Analytical modelling of the almost noncompressible viscoelastic periodontal ligament

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A root of a tooth is attached to an alveolar bone by a periodontal ligament (PDL). A PDL is a soft connective tissue consisting of collagen fibres and a matrix phase with nerve endings and blood vessels. In addition to providing interconnection for a tooth with its supporting structures, PDL responds to loads that are applied to it, demonstrating viscoelastic time-dependent properties.

Short-term and long-term (orthodontic) teeth motions can be modelled by a linear elastic, bilinear elastic, viscoelastic, hyperelastic or multiphase formulation for the PDL [1]. The same continuous models are used to calculate stress-strain states of the PDL for various load types; this was implemented in different finite-element studies. Analytical modelling of elastic and viscoelastic responses of PDLs to loads applied to the tooth was carried out in particular in a studies [2, 3]. Most important results for 3-D cases were obtained using circular and elliptic-paraboloid shapes for the tooth root and PDL surfaces [2–4]. An important feature of the used analytical model was an approximation of the PDL as an almost incompressible material with a Poisson's ratio equal to 0.4–0.49 [5]. In this case, it can be assumed that maximum deformation of the PDL tissue along a normal to the tooth-root surface coincides with thickness of the PDL in the same direction. A further development of the analytical scheme for the almost incompressible PDL proposed by Provatidis [2] can be implemented for long-term and heavy loads, taking into account time-dependent and viscoelastic properties of the PDL. The aim of our study is to develop an analytical model of a viscoelastic PDL with a fractional exponential kernel to describe evolution of deformation of periodontal tissue and the tooth root movements with time.

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