness medial meniscal tears have a variety of deleterious effects on the osteochondral surface. This paper confirms that a partial undersurface medial meniscal tear does not cause any biomechanical changes and may be safely treated non surgically if encountered during surgery.

Introduction

The advent of arthroscopy has allowed for improved evaluation and management of meniscal lesions [1]. There is a paucity of information in the literature in reference to the management of a partial undersurface medial meniscal tear be appreciated. A literature search revealed the only publication on the topic from Tetik et al. [2], recommending synovial abrasion as a treatment for partial undersurface medial meniscal tears [2].

However, the consequences a meniscal tear can be serious, altering the contact mechanics of the knee [3-5]. These altered mechanics can lead to chondral wear and degradation [6]. With the resultant osteoarthritis visible radio graphically [7,8]. A meniscal tear does not necessarily inevitably lead to osteoarthritis or even increased chondral wear, as studies have previously demonstrated [9]. In the absence of established treatment guidelines, we set out to evaluate if partial undersurface meniscal tears should be treated based on changes in contact area or peak pressure of the knee.

Materials and Methods

Approval for the use of cadaveric specimens was granted from the Institutional Review Board

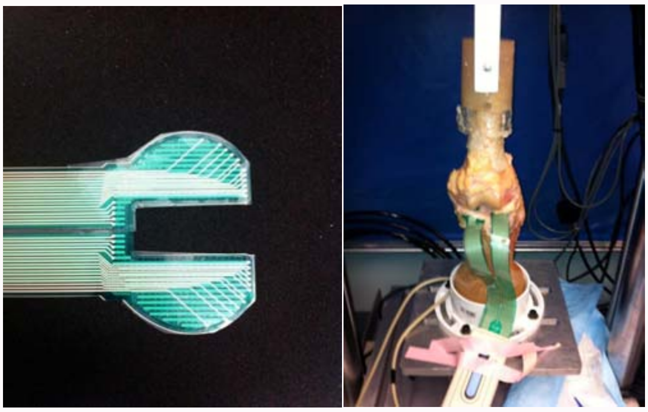

Figure 1: Tekscan 410-N knee sensor, with proper placement in the cadaveric knee.

at our institution. Nine unaltered fresh-frozen cadaveric knees were harvested from the Department of Anatomy Laboratory. Antero-posterior radiographs were taken, with any knee demonstrating radiographic signs of arthritis (joint-space narrowing, flattening of the condyles, osteophytes or chondrocalcinosis) being eliminated. The harvested knees were transected across the femur and tibia to isolate the knee joint and the knees were stripped of muscle, tendon, and patella, retaining the cruciate and collateral ligaments. An anterior capsulectomy was performed to grossly inspect the joint for any signs of meniscal or articular cartilage injury. The meniscofemoral and meniscotibial (coronary) ligaments were incised to allow placement of the Tekscan sensor (Tekscan, South Boston, Massachusetts). The sensor was placed beneath the medial meniscus and on top of the tibial plateau for better conformity.

A transverse 10-mm drill hole was made in the distal tibia and then the medullary canal of the tibia was reamed. A threaded rod was placed through the tibial drill hole and then the tibia was potted in methyl methacrylate. The femoral medullary canal was also reamed and potted in methyl methacrylate cement. A drill hole was made through the femur in the sagittal plane to allow unconstrained varus/valgus rotation during load testing. A custom stainless steel rod was inserted through the femoral hole and attached to the model 858 Mini Bionix load machine (MTS Systems Corp, Eden Prairie, Minnesota).

The tibiofemoral joint surface was oriented parallel to the floor with the knee held in full extension and measured goniometrically at 0°c, constrained but allowing for varus/valgus angulations. An 1800-N load was applied axially through the knee, consistent with prior studies and to simulate load during normal gait (2.5 times body weight of the average 70-kg individual), with the Tekscan 410-N knee sensor recording contact area and peak contact pressure (Figure 1) [10,11]. Knees were calibrated using an 1800-N load with that calibration file applied to the Tekscan data. The control knee contact area and peak contact pressure of medial or lateral tibiofemoral articulations were recorded over 3 trials.

Subsequently, a meniscal tear was simulated with a microscalpel through the anterior capsulectomy. The simulated tear was made posterior to the deep MCL continuing posteriorly towards the posterior horn. The tears were standardized at 1.5cm in length and approximately 50% of the meniscal thickness. The knees were loaded onto the MTS with 1800N of axial load, and the peak contact pressure and contact area were again recorded as the average of three trials. Medial and lateral contact area and peak contact pressure were recorded for each knee pre- and post- tear.

Descriptive statistics are provided as mean ±standard deviation. Comparisons between groups were calculated with a 1-way analysis of variance. Tukey's post hoc analysis was completed for all significant analysis of variance results to determine significant pairwise comparisons. A probability value of ≤.05 was considered statistically significant in all tests performed. All statistical analyses were performed with SPSS software (version 15.0, SPSS Inc, Chicago, Illinois).

