Dynamic Contact Mechanics of Radial Tears of the Medial Meniscus: Partial Meniscectomy Compared to Repair

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INTRODUCTION

Mechanical functions of the menisci include the transmission and distribution of loads across the knee joint. When injured, this function is compromised and the goal of any surgical reparative procedure is to relieve pain and ideally restore the load bearing capabilities of the injured tissue. The management of radial meniscal tears, however, is controversial. If the tear extends to the peripheral vascular zone, the torn ends are often sutured together; whereas if the tear is confined to the avascular zone a partial meniscectomy is favored.

The purpose of this study was to measure the contact pressures transmitted to the tibial plateau during dynamic physiologic loads as a function of percent meniscal radial tear and repair. Our hypotheses were that (i) a critical size radial tear exists above which contact mechanics are adversely affected, and (ii) partial meniscectomy results in increased contact pressure and decreased contact area compared to that after meniscal repair. To test these hypotheses, a load controlled simulator was adapted to apply physiological dynamic gait loads across human cadaveric knees equipped with a pressure sensor on the tibial plateau.

MATERIALS & METHODS

Eight human cadaveric knees were stripped of soft tissue sparing the capsule, collateral ligaments, cruciate ligaments, and the menisci. To facilitate reproducible alignment, all knees were pinned through the epicondylar axis under fluoroscopy and then aligned with the flexion-extension axis of a load-controlled Stanmore Knee Simulator. The simulator was pre-programmed with an axial force, rotational torque and flexion-extension dynamic profile that corresponds to human gait as per ISO standard #14243-1.

A pressure sensor (4010N, Tekscan Inc., MA) was covered with adhesive and conditioned, equilibrated, and calibrated as per manufacturer’s guidelines. The sensor was inserted below the medial meniscus, oriented to cover the entire medial plateau, and sutured to the base of the anterior cruciate ligament and posterior capsule using custom designed tabs. Data was recorded at 9.5Hz for 20 gait cycles for each of the following test conditions for each specimen: (i) intact meniscus, (ii) 30% meniscal width radial tear (RT) (iii) 60% RT, (iv) 90% RT, (v) inside-out repair with two horizontal mattress sutures, and (vi) partial meniscectomy.

The radial tears were consistently created at the body-posterior horn junction using a scalpel and partial meniscectomy consisted of minimal resection to the width of the tear with smooth contouring of the adjacent edges.

Contact area and the magnitude and location of the peak contact pressure were computed for each condition at 14% and 45% gait which corresponded to the two most pronounced peaks in axial force during gait (Fig 1). The sensor was divided into quadrants – antero-central, postero-central, posterocentral. The peak contact pressure in each of the 4 quadrants was used to identify the location of peak pressure for each test condition. Data was statistically analyzed using one way analysis of variance (ANOVA) followed by post-hoc Tukey test.

RESULTS

Magnitude and location of peak contact pressure demonstrated sensitivity to the phase of the gait cycle in which the data was analyzed (1st peak vs. 2nd peak of axial load), Fig. 2, with data taken at the first peak demonstrating the strongest dependency on meniscal status.

Peak contact pressure and contact area were not significantly affected by up to 90% radial tears at either point in the loading cycle (p>0.09). However, the location of the peak pressure moved posteriorly and centrally at 90% tear for the 1st peak as illustrated by a significant increase in pressure in these quadrants (Fig 2B). Horizontal mattress suture repair did not affect the peak contact pressure magnitude (p>0.05) or location when compared to the 90% tear. Partial medial meniscectomy was associated with significantly reduced contact area and significantly increased peak contact pressure relative to repaired and torn conditions (p<0.05, Fig 2B). The increase in peak contact pressure was most pronounced in the posterior aspect of the knee (Fig 3).

DISCUSSION

The optimal surgical management of radial tears remains controversial. By way of a dynamic in vitro cadaveric test, we have demonstrated that large radial tears of the medial meniscus extending to 90% of the rim width do not significantly increase mean or peak contact pressures compared to that of the intact meniscus under gait loads. Rather, tears cause a posterior shift in the location of the peak contact pressure.

Inside-out mattress suture repair of a 90% tear did not adversely affect contact mechanics; but did not restore the location of the pressure peak to that of the intact knee. Partial meniscectomy led to an increase in both mean and peak contact pressures and a further posterior shift in pressure location relative to the 90% torn and repaired conditions. Our data further indicates that the contact pressure profile on the plateau is sensitive to the phase of gait, and emphasizes the need to assess meniscal mechanics under dynamic conditions that accurately reflect physiological gait loading conditions.