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Assessment of the efficacy of an indigeniously developed pulse oximeter dental sensor holder for pulp vitality testing

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ABSTRACT

Current routine methods of assessment of pulp vitality rely on stimulation of nerve fibres and give no direct indication of blood flow within the pulp. Pulse oximeter is a proven, atraumatic method of measuring vascular status, by evaluating oxygen saturation. This study explores the use of customized dental pulse oximeter sensor holder to assess pulpal vascular oxygen saturation in permanent teeth. Pulse oximeter readily differentiated between known vital and nonvital teeth. Vital teeth consistently provided oxygen saturation values that were lower than the values recorded on the patient's fingers. Pulse oximeter is an accurate, atraumatic clinical alternative to the present electrical and thermal methods of assessing pulp vitality in teeth.

Keywords: pulse oximeter, pulp vitality, sensor holder

INTRODUCTION

The assessment of pulp vitality is a crucial diagnostic procedure in the practice of endodontics. Conventionally, the dentist has relied on tests that depend on the patient's perceived response to a stimulus as well as the dentist's interpretation of that response. These methods include thermal stimulation (as in the case of heat or cold application), electric stimulation, or direct dentin stimulation (test cavity).

These tests fall short of the ideal pulp vitality testing on several criteria. Each of the methods described, tests only sensory nerve fibre response. Stimulation of nerve fibres is not the ideal method to determine vitality status. Several authors (1,2,3,4) have stated that vascular supply and not innervation is the most accurate determinant for assessing pulp vitality. As a result, teeth that have temporarily or permanently lost their sensory function (e.g. teeth damaged by trauma or teeth that have undergone orthognathic surgery) will be non responsive to these tests. However, they may have intact vasculatures (5,6). Moreover, the nervous tissue, being highly resistant to inflammation, may remain reactive long after the surrounding tissues have degenerated. Therefore, thermal and electric tests may give false positive response if only the pulp vasculature is damaged (2). Further, all these tests have the potential to produce an unpleasant and occasionally painful sensation and inaccurate results may be obtained (3).

Recent attempts to develop a method for determination of pulpal circulation have involved the use of laser doppler flowmetry, dual wavelength spectrophotometry, and pulse oximetry. Although laser doppler flowmeter has met with some success in medical applications, its use in dentistry has been hampered by the sizeable expense, lack of reproducibility, and sensitivity of the device to motion. Dual wavelength spectrophotometry has been examined only in the laboratory setting so far and only detects quantitatively the presence of haemoglobin and not the circulation of blood (7).

Pulse oximeter is a non-invasive oxygen saturation monitoring device widely used in medical practice for recording blood oxygen saturation levels during the administration of intravenous anaesthesia through the use of finger, foot, or ear probes. It was invented by Takuo Aoyagi, a biomedical engineer working for the Shimadzu Corporation in Kyoto, Japan, in early 1970's (8). Pulse oximeter uses red and infrared wavelengths to transilluminate a tissue bed, detecting absorbance peaks due to pulsatile blood circulation, and uses this information to calculate oxygen saturation and pulse rate (3). It is the most commonly employed technique to measure oxygen saturation because of its ease and economy.

Different researchers have arrived at different conclusions regarding the efficacy of using pulse oximetry to diagnose pulp vitality. Schnettler and Wallace (9) reported a correlation between pulp and systemic oxygen saturation readings using a modified ear pulse oximeter probe on a tooth. Thus, they recommended its use as a definitive pulp vitality tester. Kahan et al (10) designed, built, and

Fig 1: Placement of customized sensor holder with sensor on patient's teeth.

tested a reflectance tooth probe using Biox 3740 oximeter. Pulse wave readings from the teeth were found to be synchronous with the finger probe but not consistently. They concluded that the accuracy of the commercial instrument was disappointing and in its present form, it was not considered to have predictable diagnostic value.

The critical requirement of using pulse oximeter in dentistry is that

- The sensors should confirm to the size, shape and anatomical contours of teeth.
- The light emitting diode sensor and the photoreceptor should be parallel to each other so that all the light emitted by light emitting diode sensor is received by phototoreceptor sensor.
- The pulse oximeter probe should be held firmly on to the tooth to ensure accurate measurements.

Taking into consideration, the above requirements, the aim of our study was

- To design and built a customized pulse oximeter dental sensor holder and evaluate its efficacy in determining the vitality of permanent teeth.
- To determine the values of oxygen saturation in normal, permanent maxillary incisors, and canines using pulse oximeter.
- To evaluate the relationship between tooth pulse oximeter readings and systemic oxygen saturation measured on the index finger.

