Pulse oximetry: a diagnostic instrument in pulpal vitality testing

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One hundred children with normal maxillary central and lateral incisors were subjected to vitality tests each by electrical and pulse oximetry. As a control population to confirm the readings, 10 known non-vital anterior teeth with complete endodontic fillings were tested. The systemic oxygen saturation values measured on the index finger of the patient served as the control for the comparison of the oxygen saturation values measure on the teeth. The SaO_2 values obtained on the teeth were correlated with the electrical test readings. The correlation between the SaO_2 readings and electrical testing readings were found to be negative i.e. as the values of the electrical pulp testing reading increased, the SaO_2 values decreased. Since a reproducible SaO_2 level is obtainable on the vital teeth, pulse oximetry has immediate clinical value in providing base line vitality data for the traumatised teeth.
J Clin Pediatr Dent 26(2): 141-145, 2002

INTRODUCTION

The assessment of pulp vitality is a crucial diagnostic procedure in the practice of dentistry[1] and for treating traumatised teeth.[2] Assessment of the tooth vitality is complicated by the fact that the dental pulp is enclosed within calcified tissues, and do so indirectly.[3] Traditionally, the dentists have relied on testing methods designed to reproduce symptoms associated with pulpal pathosis.[4]

The methods include thermal stimulation (as in the case of heat or cold application); electrical stimulation, anaesthetic testing or direct dentine stimulation (test cavity).[1] However, these testing methods have limitations in providing accurate diagnosis,[4] and all these methods are difficult to administer or inconclusive when used in children.[2] These tests are subjective tests that depend upon perceived response of the patient to a stimulus, as well as the interpretation of that response by the dentist.[5] Children cannot always describe subjective symptoms or sensitivity to a stimulus. False positive and false negatives, occur if the dentist asks the child a leading question.[6] Furthermore, these testing methods are perceived as unpleasant stimuli, which may result in behavior management / co-operation problems with the paediatric patients.[2] As children adapt behavior to avoid a painful stimulus, the ability to properly respond to pulp testing is limited.[7,8]

Another problem with the present pulp testing methods is that they only indirectly monitor pulp vitality by measuring the neural responses and not circulation. Since pulp vitality is purely a function of the vasculature health, a vital pulp with an intact vasculature may test non-vital if only the neural component is injured. This situation is commonly encountered with recently traumatised teeth.[9] On the other hand, the pulp nerve fibres are more resistant to necrosis than the vascular tissue,[10] and thermal or electric testing of only the pulp neural response may also result in false positive results if only the pulp vasculature is damaged.

For the electric and thermal testing to be effective, the pulp must have a sufficient number of mature neurons. However, both the primary and young permanent teeth are not fully innervated with alpha myelinated axons, the neural components, which are responsible for the pulpal pain response.[11] The permanent teeth may not exhibit full alpha myelinated axon innervation until 4 to 5 years after eruption.[12] This reduced number of pain receptors makes them less responsive to stimuli[13] and, therefore, more susceptible to take negative results from thermal and electrical testing. Considering all these limitations, present pulp testing with thermal and electric methods cannot be considered reliable vitality tests for the paediatric patients.

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Figure 1.

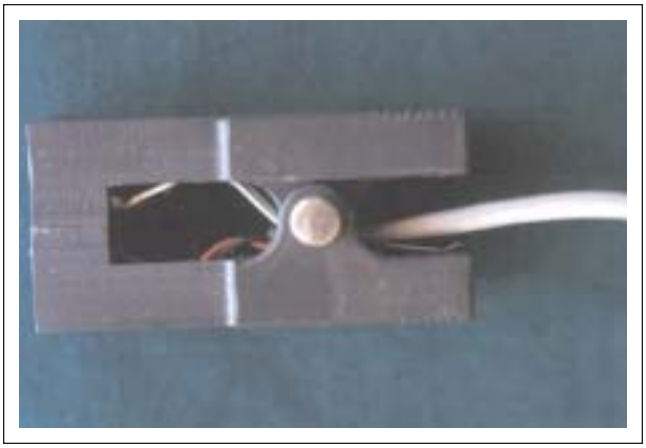

Figure 2.

