COLLAGEN-MATRIX WRAP REDUCES CONTACT PRESSURE IN MENISCAL TEAR REPAIR: AN FEA STUDY.

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Introduction

Meniscal tears are one of the most common injuries to the human knee joint. To preserve the function of the knee joint and reduce the risk of degeneration due to meniscal injuries, meniscal tears need to be repaired. A meniscal suture is the most common repair method; however, suturing alone is ineffective in promoting healing in the more avascular white (zone 2-3) of the meniscus. To promote healing, suturing and wrapping with collagen-matrix techniques have been proposed to treat more complex meniscal tears, including radial tears crossing zones 0-3, defunctioning the meniscus [1]. However, there are still uncertainties about the ideal clinical management of meniscal tears, including suitable techniques for repairing menisci [2]. Therefore, the aim of this study is to evaluate the effect of meniscal repair of a radial tear using a rip-stop 'H' suture technique with or without the addition of a collagen membrane as a wrapping technique on the meniscus and contact surfaces using finite element analysis.

Methods

Two finite element (FE, Abaqus) models of a human knee joint lateral compartment were developed from previously published three-dimensional geometry [3]. The models comprised the femur, tibia, articular cartilage and lateral meniscus. The meniscus structure was generated to represent a radial tear (Fig 1a). FE models of the two techniques of meniscal tear repair: meniscal repair with (i) suture alone and (ii) suture and collagen-matrix wrap, were modelled (Fig 1b & c). The material properties of the components were a linear elastic for the bones, a hyperelastic Yeoh model for articular cartilage, and a linear elastic and transversely isotropic material model for the meniscus. The stiffness parameter for the suture was set as 46 N/mm [4]. The material property for the meniscus wrapped with ChondroGide collagen-matrix wrap (the green section in Fig 1c) was set as the meniscus material property with an added 30% strength. The boundary conditions allowed only one degree of freedom for 1000N load in the axial direction. Results from the repair techniques were compared by evaluating the effect of repairs on the contacting areas of the articulating surfaces, meniscus kinematics, and stress distribution around the repair.

Results

Meniscal repair with suture alone had higher local stresses and strains ($\sigma_{max} = 51\ MPa$ and $\epsilon_{max} = 25\%$) around the repair compared to the repair with suture and collagen-matrix wrap ($\sigma_{max} = 36.6 MPa$ and $\epsilon_{max} = 15\%$) (Fig 2). Meniscus radial displacement was higher by ~2% in the suture alone meniscal repair model compared to meniscal suture with collagen-matrix wrapping. Pressure on the meniscus contact surface was higher by ~5% in the suture alone meniscal repair compared to the meniscal suture with wrap repair.

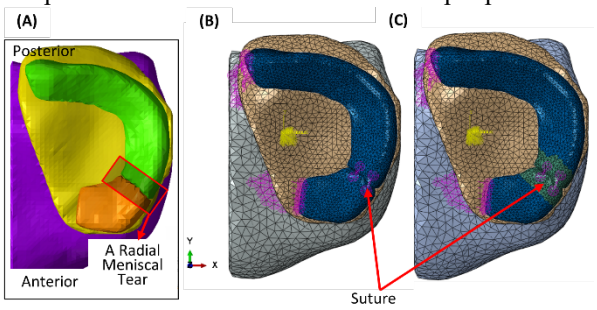

*Figure 1: A lateral compartment of a human knee joint showing **(A)** an anterior lateral radial meniscal tear and FE models of meniscal repair with **(B)** suture alone **(C)** suture and a collagen-matrix wrap (green region).*

Discussion

We found that adding collagen-matrix wraps to the suture strengthens the repaired region, thus reducing the local peak stresses and strains around the suture. During high loadings and extreme kinematics conditions in the knee joint, peak stresses and strains will build up around the suture, which can result in the suture pulling out of the meniscus. The collagen-matrix wrap has a heterogenous material property reinforcing the meniscal repair region, increasing resistance to suture tear out. In our future study, we will investigate the combined joint kinematics and loading conditions in meniscal repair with wrapping techniques.

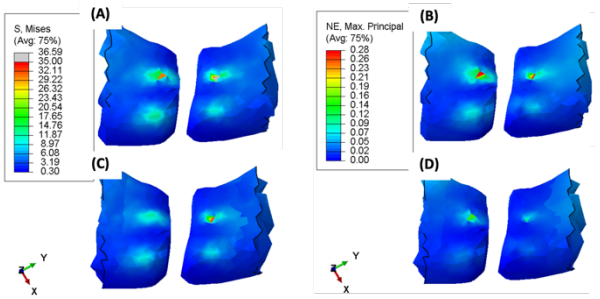

Figure 2: A sectioned view of the lateral meniscus at the repair region showing higher **(A)** stresses and **(B)** strains for suture alone repair, compared to **(C)** stress and **(D)** strains in collagen-matrix wrap repair

References

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