BIOCHEMICAL RESPONSE OF MENISCAL TISSUE TO ALTERED LOADING CAUSED BY PARTIAL MENISCECTOMY

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INTRODUCTION: Altered mechanical loading of meniscal tissue occurs following various injuries and surgical treatments such as anterior cruciate ligament (ACL) transection and meniscectomy. The degenerative sequel of the joint following partial meniscectomy is well documented. However, most studies have focused on the degradation of the articular cartilage of the joint. Few studies have focused on how the meniscal tissue responds to the altered loading [1]. Other musculoskeletal tissues, such as cartilage and bone, have been shown to respond to altered loading with a biochemical response that in turn mediates tissue remodeling. The biochemical events resulting from altered loading of meniscal tissue have received little attention.

METHODS: Utilizing a previously validated finite element (FE) model [2], partial medial meniscectomies were simulated by removing various amounts of tissue from varying locations in the white-white or white-red meniscal zones, and documenting the changes in contact mechanics. Either 5%, 10%, 30% or 60% of tissue was removed from the anterior-central (AC), central (C), posterior-central (PC), or posterior (P) region (Figure 1). The change in contact area, maximum and mean contact pressure, and maximum and mean axial strain were documented for both the superior and inferior surface of the meniscus.

This data was then used as input to a custom built bioreactor for unconfined dynamic compression of meniscal explants. Eight porcine knee joints were obtained with 24 hours of death and the menisci aseptically removed and a 6mm biopsy punch used to harvest 6 explants from each meniscus. The explants were maintained in DMEM/F12 media with 10% fetal bovine serum and 1% penicillin/streptomyocin for 48 hours before they were subjected either 0%, 5%, 10% or 20% axial compression at 1 Hz for 2 hours. Following compression, the meniscal explants were bisected into a superficial and deep zone and post-incubated for 24 hours. Regional expression of nitric oxide (NO) released into the media from the explants was quantified using the Griess reaction and was normalized to the wet weight of the explant.

RESULTS AND DISCUSSION: The results indicate that the mean axial compressive strain is approximately 2-3% for the intact, 5% and 10% meniscectomy. The mean strains increase minimally for 30% and 60% meniscectomies (data not shown). The maximum again is fairly consistent at 13% until more than 10% of the tissue is removed, where is increases to over 20%.

When this range of strains was applied to meniscal explants it appears that the deep zone produces more NO, with a significant upregulation following 20% compressive strain which is associated with removing more than 10% of the meniscus. Additionally the unloaded controls appear to produce an elevated amount of NO compared to explants compressed to 5% or 10%, possibly indicating that both overloading and underloading of meniscal tissue is damaging.

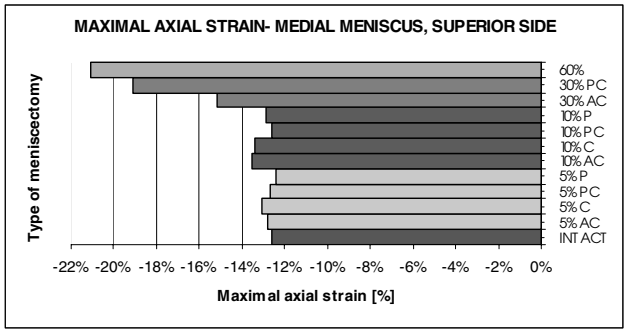

Figure 1. Maximal axial strains in the medial meniscus following various partial meniscectomies.

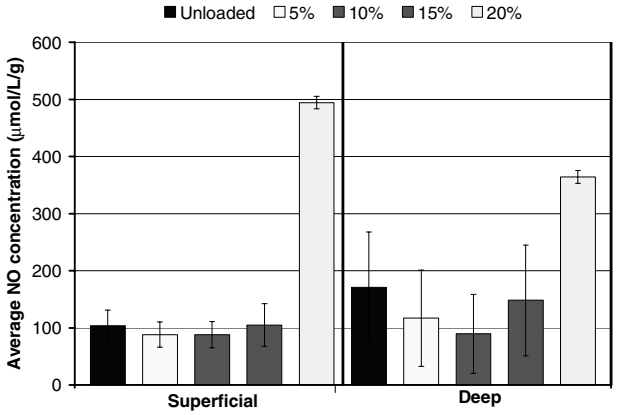

Figure 2. NO production from the superficial and deep zones of medial meniscus explants.

CONCLUSIONS: This work will provide a better understanding of the role of mechanical stimulation in the physiology and pathophysiology of the meniscus. The data gives clear indication to surgeons that removing more than 10% of the meniscus leads to axial strains which produce damaging biochemicals. Joint degeneration is the first step in the etiology of osteoarthritis. Improved treatment following meniscal excision will depend on an understanding of mechanotransduction in meniscal tissue. The findings of this work will have significant implications in the development of pharmaceutical and biophysical interventions for the treatment of the degenerative joint disease osteoarthritis.

REFERENCES: 1) Hellio Le Graverand, M. P.,et.al., Osteoarthritis Cartilage, **9(1)**, 56-64, 2001. **2)** Haut Donahue, T. L., et. al., J. Biomech. Engin. **124**, 273-280, 2002.

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