Mathematical modeling approach for dynamic testing of articular cartilage: a review of recent indentation and impact techniques

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Articular cartilage is a soft hydrated tissue covering the end of each bone at the joints. Cartilage has no known function other than maintaining mechanical competence of joints, allowing bones to move against one another without friction. But there is no need to underline its significance to health of a human body, since almost all the load transmitted by a human joint goes through the articular cartilage, and it prevents biomechanical damage caused by severe loading including impact loading. It is believed that severe articular impact can initiate post-traumatic arthritis. An impact loading of the joint constitutes the action of extremely high non-physiological loads applied very rapidly (for instance, due to a car accident, sports injury, or a fall from a height).

In recent years, a number of experimental studies have been conducted to investigate the mechanical behaviour, damage mechanisms, and viability of articular cartilage under dynamic and impact loading. While well-developed quasi-static indentation methods are suitable for many industrial applications, an enhanced indentation technique is needed for measuring time-dependent material properties of biological tissues, like articular cartilage, by taking into account dynamic effects. At present, there is the need of simple mathematical models, which allow comparing experimental results obtained in impact testing with impactors of different masses and incident velocities.

A variety of mathematical models were suggested to describe the stress-strain response of articular cartilage that represents a multiphasic, structurally complex material possessing time-dependent properties. In the present study, we develop viscoelastic models for dynamic indentation and impact problems capturing the main features of the indentation and impact tests recently suggested for assessing articular cartilage viability.