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Towards a Finite Element Model of Atraumatic Tooth Extraction

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ABSTRACT

Exodontia (tooth extraction) is one of the most common clinical procedures performed in modern practice due to broad indications (dental decay, periodontal disease, trauma) with high prevalence. However, the biomechanics of exodontia continue to be poorly understood. Current models of the dental complex focus on intrusive or orthodontic loading rather than extrusive extraction loads, or simulate extraction using boundary conditions with no clinical parallel. The purpose of this work is to bridge this gap with a finite element model to simulate the periodontal complex response to clinically-relevant loading that includes interface failure between soft connective tissue and the bone/tooth.

An axisymmetric finite element model of truncated swine incisors was developed for the FEBio dynamic solver. The model consists of alveolar bone, periodontal ligament (PDL), dentin, and a screw insert from a Benex extraction device. A mesh with sizes varying by tissue was generated in SALOME. A minimum mesh size of 0.02mm was applied at the entheses between the PDL, dentin, and alveolar bone. A maximum mesh size of 2mm was allowed in the alveolar bone furthest from the PDL. Isotropic and linear elastic materials were used to model the alveolar bone and steel insert. A viscous damage hyperfoam model was used for the periodontal ligament and an isotropic linear damage model was implemented for the dentin. A Simo damage function with a principal strain of 0.05 was used for the dentin and a quintic polynomial damage function between principal strains of 0.90-1.50 for the PDL.

A vertical displacement of 2mm/min was applied to the extraction screw for comparison to experimental data acquired at the same rate. The simulation results are dominated by strain and rupture of the PDL at the tooth-ligament enthesis and the corresponding concentration of strain in the dentin at that enthesis. The resultant extraction forces trend similarly to those measured experimentally, but the peak force and time at peak force are strongly underestimated by the simulation (52.3N at 33.8s vs. 243.8N at 69.1s). The first PDL elements to rupture in the simulation demonstrate similar stress-strain behaviour to other models available in the literature but the maximum stresses (3.80MPa) are also underestimated by the current model (2.93MPa). Future work with this model will optimize the material parameters of the model to match the experimental force data. Experiments performed with this model will compare tissue rupture patterns to experimental results and derive new extraction techniques.