Condensation Silicones and Light - curing Resin Used within a Laser Doppler Pulp Vitality Testing Method

MARIANA-IOANA MIRON[1]* DORIN DODENCIU[2], PAUL SARBESCU[3], SILVANA CANJAU[1], LAVINIA ARDELEAN[4], LAURA CRISTINA RUSU[4], CARMEN TODEA[1]

[1] University of Medicine and Pharmacy "Victor Babeş", Department of Oral Rehabilitation and Dento-periodontal Emergencies, School of Dentistry, 2 Eftimie Murgu Sq., 300041, Timisoara, Romania

[2] University of Medicine and Pharmacy "Victor Babeş" Timisoara, , Department of Functional Sciences, Discipline Medical Biophysics, 2 Eftimie Murgu Sq., 300041, Timisoara, Romaia.

[3] West University of Timişoara, Psychology Department, 2 Eftimie Murgu Sq., 300041, Timisoara, Romaia.

[4] University of Medicine and Pharmacy "Victor Babeş", Timisoara, Department of Dental Materials Technology, School of Dentistry, 2 Eftimie Murgu Sq., 300041, Timisoara, Romaia.

Records of pulpal blood flow obtained from human teeth with a laser Doppler flowmeter include a very large component derived from the periodontal tissue and other tissues outside the pulp. This contamination can be reduced by isolating the tooth from the surrounding tissues. The purpose of the present study was to show that polymers and resins make possible an optimal pulp vitality testing when used for fixing the laser probe, as well as for reducing the signals originating from the periodontium. Recordings were taken from 10 healthy, intact frontal upper teeth, in 8 individuals, ages between 20 - 40 years. Signals were recorded with the laser Doppler MoorLab and a straight optical probe, MP3b. Two consecutive determinations of the pulpal blood flow at a 5 minute interval where taken for each tooth using the following methods: 1 – a silicone impression combined with light curing periodontal liquid dam, and 2 – without periodontal isolation system. The data were processed using the statistical analysis software SPSS v16.0.1. The combination of the silicon impression with the Light curing periodontal resin isolation decreased significantly statistic the flux values (68.01% decrease) and was more effective in individualizing the pulpal blood flow than simple silicone impression. The presented technique is a viable method for determining pulp vitality, reproducible, easily applicable and shows a significant reduction in the intake of nonpulpar origin signals.

Key words: condensation silicones, light curing periodontal liquid dam, laser Doppler flowmetry, pulp vitality

Vitality testing is an important aid for dental pulp health status monitoring, especially after traumatic injuries and for the correct diagnosis concerning pulp disease and apical periodontitis. The diagnosis of dental pulp status should be seen as a synthesis of history, clinical examination, special tests, and radiological examination, and not as the outcome of one specific test [1,2]. If the pulp is considered to be unhealthy as a result of the diagnostic synthesis, then endodontic treatment is indicated. Reliable vitality assessment of the dental pulp has always been problematic; therefore, many methods have been suggested to test pulp vitality [3]. The most commonly pulp sensibility tests used in clinical practice include thermal and electric tests, which extrapolate pulp health from sensory response. Pulp vitality tests attempt to examine the presence of pulp blood flow, as this is viewed as a better measure of true health than sensitivity [4,5]. Many studies reported that the laser Doppler flowmetry (LDF) technique is valuable for measuring human pulpal blood flow in order to determine pulp vitality [6-11]. The technique can measure perfusion quantitatively in real time [8]. The major advantage of the laser Doppler techniques is their non-invasiveness and their ability to measure the microcirculation flux of the tissue and fast changes of perfusion during provocations. Yet, reliable vitality assessment of the dental pulp using laser Doppler (LD), in their present state of development, is problematic [12]. Many factors affect tissue blood flow, so precautions may need to be taken in order to standardize measurements and to eliminate other factors that may influence the blood flow. The main influencing factors of LD recordings are the following: the position of the optical fiber on the surface to be tested, movement artifact, external light sources, "lamp effects" [13 - 20]. However, it has also been claimed that signals from human teeth do not necessarily indicate pulpal blood flow and could be confused with a signal obtained from nearby gingival tissues, suggesting the periodontium and other neighbouring tissues can contribute to the signal [21- 23]. This also suggests that even with proper isolation of the tooth from the periodontal tissue, some signal contamination from the periodontium is inevitable. They also demonstrated that without isolation, the laser light can scatter from the source tooth to the whole oral cavity which can also contaminate the signal.

