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Finite Element Modelling for the Development of a Planar Ultrasonic Dental Scaler for Prophylactic and Periodontal Care

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Abstract : Dental biofilm is the main etiologic factor for caries, periodontal and peri-implant infections. In addition to the risk of tooth loss, periodontitis is also associated with an increased risk of systemic diseases such as atherosclerotic cardiovascular disease and diabetes. For this reason, dental hygienists use ultrasonic scalers for prophylactic and periodontal care of the teeth. However, the current instruments are limited to their dimensions and operating frequencies. The innovative design of a planar ultrasonic transducer introduces a new type of dental scalers. The flat titanium-based design allows the mass to be significantly reduced compared to a conventional screw-mounted Langevin transducer, resulting in a more efficient and controllable scaler. For the development of the novel device, multi-physics finite element analysis was used to simulate and optimise various design concepts. This process was supported by prototyping and electromechanical characterisation. The feasibility and potential of a planar ultrasonic transducer have already been confirmed by our current prototypes, which achieve higher performance compared to commercial devices. Operating at the desired resonance frequency of 28 kHz with a driving voltage of 40 Vrms results in an in-plane tip oscillation with a displacement amplitude of up to 75 µm by having less than 8 % out-of-plane movement and an energy transformation factor of 1.07 µm/mA. In a further step, we will adapt the design to two additional resonance frequencies (20 and 40 kHz) to obtain information about the most suitable mode of operation. In addition to the already integrated characterization methods, we will evaluate the clinical efficiency of the different devices in an in vitro setup with an artificial biofilm pocket model.

Keywords : ultrasonic instrumentation, ultrasonic scaling, piezoelectric transducer, finite element simulation, dental biofilm, dental calculus
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