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Validation of Pulse Oximeter Probe to Determine the Pulp Vitality

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Abstract

Introduction: The traditional pulp testing methods like thermal and electrical tests depend on the nerve innervation yielding sensitivity of tooth but do not infer about the vitality of tooth. An objective and non-invasive technique called Pulse oximetry is used for measuring blood oxygen saturation levels and differentiates vital pulp from necrotic pulp.

Aim: This study aimed to determine the validity of a customized pulse oximeter (CPO) for evaluation of pulpal vitality in primary and permanent teeth.

Method: PO was evaluated on 120 intact primary and permanent teeth of children aged between 4 to 16 years where vital teeth were designated group A, non-vital teeth as group B and root filled non-vital teeth as group C. For each patient PO was first applied on the finger followed by taking the vitality readings from 120 teeth which included both vital as well as non vital teeth.

Result: The PO test readings identified all the teeth with non-vital pulp as non-vital and all vital teeth as vital for identified range of %SpO2.

Conclusion: Pulse Oximeter may be used as an objective tool for diagnosing the pulpal vitality.

Keywords: Pulse oximeter (PO), Pulp oximetry, Pulp vitality

Introduction

A proper diagnosis of an endodontic condition is essential for an appropriate treatment planning and to prevent any endodontic failure. Thermal and electrical testing are the two most commonly employed sensibility tests used to diagnose various endodontic conditions. However they have a drawback that they implicate only subjective vitality of a tooth based on the sensory-neural response from the patient which may often be misleading in pediatric endodontic cases .[1, 2]

A temporary or a permanent loss of sensory function as a result of trauma in a tooth may give false negative results by sensibility testing even though tooth may still possess some vital vasculature within. Similarly, in blunderbuss or open apex cases, the sensibility testing may provide inaccurate status of thepulp.[3] False positive results may also be seen in some cases of pulpal necrosis wherein the neural response still be intact.[4]

The ideal technique for diagnosing the pulp vitality must be non-invasive, objective, painless, inexpensive, reliable, reproducible, standardized, and easily completed.[13] It has also been seen that the thermal and electrical tests do not always provide the corresponding accurate histological status of the pulp when assessed for reversible or irreversible pulpitis.[5] Therefore, diagnosing the pulpal status objectively by assessing the blood circulation or vasculature seems to be a more appropriate technique. Recent attempts to develop a latest method for determination of pulpal circulation involve the use of Laser Doppler flowmetry, Pulse oximetry, Photo plethysmography and Dual- wavelength spectrophotometry however, these methods are expensive and not economical for general practice.[6]

Pulse oximetry is an objective and non-invasive physiometric tool based on principles of spectrophotometry and photo plethysmography where absorption characteristics of hemoglobin in the red and infra-red range is measured and requires no subjective response from the patient.[7]

An electrical engineer Takuo Aoyagi at Nihon Kohden Company in Tokyo, confirmed that the pulsatile changes of oxygen saturation could be used to determine saturation from the ratio of pulse changes in transmission of red and infrared light.[6]Later in 1978, Minolta adopted and improved his ideas to further improve and market pulse oximeters worldwide. The principle is based on a modification of Beer Lambert's law which states that the absorption of light by a solute is related to its concentration at a given wavelength. Red and infra-red light waves are emitted onto a tissue and a detector inbuilt detects the absorption peaks according to blood circulation allowing the measurement of oxygen saturation and pulse rates.[8]Pulse oximeter can be an ideal chair-side screening test to diagnose pulp vitality.[6]

Materials and Method

For validation of customized pulse oximeter, a total of 120 on primary and permanent intact vital and non-vital teeth of children 4-18 years of age were selected. All the patients and parents were instructed to sign an informed consent form before examination procedures. The inclusion criteria for both primary and permanent non-vital teeth were presence of intact/ partially broken crown with-past history of severe, dull, lingering or spontaneous pain with or without periapical radiolucency.