The purpose of the present study was to show that polymers and resins make possible an optimal pulp vitality testing when used for fixing the laser probe for laser Doppler flowmetry, as well as for reducing the signals originating from the periodontium.

Experimental part

Materials and methods

The study was performed at the Department of Oral Rehabilitation and Dental Emergencies, School of Dentistry, University of Medicine and Pharmacy "Victor Babeş", Timişoara. The experimental design study was approved by the Local Ethics Committee and, after the presentation

* *eail: mariana.miron@yahoo.co.uk*

of the written protocol the patients signed their written participation agreement.

The tests were carried out on a sample of 10 single rooted anterior teeth, corresponding to 8 patients, aged between 20 and 40. All the vital teeth were decay free and intact. Radiographic examination and electrical pulp stimulation confirmed whether they were vital and healthy or non-vital. Two consecutive determinations of the pulpal blood at a 5 min interval were taken for each tooth using the following methods: the first – a periodontal isolation system with light curing liquid dam, and the second – without periodontal isolation system.

In this study we used a condensation silicone for fixing the optical fiber in the testing area, and a light curing resin for insulating the tooth from the adjacent gingival.

Condensation silicones are polymers used in dentistry primarily as an impression materials. They are supplied as a base and an accelerator. The base contains a linear silicone called a polydimethylsiloxane, which has reactive terminal hydroxyl groups. Fillers may be calcium carbonate or silica having particle sizes from 2 to 8 m, and in concentrations varying from 35% up to 75% depending on the consistencies. The accelerator may be a liquid that consists of stannous octoate suspension and alkyl silicate, or it may be supplied as a paste by adding a thickening agent. The reaction produces a three-dimensional network with the liberation of ethyl alcohol and an exothermic temperature rise of about 1^0C. The polymerization is accompanied by the release of the by-product that causes a shrinkage [24].

In our study we employed Optosil Comfort Putty and Xantopren Comfort, Haereus, that is silicon based condensation curing impression material. Optosil Comfort Putty and Xantopren Comfort combine the advantages of A- and C-silicones with those of Polyether in one perfectly matched system. Materials features: exact reproduction of detail because of Hydrocontrol; no sensitivity problems during use, especially in relation to latex gloves and retraction solutions and exceptional long term dimensional stability even after 7 days. The high dimensional stability of Optosil Comfort Putty enables reproducible results regardless if the impression is poured the next day or even after 7 days. Combinations of Optosil Comfort Putty / Xantopren Comfort show very good wetting properties in a moist dental environment and thus enable precise reproduction of detail.

The second material we used, Ultradent® LC Block-Out Resin, is a viscous light-curingd resin designed for laboratory use such as for bleaching reservoirs on plaster models, for lab procedures requiring spacing or undercut block out, and to repair small fractures or voids in laboratory models. It can also be used as a rubber dam substitute or to mask the gingiva and uninvolved areas of teeth and/or restorations during sandblasting. In addition, they can block-out gingival embrasures when taking final crown and bridge impressions to prevent the material from locking into them. Finally, they can protect the gingiva during power bleaching (block out resins). It is composed of 74% Diurethane Dimethacrylate and 16% Triethylene Glycol Dimethacrylate. Polymerization occurs when exposed to visible light, ultraviolet light or extreme heat. A disadvantage is that it gives off heat when curing, with most producing enough heat to cause pain when placed over the gingiva. Besides it is very easy to remove.

In study were also used, rotary instruments (drills, with the diameter of 1.5 mm) for the preparation of the access canals in the silicon holder and other soft isolation material.