MATERIALS AND METHODS

The sample population consisted of one hundred patients aged 15 to 40 years with normal maxillary central incisors, lateral incisors and canines. Sample criteria required the teeth to be free of caries, fracture or discolouration, with healthy periodontal status, no radiographic periapical changes, and complete formation of root apex. The patient's dental history had to be negative for any history of trauma to face, mouth, or teeth.

As a control population to confirm the pulse oximeter's evaluation of pulp vascularity, thirty nonvital primary teeth with complete endodontic fillings were tested. Pulse oximeter readings from the patient's fingers served as the control sample for comparison of pulp oxygen saturation values with the patient's systemic oxygen saturation values.

Table 1
Oxygen saturation values for maxillary anterior teeth and their correlation with finger

	Mean	Standard deviation	Correlation with finger
Maxillary central incisor	79.31	3.07	0.15
Maxillary lateral incisor	79.61	2.73	0.22
Maxillary canine	79.85	2.09	0.13
Index finger	97.58	0.57	

A Nellcor OxiMax™ Dura Y D-YS multisite oxygen sensor was used to record oxygen saturation values on teeth. It was held on the tooth using a customized sensor holder.The same sensor with sensor holder used on tooth was used to measure finger oxygen saturation values. Testing equipment consisted of the Nellcor OxiMax N-550 pulse oximeter (Tyco Healthcare Group LP, U.S.A).

Procedure

The patient's oxygen saturation values was first measured on the index finger using a finger probe. The patient's central incisors, lateral incisors and canines were then evaluated by placing the customized sensor holder with the sensor onto the tooth as shown in figure 1. The customized sensor holder allowed the light emitting diode sensor and the photoreceptor to be parallel to each other so that all the light emitted by light emitting diode sensor is received by phototoreceptor sensor. The values were recorded after 30 seconds of monitoring each tooth. Oxygen saturation results were recorded and analysed using the Pearson correlation analysis to evaluate the relationship between the finger and tooth pulse oximeter readings (Table 1).

RESULTS

The thirty non-vital teeth (control) recorded oxygen saturation values of 0%. The mean oxygen saturation value for maxillary central incisor was 79.31 (SD=3.07), for maxillary lateral incisors 79.61 (SD=2.73) and for maxillary canines 79.85 (SD=2.09). Their control values, measured on the patient's index fingers, averaged 97.58% (SD=0.57). Pearson's correlation analysis of each individual's finger and tooth oxygen saturation values showed a 0.15 correlation for maxillary central incisors, 0.22 for maxillary lateral incisors and 0.13 for maxillary canines.

DISCUSSION

This study confirmed the ability of the customized pulse oximeter dental probe to differentiate between vital and non-vital teeth. All vital teeth provided consistent oxygen saturation readings and all nonvital teeth recorded no oxygen saturation values. This shows that pulse oximeter is capable of detecting pulp vitality through enamel and dentin.

A Nellcor OxiMax™ Dura Y D-YS multisite oxygen sensor was selected for use on teeth as the length and breadth of this sensor approximated with that of the tooth. It measured 4mm in length and 5mm in breadth. For holding these sensors parallel to the tooth, the dental holder was fabricated in such a way that it provided a stable relationship between the sensor elements and the tooth, thus maintaining a constant path length for the light between the emitter and detector required for pulse oximeter to make accurate calculations. This sensor holder along with the sensors is customized to be used on all teeth except lower anteriors due to their small size.

The mean oxygen saturation value for maxillary central incisor was 79.31 (SD=3.07), for maxillary lateral incisors 79.61 (SD=2.73) and for maxillary canines 79.85 (SD=2.09). These values correlate with the oxygen saturation values reported by Munshi AK and Hedge AM (2) where the mean oxygen saturation values for permanent central incisors was 81%, permanent right lateral incisors was 80.52%, permanent left lateral incisors was 80.75%, and for index fingers used as control was 98.2%.

The lower oxygen saturation values for teeth compared to fingers can be attributed to several causes. Diffraction of the infrared light by the enamel prisms and dentin may cause decrease in oxygen saturation values. Fien et al suggested that the lower oxygen saturation values for the pulpal circulation may be attributed to light scatter through the gingiva (2).

Since reproducible oxygen saturation values are obtained using pulse oximeter, it has immediate clinical value by providing baseline clinical data for truamatised teeth. Further readings can then be compared to the baseline oxygen saturation values to determine any trends towards nonvitality. Further research, using a longitudinal study of pulse oximeter evaluation of traumatized teeth is indicated.

CONCLUSION

Consistent pulse oximeter readings in this study confirm that pulpal circulation and blood oxygen saturation can be detected by the customized dental pulse oximeter probe. This study shows that pulse oximetry is an effective, objective method of evaluating dental pulp vitality. In view of the limitations of the conventional pulp testing methods, pulse oximetry offers a more reliable and better evaluation of the changing patterns of circulation if any following trauma or other insults to the tooth.

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