

**Development of transdental treatment strategies in restorative dentistry:  
modelling the flow and mass transport mechanisms in dentinal tubules**

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**Abstract**

**Background:** Experimental or clinical evidences that the traditional dental materials placed in tooth cavities in contact with exposed dentinal tubules can fully re-establish the physiological function of the pulp-dentin complex are missing. Thus, several laboratories on a global basis are striving for novel, regenerative treatment options that better mimic natural tissue formation rather than scar formation during the healing process. Experimental attempts with specific signaling molecules (*TGF $\beta$ 1*, *BMP-7*, *bFGF*, *WNT*) to stimulate transdentally dentinogenic reactions in the pulp gave promising results. The inter-relationship between thorough testing of signaling mechanisms and the attempts aiming to develop a model simulating transdental flow and mass transfer mechanisms is of prime importance in terms of achieving the objectives of developing more effective treatment modalities in restorative dentistry.

As the transdental flow is particularly slow, the mass transfer rate of a bioactive agent is dictated by the slow process of diffusion, i.e. the mass transfer rate depends on the diffusion coefficient of the bioactive agent to the pulp. Moreover, due to the small characteristic dimension of the conduit the viscous and surface tension forces dominate over inertial forces. The development of an experimental methodology simulating clinical conditions and the measurement of selected molecules by employing advanced not intrusive techniques should be the ultimate goal. As a preliminary tool a simplified computational model for investigating the transdental fluid flow characteristics and the transport mechanism of biological or chemical compounds from the dentin surface to the pulp has been designed. Results showed that the used methodology could be run for various therapeutic applications in non-exposed dentinal cavities.

**Key milestones and research objectives:** The key milestones of the proposed project is to study the transdental fluid dynamics and the transport rate of biological or chemical molecules in dentinal tubules, which depends on the flow conditions as well as the diffusivity. The diffusivity (or diffusion coefficient) of a species to liquid is a function of the size of the molecules and according to Stokes-Einstein equation depends on the temperature and the viscosity of the fluid, which in turn is also a function of temperature. The project will start by numerically simulating the flow in the dentinal tubules using Computational Fluid Dynamics (*CFD*) and it will include:

- Literature survey concerning the diffusivity of selected molecules undergoing transdental diffusion.
- Design and construction of an experimental setup which will comprise a microchannel that simulates a dentinal tubule and experimental study of the transport rate of the selected molecules.
- Development of a *CFD* model for studying the transport rate of biological or chemical molecules and validation of the code using the experimental data.

- Numerical study concerning the effect of various parameters, e.g. temperature, pressure, flow rate of the fluids, on the transport rate.
- Checking the applicability of the findings by conducting experiments in dentinal discs from human teeth.

**Benefits and impacts of the proposed research:** The proposed cooperation with other working groups in the fields of biomedical research technology and micro-fluidics represents an intensive research area. The expected scientific and technical benefits in the area of biomedical research is the identification of the factors that mainly affect the transport rate of biological compounds in dentinal tubules where laminar flow is encountered. The benefit in the area of micro-equipment design will be the investigation of transport rate during diffusion in micro-conduits.

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