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Study of the transdentinal fluid flow and bioactive molecule diffusion characteristics

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Abstract

Objectives: The understanding of the fluid flow patterns and molecular diffusion mechanisms inside the dentinal tubules has recently attracted attention in designing regenerative treatment modalities of the dentin-pulp complex. The aim of the present study is to develop a reliable computational model for investigating the transdentinal fluid flow characteristics and the transport mechanism of biological or chemical compounds from the dentin surface to the pulp.

Methodology: Initially *CFD* simulations were performed concerning the simplified design of a typical tubule geometry followed by the discretization and solution of the appropriate differential transport equations. In a first stage the outflow from a single tubule was numerically calculated when the dentinal tubules are open to oral environment. The fluid inside the tubules is considered to have the thermophysical properties of water. The *CFD* results were successfully compared with relevant results from the literature.

The following stage was to use the *CFD* code for investigating the diffusion of bioactive molecules from the dentin surface to the pulp through the dentinal tubules. To further check the reliability of the *CFD* code relevant experiments were performed in an appropriate experimental setup comprising a microchannel that simulates a dentinal tubule. The mass transfer characteristics of bioactive molecules inside the microchannel were studied by measuring their spatial and temporal concentration using *Laser Induced Fluorescence* (***LIF***). *LIF* is a non-intrusive optical measuring technique which is based on the laser induced excitation of a tracer compound used to mark the fluid under study. The comparison of the experimental with the numerical results revealed that *CFD* is a reliable and convenient tool for studying momentum, mass and heat transfer in a tubule.

Results: The results of our study are in accordance with the literature, i.e., when the dentinal tubules are open to oral environment the velocity of the dentinal fluid inside the tubules is very low. Moreover, the simulations confirmed the clinical observations concerning the low mass transfer rates of therapeutic agents inside a dentinal tubule. The phenomenon is one-dimensional, diffusion dominated and strongly dependent on the molecule size and initial concentration of the chemical substances. We believe that the proposed methodology could be run for various therapeutic applications in non-exposed dentinal cavities and the results can also help to better understand the key issues of transdentinal regulation of the dentin-pulp complex functions.

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