The collected data were measured using a MoorLab laser Doppler equipment and a straight optical probe, MP3b, 10mm. To stabilize the probe, a double silicon impression fixed perpendicularly on the vestibular surface of the tooth in the cervical third was used. The Moor Instruments MoorLab laser Doppler monitor uses laser radiation generated by a semi-conductor laser diode operating at a wavelength of 780 + 10nm and a maximum accessible power of 1.6mW. The programmed bandwidth of the recorded laser Doppler signal was 20 Hz-20 kHz, while sampling frequency displayed a value of 40 Hz. Calibration was performed according to the instructions of the manufacturer. A PC system for collecting and processing the data was also needed.

The laser Doppler was recorded and analyzed using a MoorSoft MoorLab V2.01 software. The physical parameters assessed were flux and DC, of interest being the mean value and the standard deviation. Flow is related to the product of average speed and concentration of moving red blood cells in the tissue sample volume. It is the parameter most widely reported in Laser Doppler publications. DC gives an indication of the backscattered laser light intensity. The DC signal indicates a correct positioning of the optical probe, showing the reflected laser radiation level from the concerned area. The DC signal is the one that indicates the mechanic stability of the optical probe placed at the acquisition area.

The data were processed using the statistical analysis software SPSS v16.0.1.

On the first visit, after signing the participation agreement, the teeth for the study were selected. The patient was clinically examined and according to the electrical pulp stimulation and radiographic examination the teeth vitality status was established .

On the second visit every patient was set comfortably on the dentist's chair; the room temperature was approximately 21°C, and the lamp from the dentist's unit was positioned at a distance of approximately 45 – 55 cm from the patient. Prior to being tested, the subjects were asked to rest in the dental chair for approximately 10 min.

Around every tooth involved in the study, a light curing periodontal liquid dam was applied on a radius of 3-4 mm. Afterwards a silicon impression was taken, using Optosil Comfort Putty / Xantopren Comfort Light, sandwich technique, so that the impression covered two teeth on each side of the tested tooth. After impression material set, the impression is carefully removed from the mouth, so that the periodontal dam would not be dislocated. If the periodontal isolation was dislocated, it had to be removed and reattached correctly.

The impression obtained in this manner served for the acquisition of the both laser Doppler signals of the tested tooth. After decontaminating the impression, using a drill of 1. 5 mm in diameter, the vestibular-oral side of the impression was perforeted perpendicularly in the vestibular cervical third of the tooth involved in the study, at a 3 mm distance from the marginal gingiva. After probe calibration and disinfection the laser probe was inserted in the canal carved in the impression, and positioned afterwards in contact to the tooth surface.

In order to insure the reproducibility of the laser Doppler signal acquisition a guiding mark that permittedits placement in the same position for each testing was set on the fiber. Then, the tooth surface was cleaned and, and the impression was positioned. For each patient the flux and cardiac output signals were acquired for two minutes during each test.

After this, the impression and the periodontal protecting layer were removed, and after 5 min a new recording of the laser Doppler signal was carried out, but this time without applying the periodontal isolating layer. Between the two recordings the impression was washed and dryed.

Results and discussions

Using dedicated analysis software, MoorSoft MoorLab V3.0 software, the acquired from vital teeth (fig. 1) were viewed and analyzed from a mathematical standpoint.

The Power Spectrum signal analysis using fast Fourier transform (FFT) indicates a meaningful reduction of the amplitude of the signals recorded with the periodontal dam in place. The pulsatile nature of the signal is obvious in both situations (fig. 2).