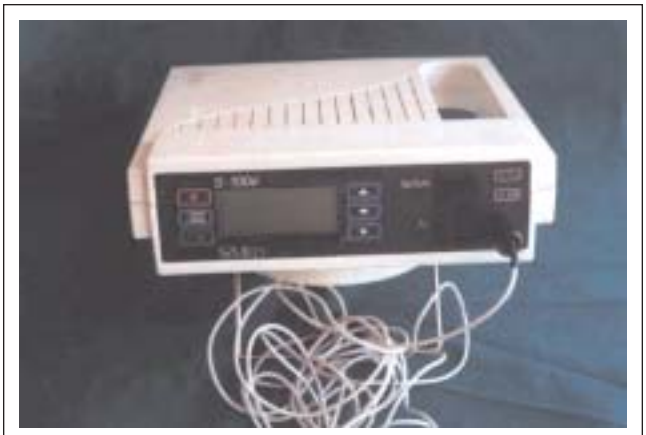

Figure 3.

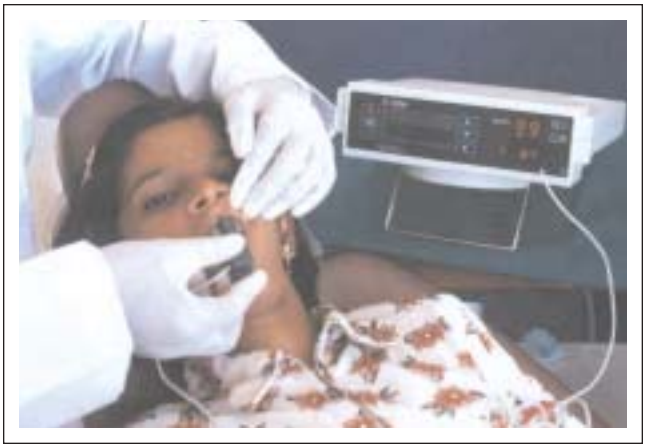

Figure 4.

So, a direct measure of the pulpal circulation is the only real measure of pulp vitality. Pulse oximetry is a completely objective test, requiring no subjective response from the patient that directly measures the blood oxygen saturation levels.

The present study was therefore done to compare the clinical effectiveness of the pulse oximeter over the conventional technique (electrical testing) of tooth vitality testing.

MATERIALS AND METHODS

One hundred children with normal maxillary central and lateral incisors were subjected to vitality tests each by electrical and pulse oximetry. These children were selected from various schools. Selection criteria required the teeth to be free of caries, restorations, developmental defects and mobility.

As a control population to confirm the readings, 10 known non-vital anterior teeth with complete endodontic fillings were tested. The systemic oxygen saturation values measured on the index finger of the patient served as the control for the comparison of the oxygen saturation values measure on the teeth.

Simed 100e was the pulse oximeter instrument used (Photograph 1). The tip of the oximeter sensor usually available in the market cannot be used intraorally. So a special probe was designed, which could be used intraorally, taking into consideration the morphology of the maxillary incisors. (Photographs 2 and 3).

The readings obtained from the pulse oximeter were correlated to vitality using a conventional electrical pulp vitality tester (Parkell Pulp Vitality Tester).

Procedure

The oxygen saturation (SaO_2) values were first measured on the index finger.

Teeth were isolated using cotton and air dried. The SaO_2 of the teeth was recorded by placing the newly developed oximeter probe on the tooth. The probe was placed on the crown so that the light would travel from the facial to the lingual through the middle of the crown (Photograph 4). The values were recorded after 30 seconds of monitoring each tooth.

Using the electric pulp tester, the vitality of the same tooth were also recorded.

The procedures were repeated twice and the readings were tabulated and statistically analysed.

Pulse oximetry

Oximetry refers to the determination of the percentage of oxygen saturation of the circulating arterial blood.[15]

Pulse oximetry is a relatively recent advancement in non-invasive monitoring of oxygen saturation of the blood and pulse rate of the patients under intensive care or during sedation procedures.[16] No other electronic monitoring device has found widespread use in the operating room more quickly than has the pulse oximeter.[17]

Matthes is often considered the father of oximetry. Between 1934 and 1944 he published a series of articles investigating oxygen transport to tissue by light transmission techniques.[18]

Work on oximetry was accelerated during World War II because of the needs of the aviation industry. Glen Millikan and colleagues from U. S. of America in 1942 developed a small ear oximeter for use in aviation research. It was Millikan who coined the term pulseoximetry.[17]

