Traumatic Anterior Cruciate Ligament Tear and its Implications on Meniscal Degradation: A Preliminary Novel Lapine Osteoarthritis Model

Megan L. Killian, M.Sc.,* Daniel I. Isaac, B.S.,† Roger C. Haut, Ph.D.,† Loic M. Déjardin, D.V.M., M.S.,‡ Darin Leetun, M.D.,§ and Tammy L. Haut Donahue, Ph.D.*,1

*Soft Tissue Mechanics Laboratory, Mechanical Engineering-Engineering Mechanics, Michigan Technological University, Houghton, Michigan; †Orthopaedic Biomechanics Laboratories, College of Osteopathic Medicine, Michigan State University, East Lansing, Michigan; ‡Collaborative Orthopaedic Investigations Laboratory, College of Veterinary Medicine, Michigan State University, East Lansing, Michigan; and §Orthopaedic Surgery and Sports Medicine, Portage Health, Hancock, Michigan

Submitted for publication January 19, 2009

Background. Injury patterns of the meniscus following impact trauma resulting in anterior cruciate ligament (ACL) rupture are not well understood. This study explored the spatial and temporal distribution of meniscal tears in a novel in vivo lapine model.

Methods. Skeletally mature Flemish Giant rabbits were subjected to either tibiofemoral impaction resulting in ACL rupture or surgical ACL transection. Meniscal damage was assessed acutely and after 12 wk for traumatically torn, and after 12 wk in ACL transected animals. Morphological grading was assessed using previously established criteria, and descriptions of meniscal damage were diagnosed by a Board certified orthopedist. Histological assessment was also made on 12 wk traumatically torn and ACL transected animals using Fast-Green/Safranin-O staining.

Results. Traumatic ACL rupture resulted in acute tears predominately in the lateral menisci. Animals subjected to both surgical transection and traumatic ACL rupture experienced degradation of the lateral and medial menisci 12 wk after injury. However, traumatic ACL rupture resulted in acute lateral damage and chronic degradation of the menisci, as well as more severe degradation of the menisci 12 wk after injury.

Conclusions. This study showed that unconstrained high-intensity impacts on the tibiofemoral joint lead to meniscal damage in conjunction with ACL ruptures. Both acute and chronic changes to the menisci following traumatic impaction were observed. This research has implications for the future use of lapine models for osteoarthritis, as it incorporates traumatic loading as a more realistic mode contributing to the progression of osteoarthritis (OA) compared to surgically transected models.

Key Words: osteoarthritis; meniscus; lapine model.

INTRODUCTION

The menisci play a crucial role in the dynamics of the knee. Their shape, attachment, and material properties contribute substantially to joint alignment and load transmission by distributing both tensile and compressive forces. Damage to the menisci can influence proprioception, stability, and mobility of the knee [1–5]. Risk factors for meniscal tears include prolonged or repeated deep knee bending, obesity, and sports [6]. Acute injury, as seen in alpine sports, involves complex dynamics which can damage singular or multiple tissue structures of the knee [6, 7]. Meniscal tears are typically thought to be initiated by coupled compression and twisting movements [8, 9], which can accompany high-energy maneuvers such as cutting, jumping, and landing during sporting events [10]. It is not uncommon for meniscal injuries to occur in conjunction with anterior cruciate ligament (ACL) lesions, and the loading imbalance that results in ACL lesions may also generate meniscal tears [8, 11]. The presence of meniscal tears following ACL lesions has been found to significantly increase as time after initial injury increases [11, 12]. Clinical studies for meniscal tears following ACL rupture indicate chronic damage to the medial...