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Initial observations regarding the measurement of dielectric properties of human teeth

Mariya Berezhanska[(1)], Daniela Godinho[(2)], Paulo Maló[(3)] and Raquel C. Conceição* [(2)]
(1) Physics Department, Nova School of Science and Technology, Nova University Lisbon, 2829-516 Caparica, Portugal; https://www.fct.unl.pt e-mail: m.berezhanska@campus.fct.unl.pt
(2) Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências, Universidade de Lisboa, Campo Grande, 1749-016-Lisbon, Portugal; http://ibeb.ciencias.ulisboa.pt e-mail: dgodinho94@gmail.com, raquelcruzconceicao@gmail.com*
(3) MALO DENTAL INTERNATIONAL; https://www.malodental.com

Abstract

In this paper we show our initial observations regarding the measurement of dielectric properties of human teeth and the challenges of using an Open-Ended Coaxial Probe to measure a non-regular solid and ensuring good contact between the probe and teeth.

1. Introduction

Dental decay is one of the most prevalent chronic diseases in the world, affecting between 60 to 90% children and most of the adult population [1]. The most commonly used imaging modality to diagnose dental health is X-ray. However, it cannot detect dental decay in initial stages [2] and uses ionising radiation.
To address this issue, we have recently established a clinical protocol with MALO Dental called "Exploratory study to use microwave imaging to detect dental cavities and monitoring of dental implants" (original name in Portuguese: "Estudo exploratório do uso de Imagem por Micro-ondas para deteção de cáries dentárias"). We report the first part of our study in which we developed a methodology to measure dielectric properties of human teeth, which is an important milestone in order to proceed with our study.

2. Materials and Methodology

We have used an Open-Ended Coaxial Probe, OECP (Slim form probe, N1501A, Keysight) with a Vector Network Analyzer (E5063A, Keysight) to measure our samples, which comprised healthy teeth that were removed from patients admitted to MALO Dental clinic for fitting of full mouth dental implants.

OECP is usually used for the measurement of liquids and semi-solids [3]. We propose a methodology to make meaningful measurements of solids (teeth), while ensuring good contact between the probe and the irregular surfaces of teeth.

Irastorza et al [4] suggested that measuring dielectric properties of solids immersed in water minimised the error that yields from poor contact between the OECP and solid materials under test (MUT). However, the introduction of a coupling medium between the probe and the MUT leads to the contamination of the measurement of the MUT.

In this paper, we present a summary of our observations over the course of our work. We empirically picked a surface of the root of molar tooth (dentin) that seemed as plane as possible, given the diameter of the slim form probe (2.2mm). We made an initial measurement of the dentin (in air) and we compared our measurement to the only measurements we found of the dentine in the literature measured with a waveguide, in the frequency range of 0.04-40GHz [5]. We observed that our measurement was below those reported, motivating us to pursue better contact between the dentin and the OECP.

We then proceeded to measure different coupling media, these included TX100, water, acetone, ethylic alcohol, and glycerine. We picked glycerine and mixes of glycerine and water as we observed these did not evaporate at room temperature (21º-22.5ºC), and we knew that these did not interact with the dentin tissue. We made several mixes of glycerine and water, namely 100:0 (G100), 95:5 (G95), 90:10 (G90), 85:15 (G85), 80:20 (G80), 75:25 (G75), 70:30 (G70), 65:35 (G6) percentage in volume. We measured all these mixes, and as expected we observed higher relative permittivity with higher content of water.

Finally, we completed the measurement of the dentin when a drop of one of the above-mentioned mixes (i.e. the coupling medium) was placed between the OECP probe and the dentin, to ensure the best contact possible, while minimising the effect of the chosen coupling medium, as much as possible.

3. Results and Discussion

We completed the measurement of the dentin in air and dentin with the tested coupling media. We observe that if the coupling medium and the MUT have similar properties for a given range of frequencies, the error introduced by measuring the combination of a MUT with a coupling medium can be kept to a minimum. We then empirically defined which coupling medium was closest to the dentin measurement given each frequency sub-range.

In Figure 1, we show a measurement in which the MUT has similar dielectric properties with several coupling media in sub-ranges of the tested frequencies (500MHz-18GHz), as means to a better estimation of the true properties of the MUT.

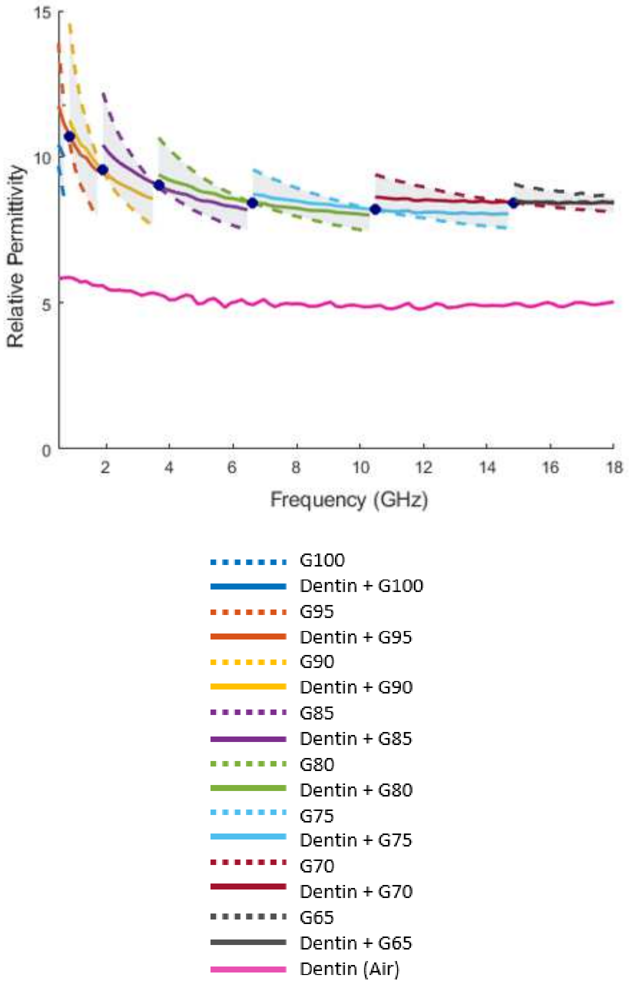

Figure 1. Relative permittivity of a tooth root (dentin) estimated from the combination of 7 sub-frequency regions. Each region is limited by the properties of the coupling medium with higher content of water (upper bound) and the coupling medium with lower content of water (lower bound). The coupling media are mixes of glycerine and water, the different percentages (in volume) of glycerine in the mix are shown after G, e.g. G65 is 65% of glycerine, and the remaining 35% of water.

Through Figure 1, it can be observed that we were able to restrict the upper and lower boundaries of relative permittivity of dentin, in given frequency sub-ranges, in attempt to obtain the true properties of dentin. Each region is limited by the properties of the coupling medium with higher content of water (upper bound, e.g. G65 for the highest frequency sub-interval) and the coupling medium with lower content of water – less 5% volume of water (lower bound, e.g. G70). The region is also restricted by frequency, the lowest frequency (for the same example of the highest frequency sub-interval) is the frequency at which the properties of G70 and the Dentin+G70 intersect, and the highest frequency is the frequency at which the properties of G65 and the Dentin+G65 intersect.

4. Conclusion and Future Work

We have shown promising initial measurements of the dentin in the range of 500MHz and 18GHz. We hope to extend our initial study to the enamel tissue of teeth, and then pursue the measurement of teeth (both dentin and enamel tissues) affected by cavities.

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