The newer devices used light emitting diodes in the finger or ear sensor to produce the red and infrared light were introduced in 1980's. This innovation allowed for the production of lightweight inexpensive sensors that were even disposable. The monitors themselves were also lightweight and relatively inexpensive. Only since 1985 have the pulse oximeters become a common place in the operating rooms and intensive care unit.[17]

The probe sensor consists of two Light Emitting Diodes (LED), one to transmit red light (640 nm) and the other to transmit infra red light (960 nm) and a photodetector on the opposite side of the vascular bed. The probe transmits red infrared light through a vascular bed such as finger or ear. Oxygenated haemoglobin and deoxygenated haemoglobin absorb different amount of red infra red light. Well-oxygenated blood appears bright red than poorly oxygenated. The pulsate change in the blood volume causes periodic changes in the amount of red infra red light absorbed by the vascular bed before reaching the photodetector. The relationship between the pulsate change in the absorption of red and the pulsate change in the absorption of infra red light is analysed to determine the saturation of the arterial blood.[19]

OBSERVATIONS

The 10 known non-vital teeth (control) with complete endodontic fillings recorded SaO_2 values of 0% and showed no response to electrical testing procedures.

The means SaO_2 value measured on the finger of the patient as a control was 98.2% (S.D. = ± 0.6963).

The SaO_2 values on permanent right central incisors averaged 81% (S. D. = ± 1.6817) and the permanent left central incisors averaged 81% (S. D. = ± 1.3366) respectively (Table I).

Table I .

Tooth		Mean	Std Deviation(±)
11	EPT*	4.4600	0.7775
	O_2RFING**	98.2000	0.6963
	O_2RTOOT***	81.0000	1.6817
12	EPT	4.3600	0.5777
	O_2RTOOT	80.5200	1.3064
21	EPT	4.4800	0.7693
	O_2RTOOT	81.000	1.3366
22	EPT	4.3125	0.7228
	O_2RTOOT	80.7500	1.9947

* - Electric Pulp tester reading
** - Oxygen saturation in the finger
*** - Oxygen saturation in the tooth

Table II.

Tooth	Pearson's Correlations			
11		EPT	r = -0.479	Very highly significant (P < 0.001)
	(2-tailed)	EPT	P = 0.00	
12		EPT	r = -0.163	Significant (P < 0.05)
	(2-tailed)	EPT	P = 0.049	
21		EPT	r = 0.359	Very highly significant (P < 0.001)
	(2-tailed)	EPT	P = 0.000	
22		EPT	r = 0.223	Significant (P< 0.05)
	(2-tailed)	EPT	P = 0.029	

The mean SaO_2 values on the permanent right lateral incisors was 80.52% (S. D. = ± 1.3064) and on the permanent left lateral incisors was 80.75% (S. D. = ± 1.9947) (Table I).

The SaO_2 values obtained on the teeth were correlated with the electrical test readings. The correlation between the SaO_2 readings and electrical testing readings were found to be negative i.e. as the values of the electrical pulp testing reading increased, the SaO_2 values decreased (Table II).

The correlation of the readings on the central incisors were highly significant and those of the lateral incisors were significant (Table II).

DISCUSSION

Pulse oximeter estimates the arterial haemoglobin saturation by measuring the light absorbance of pulsate vascular tissue at two wavelengths. The relationship between the measured light absorbances and saturation was developed empirically and is built into oximeter software. Studies in human volunteers have shown good performance of the device in healthy adults for saturation in the range of 70 to 100%. Studies in the operating room and intensive care units have established its clinical accuracy and usefulness.[17]

Recently, studies had shown the effectiveness and accuracy of laser Doppler flowmetry in determining the blood flow in the pulp, but could not find practical application due to its high cost and uncontrolled movement of the probe.[16] Other studies[1,2,16] have shown the effectiveness of pulse oximetry in determining the SaO_2 of the blood in dental pulp. Of these, one by Noblett 1996 was an *in vitro* study. However, the present one is also one such *in vivo* study.

The SaO_2 readings obtained in the teeth were lower than the SaO_2 values recorded on the fingers of the patients. These lower values may be attributed to diffraction of the infrared light by the enamel prisms and dentine.[20] Fien *et al*.[21] in 1977 suggested that the lower SaO_2 values for the pulpal circulation may be attributed to light ray scatter through the gingiva.