The criteria for vital teeth included healthy non-cavitated teeth, teeth with symptoms of mild to moderate pain but without nocturnal history indicating some inflammatory pulpal alteration. Teeth that presented with history of dental trauma, advanced periodontal diseases, swelling or increased mobility, tenderness to apical palpation and vertical or horizontal percussion were excluded from the study. After selection of the teeth as per inclusion criteria, they were divided into 3 groups which consisted of:

1. Group A: Vital maxillary and mandibular primary and permanent teeth
2. Group B: Non-vital maxillary and mandibular primary and permanent teeth
3. Group C: Root canal obturated maxillary and mandibular primary and permanent teeth

The patients were seated on dental chair and involved tooth was examined without chair side illumination. The tooth surface was air dried and isolated with cotton rolls.

Initially cold test (Thermal test) was done with Roeko Endo Frost (Figure 1) on the particular tooth followed by electric pulp test. After that, for pulse oximeter testing purpose, the patient was instructed to avoid moving the head during testing interval to avoid motion interferences. The operating light of the dental chair or the intense fluorescent ambient light was not used during measurement to prevent any interference for capturing the signal of the pulp oximeter. The sensor was positioned on the buccal surface (emitting diode) and the palatal or lingual surface (receiving diode) maintaining parallel alignment between the two diodes and the signal readings were obtained in approximately 5 to 20 seconds.

Figure 1: Roeko Endo Frost used for cold test

Figure 2- Customized pulse oximeter

Figure 3- Application of customized pulse oximeter on vital tooth

A commercial Pulse oximeter (Contec CMS 60C Handheld Pulse Oximeter Black) was modified for dental application (figure 2). The sensor provided along with it is an ear probe allowing measurement of SpO2 from the ear lobes. The sensors were removed from their original rubber casing and we modified it to approximate the tooth anatomy and contours. Initially, sensor of pulse oximeter was placed on the index finger of hand of patient and reading was recorded. Then the specific tooth was checked for vitality (%SpO_2 in systemic blood) with customized pulse oximeter. The sensor was applied on the tooth (primary or permanent) appropriately permitting parallel positioning of the emitting diode with the photo receiver. The sensors were isolated using a transparent PVC film placed between the tooth and the sensor (finger 3).

The critical requirements of using pulp oximetry were met as the sensor conformed to the size, shape and anatomical contours of the teeth. Also, while placing the pulse oximeter, the light-emitting diode sensor and the photoreceptor were placed parallel to each other so that the photoreceptor sensor receives the light-emitted from LED. The use of sensor holder allowed firm placement of the sensor onto the middle third of tooth to obtain accurate measurements.

Data was entered into Microsoft Excel spreadsheet and then checked for any missing entries. It was analyzed using Statistical Package for Social Sciences (SPSS) version 21. The variable Oxygen saturation is a continuous variable and thus it was summarized as mean and standard deviation. Graphs were prepared on Microsoft Excel. Inferential statistics were performed using Pearson correlation coefficient**.** The level of statistical significance was set at 0.05.

Results

Table 1: Oxygen saturation values in finger & teeth among study population

	Permanent teeth			Primary teeth		
	Mean	SD	Range	Mean	SD	Range
Vital Tooth Reading	89.607	7.3753	75-99	88.300	5.6298	79-99
finger	97.643	1.4711	95-99	97.250	1.3717	95-99
Obturated tooth reading	.000	-	0-0	0	-	0-0
finger	97.133	1.8465	95-99	97.200	1.6092	95-99
Non-vital tooth reading	65.824	10.4117	43-84	67.400	7.9167	43-75
finger	98.059	1.1974	95-99	96.950	1.6376	95-99

