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EFFICIENT NUMERICAL SIMULATION OF PERIODONTAL LIGAMENT

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The Periodontal Ligament (PDL) is a thin layer of dense soft connective tissue located between the tooth root and the alveolar (jaw) bone. The PDL is mainly formed by a solid fibrous tissue and an interstitial fluid (Figure 1). The distribution of these two phases cannot be geometrically resolved at the macro-scale. A poroelastic model perfectly suits to describe this biological tissue, even if the PDL cannot be considered a standard poroelastic medium: the poroelastic model uses a smeared approach which allows to specify its local composition by means of macroscopic *volume fractions* instead of resolving the complicated micro-structure of the collagen fibers.

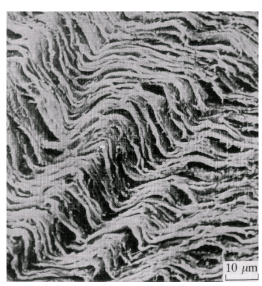

Figure 1: Internal structure of the PDL.

Periodontal diseases have a crucial influence on the PDL status and might even lead to the loss of teeth. The changes of PDL status in the course of a disease is reflected in a change of the mechanical properties of the teeths anchorage. A complete and detailed model of the PDL allows understanding the biomechanical behaviour of teeth and might also help the early diagnosis of periodontal illnesses.

The simulation with the Finite Element Method of a complete PDL-tooth system gives rise to a very large linear system due to the fine mesh necessary to describe the PDL. Because of the generalized saddle-point nature of the problem, arising from the incompressibility constraint, efficient solution methods like Domain Decomposition and Multigrid do not behave optimally as for the elliptic case. Moreover, the large jump in the material coefficients may hinder convergence of parallel iterative solvers.

In this work, we will extend the model presented in [1] by employing large displacements and a Fung material hyperelastic law. Then, we will present an efficient solution strategy based on a multigrid solver that can be used for these generalized saddle-point system. The solver will be tested on realistic geometries obtained from μ-CT scans of porcine (Figure 2-left) and human teeth. The model will be validated reproducing loading experiments in which a displacement is applied on the tooth crown by means of an indenter and the resulting force response is measured (Figure 2-right).

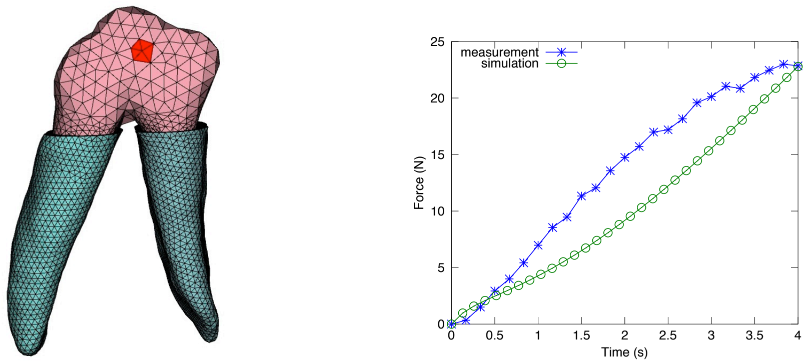

Figure 2: Mesh of the tooth-PDL system of a pig (left). Comparison of experimental measurements and a numerical simulation (right).

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