IMPLANTABLE MATERIAL AND A METHOD FOR THE PREPARATION THEREOF

FIELD OF THE INVENTION

[0001] The present invention relates generally to an implantable material and a method for the preparation thereof. The material is useful, for example, for the replacement, partial replacement, augmentation or repair of damaged articular cartilage, or fibrocartilage of the knee menisci, the temperomandibular joint, the intervertebral disc and articular cartilage of synovial joints.

BACKGROUND OF THE INVENTION

[0002] Except where specified below the term fibroin is used to refer generically to the main structural protein of cocoon silks whether they are derived from the domesticated Mulberry Silkworm (*Bombyx mori*) or a transgenic silkworm or from any Wild Silkworm including, but not limited to those producing Muga, Eri or Tussah silks. Furthermore, the term 'silk' is used to refer to the natural fine fibre that silkworms secrete, which comprises the two main proteins, sericin and fibroin, fibroin being the structural fibres in the silk, and sericin being the material surrounding the fibroin and sticking the fibres together in the cocoon. 'Silk cocoon' is used to refer to the casing of silk spun by the larvae of the silk worm for protection during the pupal stage.

[0003] Three types of cartilage are found in the body of mammals: white fibrocartilage; yellow elastic cartilage; and hyaline cartilage. Hereafter except where stated, the term cartilage is used in its generic sense including these three different types of cartilage.

[0004] White fibrocartilage is found in the menisci of the knee and the tempero-mandibular joint and in intervertebral discs. Yellow elastic cartilage is found in the pinna of the ear, the epiglottis and around the auditory canal. Hyaline cartilage is found mainly as articular cartilage in non-synovial joints where it provides smooth articulating surfaces and in synovial joints where it provides a hard and stiff connective tissue covering the articular surfaces of diarthroidal synovial joints.

[0005] Articular hyaline cartilage provides a long lasting, lubricated, low friction joint surface, distributes stresses over a broad area of underlying bone and may help to dissipate shocks during dynamic loading (Mow V C, Ratcliffe A. Structure and function of articular cartilage and meniscus. In: Mow V C, Hayes W C, eds. Basic Orthopaedic Biomechanics. New York: Raven Press, 1991; 143-198). The compressive stiffness of cartilage is extremely important in its function. The stiffness of viscoelastic materials such as cartilage depends greatly on the loading history of the material and the method for measuring it and consequently several moduli are used to describe articular cartilage. For example, Spiller, K. L., Laurencin, S. J., Charlton D, Maher, S. A., Lowman, A. M. (2008) in their paper "Superporous hydrogels for cartilage repair: Evaluation of the morphological and mechanical properties" Acta Biomaterialia 4, 17-25, state that the unconfined compressive elastic modulus of adult articular cartilage is about 1 MegaPascal (MPa), while the aggregate compressive modulus is about 0.33 MPa. Treppo, S. et al. in Comparison of biomechanical and biochemical properties of cartilage from human knee and ankle pairs, Journal of Orthopaedic Research 18, 739-748 (2000), state that the equilibrium modulus of healthy adult human articular cartilage lies between 0.2 and 1.5 MPa with a mean about 0.6 MPa depending on, which joint the cartilage is taken from, the location on the joint and depth. Park, S., Hung, C. T. & Ateshian, G. A. in Mechanical response of bovine articular cartilage under dynamic unconfined compression loading at physiological stress levels, Osteoarthritis and Cartilage 12, 65-73 (2004), state that the unconfined dynamic modulus for bovine tibial cartilage lies between 15-65 MPa depending on applied stress and loading frequency.

[0006] The menisci of the knee joint are crescent shaped discs, largely constructed from white fibrocartilage. They are interposed between the femoral condoyle and tibial plateau and have the function of compressive load spreading, shock absorption, stabilization and secretion of synovial fluid for articular lubrication. The structure, function and pathology of the menisci have been reviewed by S. M. Bahgia and M. Weinick, Y. Xing, and K. Gupta (2005) Meniscal Injury, *E-medicine World Library,* 27 Jul. 2005, http://www.emedicine.com/pmr/topic75.htm. The outer rim is vascular while the central part is avascular fibrocartilage. The menisci contain 70% type I collagen (non-articular cartilage fibrillar collagen). The collagen fibres of the meniscus show a predominantly circumferential orientation together with some radial tie fibres. Collagen orientation is extremely important for the mechanical function and fixation of this structure. Compression of the meniscus leads to tensile hoop loading of the circumferential fibres and radial loading of the radial fibres, resisting spreading and flexing of the menisci. Thus the ability of the meniscus to spread load and dissipate energy is dependent on the integrity of the collagen fibre lay. For this reason damage to these fibres increases the risk of secondary osteoarthrotic damage to the condylar cartilages as the normal load distribution and shock-absorbing functions are impaired.

[0007] Meniscal injuries are fairly common in adults and are frequently sports-related. They are less common in children over 10 years old and rare in children under 10 with morphologically normal menisci (Iobst, C. A. and Stanitski, C. L., 2000, Acute knee injuries. Clin Sports Med. 2000 October; 19(4):621-35).

[0008] Total knee replacement involves the insertion of a highly complex metal and polymer implant and cannot be considered as treatment for uncomplicated meniscal injury. The Dacron and Teflon meniscal component may initiate severe synovial reactions (Cook, J. L., Tomlinson, J. L., Kreeger, J. M., and Cook, C. R. 1999. *The American Journal of Sports Medicine* 27:658-665 Induction of meniscal regeneration in dogs using a novel biomaterial) while loosening and mechanical failure are a problem (de Groot, J. H. 1995 Doctoral dissertation. University of Gronigen, Summary p153).

[0009] Surgical treatment of damaged menisci is often necessary, for which there are different surgical treatment options.

[0010] Small meniscal tears can be repaired directly using sutures, fasteners or arrows. however small tears account for less than <3% of all presented mensical injuries.

[0011] Although total or partial removal of the meniscus (meniscectomy) to remove damaged meniscal tissue was popular some forty years ago, it is well understood that this procedure leads to articular cartilage degeneration (King, D. Clin. Orthop. 1990, 252, 4-7; Fairbank, T. J. Journal of Bone and Joint Surgery 1948, 30, 664-670) in turn leading to osteoarthrosis. The extent of the secondary osteoarthrosis caused by menisectomy appears to depend on how much meniscal tissue has been removed. Therefore partial menis-