

Float-Ring Implant Reduces Cartilage Contact Pressure After Partial Meniscectomy: A Finite Element Analysis

Go Yamako¹, T. D. I. Udayanga¹, Etsuo Chosa¹
¹University of Miyazaki, Japan
 g.yamako@cc.miyazaki-u.ac.jp

Disclosures: Go Yamako (N), T. D. I. Udayanga (N), Etsuo Chosa (N)

INTRODUCTION: Menisci are crescent-shaped fibrocartilaginous wedges located in the medial and lateral compartments of the knee. They play crucial roles in load-bearing, load transmission, shock absorption, and in the lubrication and nourishment of the articular cartilage. Meniscal tears are the most common knee injury, affecting both elderly individuals and athletically active youth. Treatment options, depending on the severity of the injury, include meniscal suturing repair, partial meniscectomy, or total meniscectomy. However, even partial meniscectomy alters the contact mechanics of the articular surfaces, thereby increasing cartilage loading and substantially elevating the risk of osteoarthritis. To address this issue, a float-ring meniscus implant has been developed as a cushioning device for knee cartilage after partial or total meniscectomy. Previous studies have demonstrated its protective effect following total meniscectomy. The present study aims to evaluate its efficacy after partial meniscectomy using finite element (FE) analysis.

METHODS: The medial compartment of the knee joint was reconstructed using MR scan images (40-year-old male, BMI 20.1) from the OpenKnee project. The knee joint geometry was then imported into ABAQUS to generate the FE model (Fig.1). The cartilages and the meniscus were meshed to hexahedral elements. A compressive load equivalent to 60% of the total load during walking was applied to the reference point in the femoral cartilage. The motion of the reference point was restricted in all directions except for the loading direction. The tibial cartilage was fully constrained. The meniscal horn attachments were modeled using nonlinear springs. A linear elastic material model was used for all cartilages, and an anisotropic hyperplastic Holzapfel-Gasser-Ogden (HGO) material model was used for the meniscus. The following cases were analyzed: intact meniscus, total meniscectomy, partial meniscectomy with 10%, 20%, 30%, 40%, 50%, 60%, and 65% width reduction, and float-ring implantation following partial meniscectomy (Fig.2).

RESULTS SECTION: When intact, the meniscus shared the compressive load, and the contact stress was distributed beneath the meniscus on the cartilage. Following total meniscectomy, peak contact pressure increased by 28% compared with the intact condition. In partial meniscectomy cases, peak contact pressure increases were 4.7%, 7.8%, 12.4%, 17.1%, 22.1%, 25.5%, and 26.7% for 10%, 20%, 30%, 40%, 50%, 60%, and 65% width reductions, respectively (Fig.3). In contrast, with the float-ring implant, the corresponding changes in peak contact pressure relative to the intact condition were -8.5%, -4.8%, -0.2%, 4.7%, 10.0%, 13.4%, and 14.6%, respectively.

DISCUSSION: Total or partial meniscectomy increases contact pressure on the tibial cartilage, leading to the development of osteoarthritis. Implantation of the float-ring reduced the contact pressure concentration. Increasing the extent of meniscal resection from 10% to 65% leads to higher maximum contact pressure on the tibial cartilage, suggesting that determining an appropriate amount of resection is critical in partial meniscectomy to prevent osteoarthritis. Our results indicate that the proposed float-ring implant can mitigate this pressure increase following partial meniscectomy. Therefore, the float-ring implant has the potential to reduce the risk of osteoarthritis development after partial meniscectomy.

SIGNIFICANCE/CLINICAL RELEVANCE: The float-ring implant may offer a simple, minimally invasive option to reduce cartilage stress and lower the risk of osteoarthritis after partial meniscectomy.

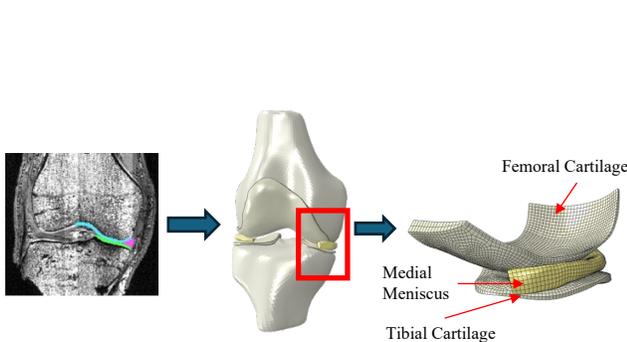


Fig. 1 Finite element model of the medial compartment from MR images.

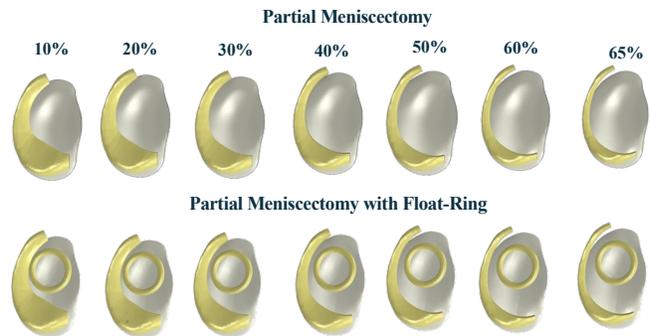


Fig. 2 Variations of partial meniscectomy

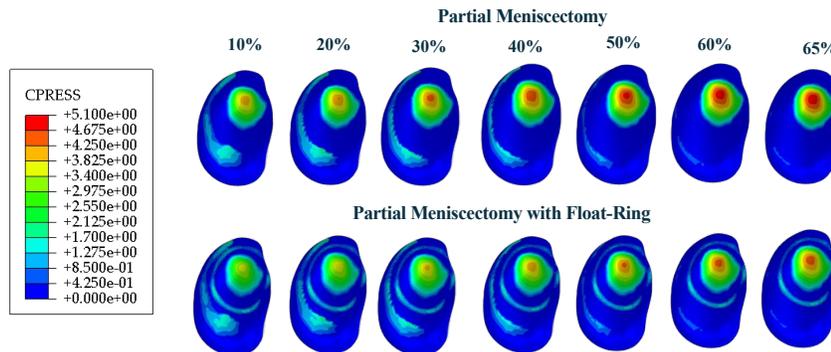


Fig. 3 Contact pressure distributions on the tibial cartilage.