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Influence of Operating Conditions on a Novel Planar Ultrasonic Piezoelectric Transducer for Use in a Periodontal Scaler

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Abstract— **Our group develops a novel periodontal scaler based on a planar ultrasonic transducer. This study investigates the electrical and mechanical properties of this transducer under varying operating conditions. The results obtained enable further optimization of the design and development of a high-performance control system.**

***Clinical relevance*—The planar design combined with a high-performance control system will allow to remove biofilm more efficient and reduce tooth hard-substance-loss and surface roughness. Furthermore it will facilitate subgingival treatment due to a more compact design and promote application of power-driven scalers in new markets due to reduced cost.**

I. INTRODUCTION

Periodontal disease can seriously impair the quality of life and may increase the risk of cardiovascular and respiratory diseases, arthritis or diabetes [1]. Scaling by a periodontist is commonly necessary to prevent and treat periodontal disease. Compared to manual scalers, power-driven scalers reduce operator fatigue and improve removal of calculus and biofilm and protection the gingiva and the teeth [2]. In 1996 Amit Lal et al. proposed a concept of a planar ultrasonic transducer to improve the performance and reduce the cost of ultrasonic scalers [3]. More recently, J. Burger et al. have developed a scalpel for medical applications based on planar ultrasonic transducers [4] showing promising results. However, challenges imposed on feedback control systems by this concept impeded to deploy the superior properties of planar ultrasonic transducers to periodontal scalers so far.

II. METHODS

A prototype of a planar ultrasonic transducer for a periodontal scaler as shown in Figure 1 was developed by our group. A measurement system was developed to characterize the transducer at varying driving voltages and with varying load applied to the tip using a mechanical model for calculus developed by E.M.S. S.A. (Nyon, Switzerland).

III. RESULTS

An increased driving voltage amplitude results in a stronger tip vibration, as expected. The mechanical resonance frequency is reduced as well as the magnitude of the input impedance at resonance. Without load applied at the tip, increasing the driving voltage amplitude from 60 V to 100 V increases the amplitude of tip displacement from 24 µm to 51 µm, while the resonance frequency is reduced from 27.45 kHz to 27.42 kHz. At mechanical resonance, the magnitude of the input impedance is reduced while it's phase remains almost unchanged.

On the other hand, a force acting on the tip reduces the displacement of the tip, as expected. In contrast to increased voltages, the mechanical resonance frequency and the magnitude of the input impedance at resonance are increased. Interestingly, forces pulling the tip away from the scaler alter the characteristics more than forces pushing on the tip. Applying a pulling force of 200 mN at the tip reduces the amplitude of tip displacement from 51 µm to 44 µm, at 100 V driving voltage amplitude, while the resonance frequency is increased from 27.42 kHz to 27.44 kHz. At mechanical resonance, the magnitude of the input impedance is increased in this case while it's phase remains almost unchanged as for varying driving voltage.

IV. DISCUSSION & CONCLUSIONS

The detailed characteristics we obtained allow to develop a feedback control system that can tap the full potential of the planar ultrasonic transducer. This will result in a power-driven periodontal scaler with unprecedented performance, improved handling, and reduced production cost.

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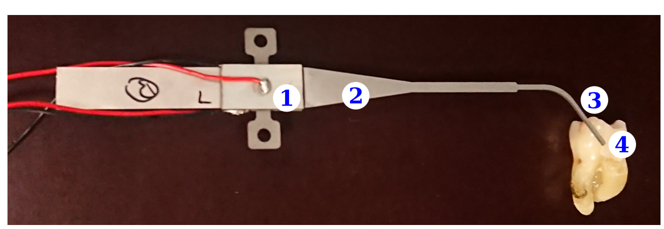

Fig. 1. Prototype of a planar ultrasonic transducer for a periodontal scaler consisting of two piezoelectric elements (1) glued to a titanium sheet (2). The tip (3) vibrates when an AC-voltage is applied and removes calculus or biofilm from a tooth (4).

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