The SaO_2 values recorded were lower in the present study as compared to those observed during the earlier ones,[2,16] this could be attributed to the probe design. In all the previous studies, the commercially available pulse oximeter ear probes were modified and used.

CONCLUSION

Since a reproducible SaO_2 level is obtainable on the vital teeth, pulse oximetry has immediate clinical value in providing base line vitality data for the traumatised teeth.

In view of the limitations of the conventional pulp testing methods, pulseoximetry offers a more reliable and better evaluation of the changing patterns of the circulation of the pulp if any following trauma or another insults to the teeth.

The study shows that pulse oximetry is an effective, objective method of evaluating dental pulp vitality especially in pediatric patients where patient co-operation and incomplete pulp innervation reduces the effectiveness and reliability of electric pulp testing methods.

ACKNOWLEDGMENTS

The author wish to thank Mr. Koruthu P. Varughese, Biomedical Engineer, Sree Chitra Thirunal Institute of Medical Sciences and Technology, Thiruvananthapuram, for assisting in the developing of the modified sensor for the teeth.

REFERENCES

1. Noblett WC, Wilcox, LR et al. Detection of pulpal circulation in vitro by pulse oximetry. J Endo 22: 1996.
2. Goho C. Pulse oximetry evaluation of vitality in primary and immature permanent teeth. Pediatr Dent 21: 125-127, 1999.
3. Rowe AHR, Piff Ford TR. The assessment of pulp vitality. Int Endod J 23: 77-83, 1990.
4. Peters D, Baumgartner J, Lorton L. Adult pulpal diagnosis. Evaluation of the positive and negative responses of cold and electric pulp tests. J Endo 20: 506-511, 1994.
5. Ehrmann EH. Pulp testers and pulp testing with particular reference to the use of dry ice. Austral Dent J 22: 272-9, 1977.
6. Cash R. Bruxism in children. J Pedodont 10: 105-126, 1986.
7. Mc Donald I, Avery D. Dentistry for child and adolescent. 5th edition, Phila, CV Mosby, p. 516-517, 1987.
8. Kennedy D, Kiely M, Keating P. Efficacy of pulp testing. J Irish Dent Assoc 33: 41-46, 1987.
9. Gazellus B, Olgat L, Edwell B. Restored vitality in luxated teeth assessed by laser Doppler flowmeter. Endod Dent Traumatol 4: 265-268, 1988.
10. Fun Z, Trowbridge H, Bender I. Assessment of reliability of electrical and thermal pulp testing agents. J Endo 12: 301- 305, 1986.
11. Johnson D, Hurschbarger J, Rymer H. Quantitative assessment of neural development in human premolars. Anst Rec 205: 421-429, 1983.
12. Fearnhead R. The histological demonstration of nerve fibres in human dentine. Sensory mechanism of dentine. Oxford, Pergunnon Press p. 15-29, 1968.
13. Klien H. Pulp response to an electric pulp stimulator in the developing permanent anterior dentition. J Dent Child 45: 199-202, 1978.
14. Fulling H, Anderson J. Influence of maturation status and tooth type of permanent teeth upon electrometric and thermal pulp testing. Scand J Dent Res 84: 286-290, 1976.
15. Khandpur RS. Oximeter: measurement and analysis techniques: test book of biomed engineering. Edition 5: 355-368, 1999.
16. Schnettler JM, Wallace JA. Pulse oximetry as a diagnostic test of pulpal vitality. J Endodont 17: 488-490, 1991.
17. Steven JB, Tempu KK. Pulse oximetry application and limitations. Int Anaesthesiol Clinic 25: 155-175, 1987.
18. Matthes K, Gross F. Zur methode der fortlaufenden Registrierung der Farbe des menschlichen Blutes. Arch Exp Pathol Pharmacol 191: 523-528, 1939.
19. Simed 100e Pulseoximeter – Operating Manual
20. Schmitt J, Webber R, Walker E. Optical determination of dental pulp vitality. Trans Biomed. Eng 4: 346-352, 1991.
21. Fien M, Gluskin A, Goon W. Evaluation of optical methods of detecting pulp vitality. J Biomed Optics 2: 58-73, 1997.