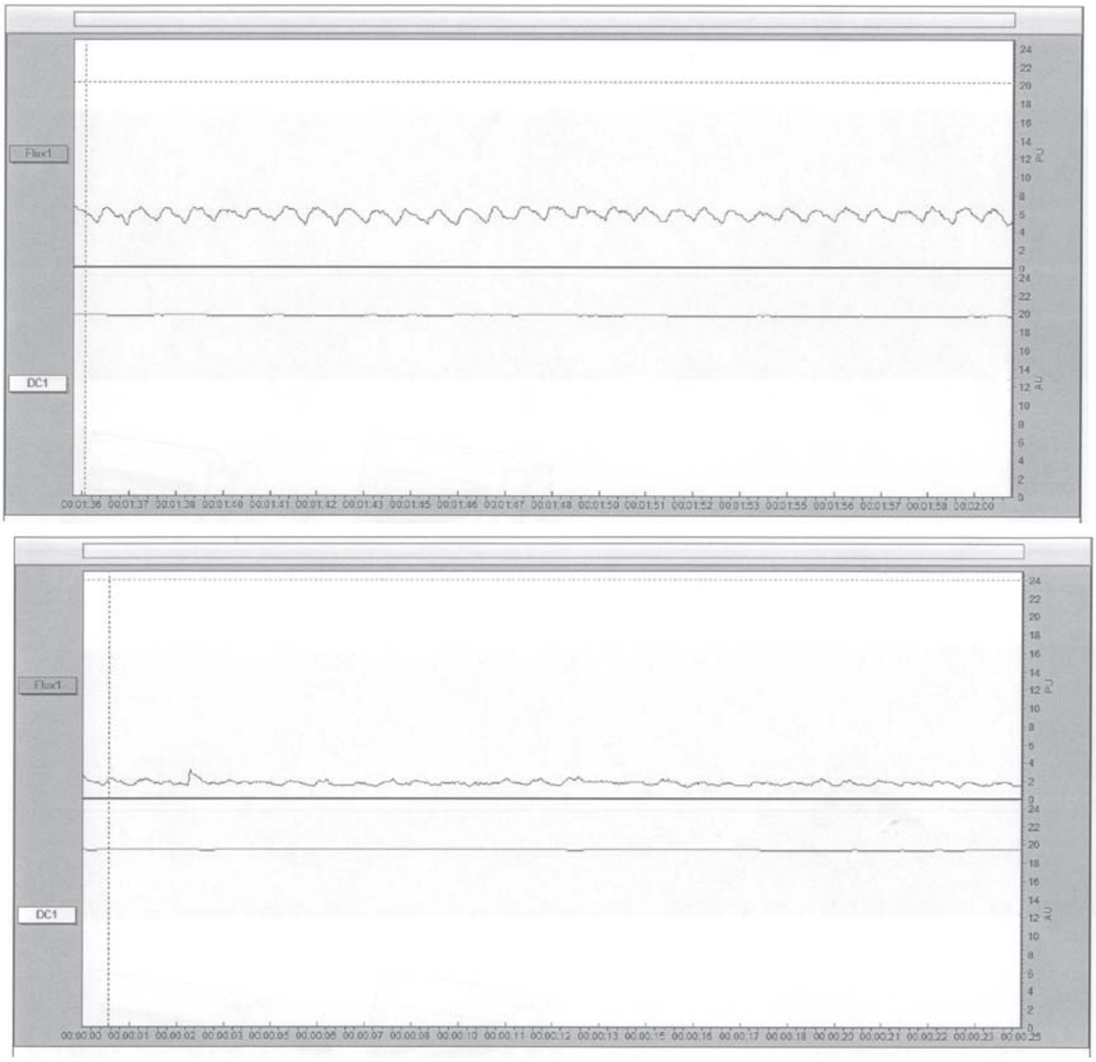

Fig. 1. Laser Doppler path examples for a vital tooth 2.1. using: a - silicon impression, b - silicon impression combined with light curing periodontal liquid dam.

