DIGITALLY DESIGNED AND MANUFACTURED LASER DOPPLER PROBE HOLDER FOR TOOTH VITALITY ASSESMENT – A PRELIMINARY STUDY FOR A NOVEL TECHNIQUE

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ABSTRACT

Aim of the study. The purpose of this study was to develop a new method to facilitate laser Doppler tooth vitality assessment, using a digitally designed probe holder. **Material and methods.** A laser Doppler probe holder was digitally designed after scanning a casted model and then the probe holder was 3D printed. In order to test the probe holders, a straight optical probe from MoorLab instruments was used. **Conclusions.** The probe holder proved to be stable and could be used to obtain accurate signal acquisition in these experimental conditions, however further testing is necessary.

Key words: Laser Doppler, probe holder, pulp vitality

INTRODUCTION

Diagnosis of dental pulp status presents significant importance in daily dental practice. Vitality testing is an essential aid for dental pulp status monitoring, especially after prosthodontic tooth preparation [1, 2].

Current methods include thermal stimulation, electrical or direct dentine stimulation, done by applying the stimulus to the outer surface of the tooth and indicate that the nerve fibers are functioning, but does not give any indication of blood flow within the pulp. These testing methods often produce an unpleasant and occasionally painful sensation and might have an inaccurate result, therefor sensibility tests are not an ideal method to determine vitality status [1, 2, 3, 4].

Laser Doppler flowmetry is a proficient technique for the real-time assessment of microvascular red blood cell dynamics, however special conditions are mandatory in order to have an accurate reading. [1] The optical probe stability, positioning and the design of the holder are the main influencing factors during assessment [3]. Accurate signal acquisition also requires a correct and constant positioning on the tooth surface, minimizing false signals from surrounding tissues as well as involuntary patient movements [1, 3]. The optical probe needs to be completely still to make an accurate record of the pulpal blood flow. Most commonly used stabilising splints are made of silicones or acrylic resin [1, 2, 3, 6, 7, 8].

Until now the best solution for the probe holders was the use of condensation silicones combined with light-cured resin materials to isolate the signals coming from the gingiva [1, 2, 3, 5, 6, 9].

Probe holder manufacturing still presents certain shortcomings, being made manually by the investigator. It is necessary to find an objective execution technique that does not depend on the technical abilities of the investigator.

To achieve the desired results, we developed a digitally designed Laser Doppler probe holder that will solve some of the shortcomings of the classic technique.

MATERIAL AND METHODS

Design of the probe holder in Exocad.

In order to digitally design an individualized laser Doppler probe holder, two models (upper and lower arch) obtained from Frasaco typodont were used. For scanning the models, a high accuracy laboratory scanner (NeWay Scanner – Open Technologies) was used (Fig 1.). The trueness of this scanner is less than 5µm and the precision less than 2µm, according to the ISO 12836 specifications.

The STL file obtained after scanning was then transferred in order to create a design that would fit are needs. Exocad software was used for the design. (Fig. 2 and Fig. 3.) The probe holder covers and isolates the neighbouring teeth from the one that needs to be tested. The diameter of the tube and the hole had to be 1.2 mm to facilitate the positioning of the probe (probe diameter 1mm). The thickness of the holder should not exceed 5 mm. The optical probe used in this study was a straight one, MP3b form MoorLab – Moor Instruments.

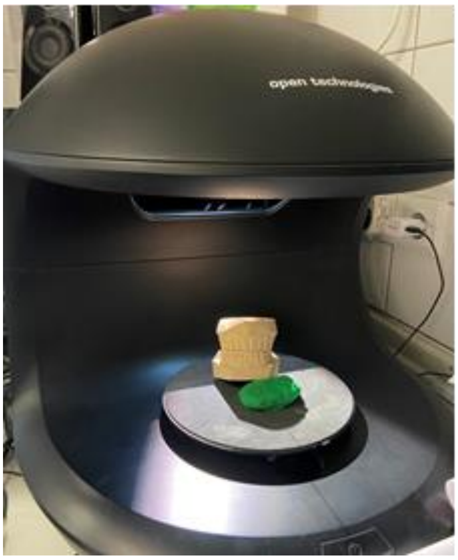

Figure 1. The casted model being scanned

3-D Printing of the probe holders.