Results

A total of nine knees were evaluated using the methods described above. No knees were eliminated during the course of study. The mean peak contact pressure and mean contact area measured in the medial and lateral compartments both before and after meniscal tear are presented in (Table 1).

No significant difference in contact area or peak pressure was demonstrated in either medial or lateral compartments with a native meniscus compared to those with a created undersurface tear.

Discussion

The knee menisci play an integral part in the complex biomechanics of the knee and function, in part, to protect the adjacent cartilaginous surfaces from axial loads [12-14]. Menisci increase the congruity of the convex femur to the comparatively flat tibia, playing an integral role in joint lubrication, load distribution, joint stability, and proprioception. During weight bearing, the circumferential collagen bundles of the menisci bear hoop stresses, allowing distribution of axial load across the joint, effectively protecting the articular cartilage [15]. There is a negative biomechanical effect of meniscal loss, with 50-200% increases in medial contact pressure in meniscectomized versus normal knees [16-18].A correlation exists between the amount of meniscus resection and both the onset and severity of osteoarthritis [19,20].

After an extensive literature search, there appears to be little addressing the presence of undersurface tears of the menisci. We hypothesized that the decision of whether or not to repair the tear may hinge on the results of differences in contact pressure. The only paper found, by Tetik et al. [2], suggests synovial abrasion as a viable treatment plan for undersurface meniscal tears. 2 The consequences of untreated meniscal tears, as discussed earlier, are severe enough that we thought it prudent to examine if undersurface tears affected the peak pressures exacted upon the chondral surface.

Nine cadaveric specimens were examined, with medial meniscal undersurface tears created after peak pressure and contact areas

Table 1: Mean peak contact pressure and mean contact area measured in the medial and lateral compartments both before and after meniscal tear.

		Mean	N	Std. Deviation	P
Contact Area (mm^2)	Medial	286.2	9	93.6	
	Medial (Tear)	294.7	9	78.9	0.441
Contact Area (mm^2)	Lateral	400.3	9	82.7	
	Lateral (Tear)	383.6	9	83.3	0.139
Peak Pressure (Kpa)	Medial	3678.7	9	966.8	
	Medial (Tear)	3545.8	9	990.7	0.201
Peak Pressure (Kpa)	Lateral	5893.2	9	2075.6	
	Lateral (Tear)	5721.0	9	1672.5	0.953

were established in the native menisci. A statistical analysis of the peak contact pressures and areas demonstrated no biomechanical difference between the cut menisci and the native ones. This data affects the clinical decision-making of an orthopaedist in that, should an undersurface medial meniscal tear be discovered pre or intra-operatively, it may be treated nonoperatively. Establishing that undersurface meniscal tears may be treated non operatively places these type of tears into a category with certain other tear types as demonstrated on cadaveric specimens [21]. This knowledge assists the surgeon both in the allocation of operative time and in overall cost of procedure. Cost amelioration stems from decreased operating room time and the saved cost of an unnecessary procedure.

The possibility exists that cyclic loading could reveal the extension of undersurface tears into full thickness tears with deleterious effect on meniscal strength and resultant chondral pathology. However, the lack of promulgation of the tear as shown by our study and concomitant lack of contact area changes suggest that cyclic loading would not play a great role in the future extension of undersurface tears.

We excised the coronary ligaments to allow the test film to lie flat on the tibial plateau. It was previously found in pilot testing of our MTS that other positions of the film, for instance, on top of the meniscus, led to slippage of the film and inconsistent data collection. Transecting the coronary ligaments may have rendered the control knee meniscus more unstable, thus altering contact area and peak pressures. However, the effect would have been the same on both the control and tear groups, leading to the same results as we have demonstrated. The protocols used and the weaknesses of this study are similar to previous studies using this MTS machine [22].

Limitations of this study include that the protocols in this study tested knees in full extension only, with surrounding muscle forces eliminated. We fixed the flexion angle of the knee to simplify the testing apparatus and sequences, assured in the knowledge that other studies have demonstrated a consistent pattern of change in loading profiles across all flexion angles [11]. Although both cyclic loading and full extension testing represent potential limitations of this study, each conform to protocols of previously published biomechanical knee studies.

Summary

Often during diagnostic arthroscopy, undersurface tears of menisci are encountered. The decision concerning whether or not to repair may hinge on the results of differences in contact pressure. It is well documented in the literature that certain meniscal tears can result in osteoarthritis of the knee, secondary to increased compartment pressures. Our study demonstrates a lack of difference between peak pressures and contact area in control and torn menisci, suggesting nonoperative treatment or non-repair of undersurface meniscal tears. The clinical implications of this finding include decreased intraoperative time and the lack of unnecessary surgical intervention.

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