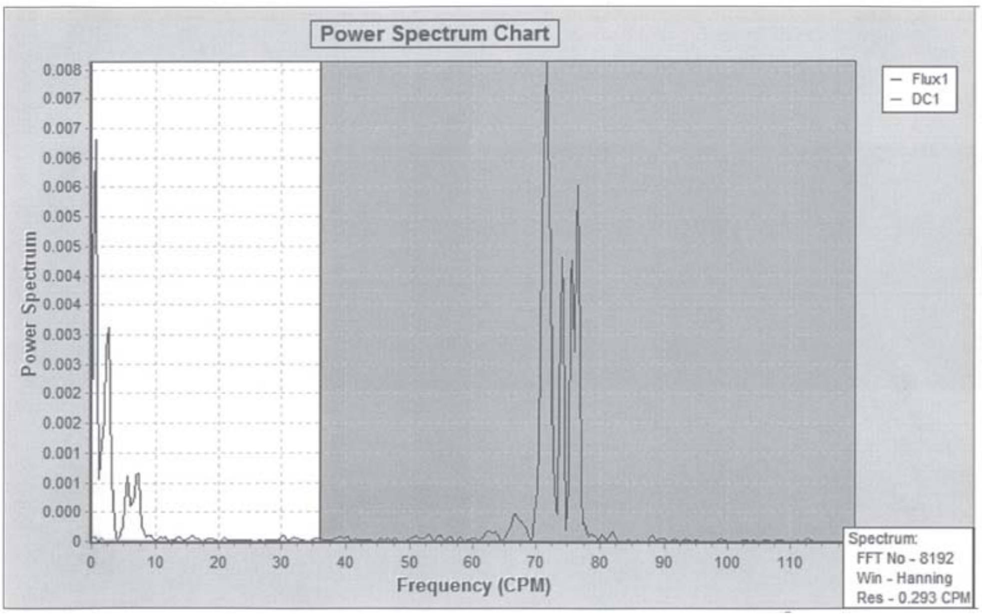

Fig. 2a. Laser Doppler Power Spectrum Chart examples for a vital tooth 2.1. using: a - silicon impression,

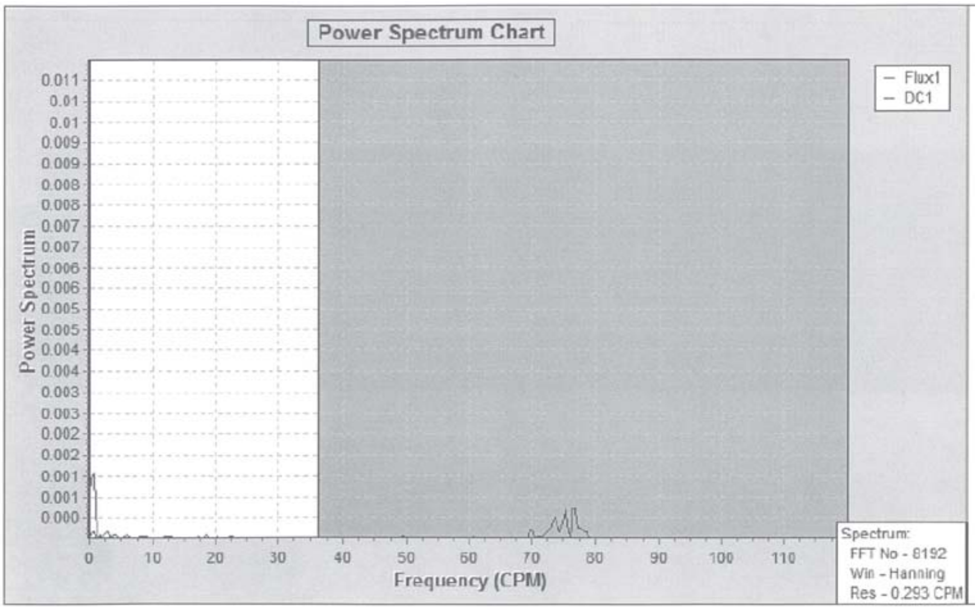

Fig. 2b. Laser Doppler Power Spectrum Chart examples for a vital tooth 2.1. using: silicon impression combined with light curing periodontal liquid dam

Table 1
MEAN VALUES, STANDARD DEVIATIONS AND T TEST RESULTS FOR VITAL TEETH

Parameter	*Vital tooth simple impression* (*n = 10*)		*Vital tooth impression and periodontal dam* (*n = 10*)		*T*
	M	*AS*	*M*	*AS*	
Flux	9.16	1.22	2.93	.38	23.77**
DC	35.62	11.14	35.55	11.10	.89

Note: ** p < .001.

Results obtained within the two experimental conditions (1 - vital tooth silicon impression, 2 - vital tooth silicon impression and light curing periodontal liquid dam) were used for subsequent statistical data processing. In order to evaluate the differences between the signals aquired from the teeth on which silicon impression was used and light curing periodontal liquid dam and the teeth on which was used only a simple silicone impression, regarding the parameters involved (flux and DC), the paired samples t test was used. The obtained results are showed in the following table 1.

