Modelling of structures and solids: Asymptotic modelling in articular contact mechanics of the knee

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Osteoarthritis (OA) is a degenerative disease which involves deterioration of the articular cartilage and affection of the underlying bone. The most common target joint affected by OA is the knee joint. Though the degeneration process at the OA knee joint is believed to result from a combination of mechanical loading and biological weakening of the cartilage matrix, considerable epidemiological evidence supports the concept that mechanical conditions producing increased load transfer across the joint and altered patterns of the contact pressure distribution can accelerate the initiation and progress of OA.

While experimental investigations are a key component in developing disease-modifying therapy for OA, the understanding of articular contact mechanics can be gained with the help of mathematical modelling. Moreover, at present, it is impossible to measure in vivo the time-dependent contact stress and deformation within articular cartilage for dynamic and impact loading. Many analytical solutions for the axisymmetric problem of contact interaction of biphasic cartilage layers in joints are available. However, the ability of these axisymmetric models to accurately predict patient-specific articular contact mechanics is questionable due to oversimplification of joint geometry. To our knowledge, there has been no published analytical research addressing the non-axisymmetric effects of the changing geometry of articular cartilages and their properties on the contact pressure distribution.

A three-dimensional unilateral contact problem for articular cartilage layers is considered in the framework of the biphasic cartilage model. The articular cartilages bonded to subchondral bones are modeled as biphasic materials consisting of a solid phase and a fluid phase. It is assumed that the subchondral bones are rigid and shaped close to an elliptic paraboloid. The obtained analytical solution is valid over long time periods and can be used for increasing loading conditions.