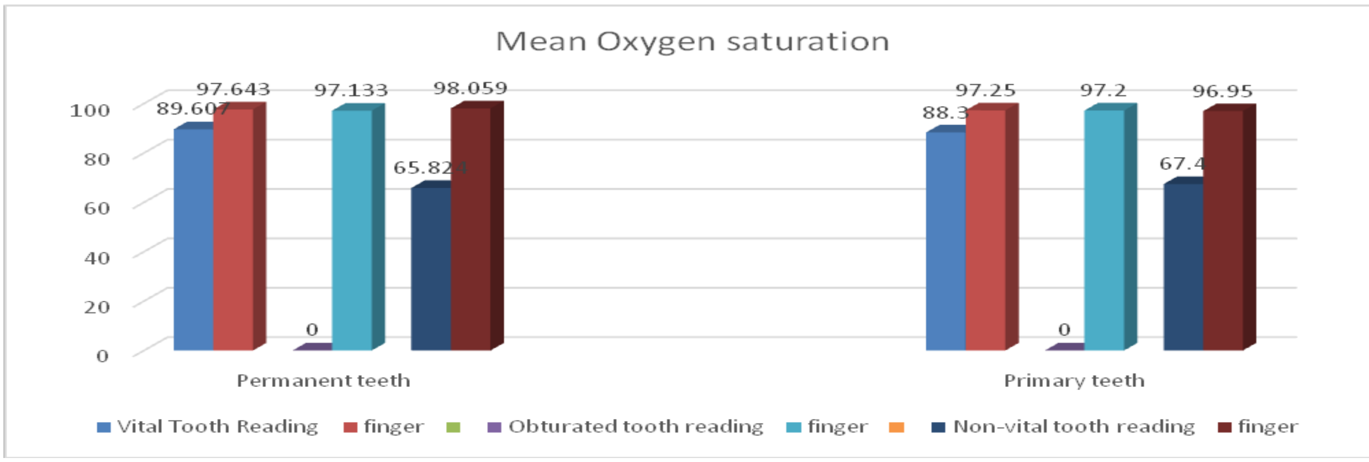

Figure 4: Correlation between tooth & finger oxygen saturation values among study population

Table 2: Correlation between tooth & finger oxygen saturation values among study population

		Permanent teeth		Primary teeth	
		Pearson Correlation coefficient	P value	Pearson Correlation coefficient	P value
Pair 1	Vital Tooth Reading & finger	0.847	<0.0001	0.855	<0.0001
Pair 2	Obturated tooth reading & finger	-	-	-	-
Pair 3	Non-vital tooth reading & finger	0.076	0.772	-0.425	0.062

Overall, Pearson correlation coefficient and its p value were calculated to assess the correlation of vital tooth, & non-vital tooth oxygen saturation readings with that of finger oxygen saturation (Table 2). A Strong & Positive Correlation was found between vital tooth & finger readings of oxygen saturation in both primary & permanent teeth. These correlations were also found to be statistically significant ($p<0.0001$)

No statistically significant correlation could be found among non-vital teeth readings of oxygen saturation with that to corresponding finger readings.

The sensitivity and specificity of pulse oximeter readings was seen to be 100% when compared to thermal test which showed a sensitivity of 95% for primary and 93.75% for permanent teeth and specificity of 100% (Table 3).

Table 3:	Sensitivity		Specificity		PPV		NPV	
	Primary	Permanent	Primary	Permanent	Primary	Permanent	Primary	Permanent
Thermal	95%	93.75%	100%	100%	93%	100%	90.91%	93.33%
EPT	97.44%	96.77%	95.24%	93.33%	97.44%	93.55%	95.24%	96.55%
Pulse oximetry	100%	100%	100%	100%	100%	100%	100%	100%

Table 3: Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) for thermal pulp test, electric pulp test and pulse oximetry in primary and permanent teeth (vital &non-vital).

Discussion

A pulse oximeter is a device with a monitor providing digital display of oxygen saturation values. Its Photo detector allows detection of light absorbed by oxygenated and deoxygenated hemoglobin and is connected to a microprocessor.[2, 9] The modern pulse oximetry was developed on two physical principles; firstly, the pulsatile changes in light transmission through living tissue occur due to alteration of arterial blood volume and secondly, the different absorption spectra of oxy-hemoglobin and reduced hemoglobin The pulse oximetry device consists of a probe/ sensor containing two light-emitting diodes that transmit red light (approximately 660nm) and infrared light (900-940nm) operating at 500 on/off cycles/sec. Although no pulse oximeter probes are commercially available for the dental use, various authors have devised indigenous probe systems to assess its efficacy in determining pulp vitality.[3, 7, 10]

A crucial characteristic for a dental pulse oximeter probe is that the sensor conforms to the varied teeth size and anatomic contours, LED sensors placed parallel to each other and stability to avoid false results by movement of probe or the patient.[11] Based on this criteria, the prime purpose and objectives of this study was to design and build a custom-made pulse oximeter dental sensor holder and to evaluate its effectiveness in determining the status of pulpal blood flow in primary and permanent teeth by comparing the oxygen saturation levels obtained in the patient's finger. During the testing interval, the patients complied with the placement and evaluation using our CPO probe and depicted cooperation for repetition of readings with report of no discomfort.