Table 1 presents the mean values (M), standard deviations (AS) and t test results (T) for vital teeth. A significant difference can be noticed in the Flux parameter ($t = 23.77$, $p < .001$). Thus, we recorded a decrease of 68.01% in blood flow when Light curing periodontal liquid dam was associated with silicon impression. In order to identify how strong this differences were, we used an effect size analysis (this procedure has been frequently used in the past decade, by researchers from wide areas of expertise; it provides a more specific analysis of the effect's intensity). The effect size analysis reveals a very strong effect (d (Cohen) = 7.79). Regarding the DC, the recorded differences are not significant ($t = .89$, $p > .05$).

There are many studies in literature [1-3,6,15,13,22,25] in which researchers presented various kinds of holders, which have been used for LDF probes: modified rubber dam clam, manual holding, silicone splint, plastic splint, custom fabricated jig, green rubber base splint, acrylic splint, self-cured resin splint, polyurethane splint, polyvinylsiloxane stents, individual resin cap, individual resin plate [5]. All this holders tried to develop different laser Doppler fiber positioning systems that permit obtaining both a stable and reproducible position of the laser probe during pulp vitality testing. At the same time, a reduction of the signals originating from the tooth adjacent tissues is necessary for obtaining a valid signal.

In our study, following the statistical analysis of experimental data, there it was noticed a significant reduction of 68.01% for vital teeth of the signal levels acquired by using silicon impression/splint combined with light curing periodontal liquid dam. Due to the laser Doppler signal acquisition sequence at five minutes, through the two compared methods, pulpal blood flow can be considered approximately invariable. Thus, the signal variation is due exclusively to the non-pulpar origin signal input variation. According to these results, we could claim that the reduction is due to partial shielding of the non-pulpar origin signals through the proposed method.

Many studies suggest that 45 to 82% of the blood flow recorded from human teeth may not be from the pulp [5,13,16,19].

The results obtained in terms of the present study show that about 68.01% of the acquired laser Doppler signal is of non-pulpar origin, which is consistent with the existing literature [5,6,15,16]. Moreover, the existence of a very low flow signal even with light curing periodontal dam isolation shows that the method cannot entirely eliminate artifacts of non-pulpar origin but it can significantly reduce them.

From the visual analysis of the signals obtained by the method proposed in this study, in comparison with existing signals in the literature by using a rubber dam, it can be observed the maintenance of the pulsed nature of the signals in case of the vital teeth. In case of the non-vital teeth signal analysis, it is noted that the employment of isolation system used in the study, leads to marked attenuation of the pulsatile nature of the signal, making it the pseudorandom.

Moreover, the high dimensional stability of Optosil Comfort Putty enables reproducible results regardless if the impression is poured the next day or even after 7 days, so we can record signals from the same position each time.

LD signals acquired by the proposed method are suitable for pulp vitality testing. Mean value of the LD signals obtained through the method of isolation with silicon impression combined with light curing periodontal dam is much lower, 2.93 for vital teeth than for simple impression without periodontal isolation, 9.16 for vital teeth.

Random variations of the flow signals are very reduced by providing a stable positioning of the optical fiber and keeping constant periodontal artifacts due to the stiffness of the light curing periodontal liquid dam.

Lack of significant changes of the DC, with and without periodontal isolation, indicates that isolation does not alter the positioning of the fiber. The very low standard deviation value of 0.1 indicates an insignificant variation of the DC physically correlated with the rigid positioning of the fiber and the elimination of motion artifacts from the acquired path.

Conclusions

The presented technique – which used condensation silicon (Optosil Comfort Putty / Xantopren Comfort Light) for fixing the laser Doppler probe, and light curing resin (Ultradent® LC Block-Out Resin) for insulating the tooth from the adjacent tissues – is viable for determining pulp vitality, reproductable, easily applicable and shows much less discomfort for the patient than traditional isolation with rubber dam. Additionally, it shows a significant reduction of the input of non-pulpar origin signals, which could alter the pulpar test validity.

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