Failure properties and strain distribution analysis of meniscal attachments

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Abstract

The menisci are frequently injured due to both degeneration and traumatic tearing. It has been suggested that the success of a meniscal replacement is dependent on several factors, one of which is the secure fixation and firm attachment of the replacement to the tibial plateau. Therefore, the objectives of the current study were to (1) determine the failure properties of the meniscal horn attachments, and (2) determine the strain distribution over their surfaces. Eight bovine knee joints were used to study the mechanical response of the meniscal attachments. Three meniscal attachments from one knee of each animal were tested in uniaxial tension at 2%/s to determine the load deformation response. During the tests, the samples were marked and local strain distributions were determined with a video extensometer. The linear modulus of the medial anterior attachment (154 ± 134 MPa) was significantly less than both the medial posterior (248 ± 179 MPa, \( p = 0.0111 \)) and the lateral anterior attachment (281 ± 214 MPa, \( p = 0.0007 \)). Likewise, the ultimate strain for the medial anterior attachments (13.5 ± 8.8%) was significantly less than the medial posterior (23 ± 13%, \( p < 0.0001 \)) and the lateral anterior attachment (20.3 ± 11.1%, \( p = 0.0033 \)). There were no significant differences in the structural properties or ultimate stress between the meniscal attachments (\( p > 0.05 \)). No significant differences in ultimate strain or moduli across the surface of the attachments were noted. Based on the data obtained, a meniscal replacement would need different moduli for each of the different attachments. However, the attachments appear to be homogeneous.

Key Words: Meniscus; Knee; Material properties; Meniscal replacement

1. Introduction

The menisci perform a variety of functions within the knee, but their most prevalent role is in weight bearing and load transmission across the knee joint (Morrison, 1970; Walker and Erkman, 1975; Shrive et al., 1978; Ghosh and Taylor, 1987; Renstrom and Johnson, 1990; Ahmed, 1992; Messner and Gao, 1998). The menisci are able to carry out this function due to their structural shape and firm attachment to the tibia (Shrive et al., 1978; Fithian et al., 1990; Renstrom and Johnson, 1990; Gao et al., 1998; Messner and Gao, 1998). When a meniscus is injured, two options are available to repair the damaged meniscus: surgical repair of the meniscal tear or a partial or full meniscectomy (Ghadially et al., 1986; DeHaven, 1992; Newman et al., 1993; Asik and Sener, 2002). In the latter case, the procedure has been shown to lead to degeneration of the articular cartilage of the knee (Allen et al., 1984; McBride and Reid, 1988; Moon et al., 1988; Messner, 1999; Rodeo, 2001; Wyland et al., 2002). Therefore, if the meniscus must be removed, a sound option for its replacement must be readily available that can duplicate its biomechanical function.

While the material properties of meniscal tissue have previously been studied, meniscal attachments have received little attention. It has been shown that the meniscal attachments are important for restoring functionality to the knee (Chen et al., 1996; Goertz et al., 1996; Paletta et al., 1997; Alhalki et al., 1999; Rodeo, 2001; Sekaran et al., 2002; Haut Donahue et al., 2003). Therefore, their time-dependent and failure properties need to be determined. We have already obtained the time-dependent properties of the meniscal attachments and found no...