We customized the pulse oximeter by removing the manufacturer designed outer plastic and silicone casing to obtain the basic sensors in order to facilitate close adaptation of sensors on tooth. The difference in designs of customized pulse oximeter varied in the depiction of %SpO2 in vital teeth indicating importance of sensors to be closely adapted to the tooth surface. Use of ear probes may be the reason for higher %SpO_2 values since ear probes are considered to be sensitive to oxygen saturation changes in blood.[2, 8, 12]

The statistical analysis of the differences between finger and tooth readings, using Pearson's correlation coefficients, showed that there was a statistically significant strong & positive correlation found between vital tooth & finger readings of oxygen saturation (both primary & permanent teeth). However, no statistically significant correlation was found in our observations among non-vital teeth readings of oxygen saturation with that of corresponding finger readings. The findings of this study confirmed the ability of pulse oximeter to differentiate between clinically normal pulp and teeth with root canal filling. The data demonstrated that both primary and permanent teeth recorded lower SpO_2 values (43–98%) when compared with readings from the fingers (95–99%). These results are in agreement with the previous studies.[11, 12]

Literature suggests that the sensor needs to be placed in the middle third of crown since interferences from gingival circulation, gingival trauma or bleeding may alter the readings if placed in the gingival or incisal third where lesser pulpal tissue is present for adequate detection of the pulse.[14]

Standard organizations such as Food and Drug Administration (FDA) certified PO efficacy between 70-100%.[15] In a study, the sensitivity of the pulse oximetry was noted to be 100%, 81% for cold test and 71% for electric pulp testing.[16] Our study is in accordance with the results obtained by Gopikrishna et al where in pulse oximetry is seen to be more accurate as compared to the conventional pulp sensitivity tests.

A pilot study on 48 deciduous and permanent teeth showed SpO_2 in the range of 93– 94% in comparison to the $SpO_2$of 97% taken from index fingers.[17] Radhakrishnan et al. found that SpO_2 of 100 permanent teeth of children to be in the range of 80%. The lower SpO_2 values obtained in these studies are due to the direring optical properties of teeth because infrared light undergoes direction when passing through the enamel prisms and dentin, scattering the light rays occurs as they pass through the gingivae.[18]

Furthermore to verify the efficacy of CPO, we placed it on the root filled teeth in mouth and other non-vital articles outside, displaying no readings on the monitor. The results of this study found that the CPO could differentiate between vital, non-vital and root filled teeth both in primary as well as permanent teeth, implicating its use in pediatric patients.

All %SpO_2 values below 84% in permanent and 75% in primary by our CPO proved to be for non-vital teeth (as diagnosed clinically), therefore should it should be considered non-specific. If signal noise and interference with light transmission were kept under control, dyshaemoglobin present in non-vital pulp may still be the reason of false readings by pulse oximeter.[19] Venous blood has %SpO_2 of 75% according to Wong JK et al, therefore our readings probably represented arterial ischemia and venous congestion (necrosis) in pulp chamber. Nonetheless, there was 100% accuracy for tested range of %SpO_2 for clinically diagnosed non-vital but untreated teeth.

This device may be advantageous as an effective and objective method for evaluating dental pulp vitality in cases of traumatic injury where the blood supply remains intact even after neural damage. The drawbacks associated with this device can be classified as intrinsic and extrinsic.[20] Intrinsic factors include background absorption associated with venous blood and tissue constituents, Electro-cautery near the sensor, ambient light interferences, and ipsilateral blood pressure readings that are not differentiated. The extrinsic factors include probes which are nonspecific for the anatomy of a tooth and the fact that the oxygen saturation values from the teeth routinely register lower than the readings from the patient's finger.[14, 15]

Conclusion

Various devices that test pulp viability are available, but they only test the viability of nerve fibers as measures of pulp vitality resulting sometimes in false positive or false-negative results. It is therefore evident that a Pulse oximeter is an appropriate and accurate method for assessment of the pulp vitality. With limited research on commercial pulp oximetry to test pulpal blood flow in teeth, it seems to be very promising and may be introduced in the dental clinics in near future, especially for pediatric patients.

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