The design of the probe holders was exported in STL format to a 3-D Varseo XS printer from Bego (Fig. 2 and Fig. 3.) After printing, the holder was fitted on the model and then the laser Doppler probe was inserted in the specially designed tubes that have a diameter of 1.2 mm just enough to permit the probe to slide freely and still stay in place this way the same positioning could be replicated several times. (Fig. 4).

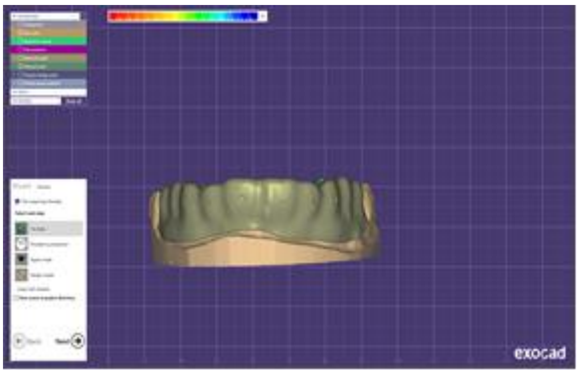

Figure 2. The design of the probe holder in

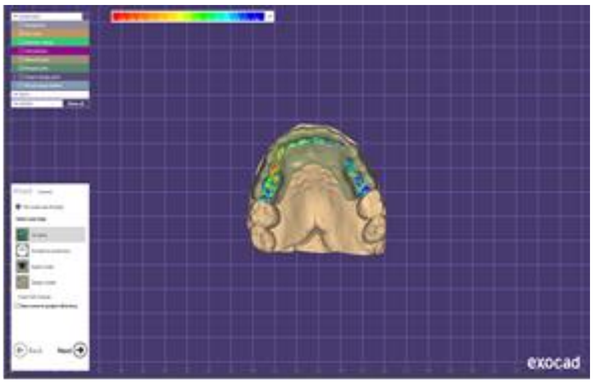

Figure 3. The design in Exocad, occlusal view

Figure 4. The probe holder with the 1mm diameter laser Doppler optical probe

Exocad, frontal view

RESULTS AND DISCUSSIONS

Due to the complexity of accurate signal acquisition technique which requires a fixed and constant position, minimizing involuntary patient movement is mandatory [2]. These 3-D printed probe holders might offer the solution. In the literature, an acquisition time of 1 to 3 minutes is used most frequently, and it depends on the tooth that is going to be tested. This time interval can cause a discomfort to the patient as he must keep still during the acquisition, otherwise the movement artefacts may appear and these can invalidate the testing, even if the technique of the probe fixation at tooth level is perfect. This situation causes problems to the investigator, who performs the test [1].

The probe holders designed in this experiment are more stable, fit perfectly and might also better isolate the testing surfaces, compared to a double silicone impression [1, 2, 4, 5], however manufacturing it is more time consuming, implies more steps and additional equipment is needed. In order to validate this, further testing is necessary. The digitally designed holder offers a better fit and isolation, so the signals that come from the gingiva or the neighbouring teeth are not interfering with the signal acquisition. In the future, an intraoral scanner can be used for scanning the dental arches, this way the need for a casted model will be eliminated thus the process will be optimized.

The holders manufactured in this study are light weight and permit individualizations, so they can be more helpful for determinations at the level of prepared teeth. The positioning of the optical probe will be also digitally pre-determined, this way after fitting the holder in place the possibility of positioning errors is reduced.

The holder can also be disinfected more easily compared to the condensation silicone holders.

Limits and future directions for perfecting the technique

Following our speciality literature search, we did not find studies in which the technique of manufacturing 3-D printed probe holders that eliminate the elements of subjectivism and allow reproducibility in case of loss or destruction is described.

The 3-D printed probe holders at this point are conditioned by having first a scanned digital model. The use of proficient intraoral scanners may offer the solution.

During additive manufacturing of the probe holders there can be excess material that can interfere with the adaptation of the holder on the teeth or may block free movement of the optical probe.

In the future the use of a different resin materials can make the 3-D printed holders also autoclavable.

CONCLUSIONS

1. The probe holders are stable and can replicate the positioning of the probe without difficulty.
2. The manufacturing is cost efficient, however there are more design steps that need to be taken into consideration.
3. The holder can also be more efficiently disinfected.

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