

Oxygen Saturation in the Dental Pulp of Maxillary and Mandibular Molars - Part 2

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This study determined the oxygen saturation (SaO₂) in dental pulp of healthy maxillary and mandibular molars. Mean of SaO₂ was evaluated in 112 maxillary and mandibular molars using pulse oximetry. Quantitative variables were described by mean and standard deviation. Variables with symmetric distribution were compared by Student t test and Mann-Whitney test. Pearson's correlation coefficient was used to correlate quantitative variables. Analysis of variance was used to assess differences in SaO₂ levels between the molar groups, followed by post-hoc Tukey. The significance level established at p<0.05. Mean of oxygen saturation for the 112 molar dental pulps was 85.09%. There was no significant correlation (r=-0.007; p=0.977) between the mean of SaO₂ of molar pulps with patient's indicator finger (92.89%). There was a significant difference (p=0.037) between the mean of SaO₂ of the first (85.76%) and second maxillary molars (81.87%), and it was not significant (p=0.1775) between the first and second mandibular molars. Maxillary molars had lower pulpal SaO₂ (83.59%) than mandibular molars (86.89%) (p=0.018). The mean of the patient's response time to the cold stimulus was 1.12 s (maxillary molars 1.25 s and mandibular molars 0.99 s) (p=0.052). There was no significant correlation between the time response of the patient to the cold stimulus and the SaO₂ for molars. The mean oxygen saturation level was 85.09%. The mandibular molars presented higher SaO₂ level than maxillary molars.

Introduction

The endodontic treatment plan depends of perfect institution of pulpal diagnosis. The information to determine the pulpal condition is obtained through anamnesis, associated with clinical features, imaging exams and vitality pulp test (1). The dental pulp cannot be directly inspected due to its location. The clinical investigation of dental pulp status normally is made by indirect methods, being thermal (heat and cold) and electric stimuli testing the most commons. The pulpal response to these tests has been considered to determine its actual status (1-3).

However, these tests only measure the pulp sensitivity, which is associated with vasoconstriction and stimulation of nerve pulp structures and not its vitality, because it does not provide information about the pulp blood flow (3-6). Therefore, these tests may have limited value when the objective is to evaluate the pulpal condition. False-negative or false-positive results may be found in immature teeth (6-9). Teeth that have experience of traumatic dental injury may lose their sensitivity to transient or permanently. In these cases, the tooth may appear non-responsive to sensory tests, but may have their vascularity preserved (7).

The subjectivity of the pulp sensibility test constitutes a disadvantage, because depend on the patient perception and the dentist interpretation. These methods have also the potential to produce unpleasant sensations and, occasionally, painful to the patient (3-7). Thus, efforts has been made to develop methods that provide measurable

values of dental pulp blood flow, as spectrophotometry, laser doppler flowmetry and pulse oximetry (7-13).

The pulse oximeter has been studied and used as a tool for the diagnosis of pulp condition, because in a healthy pulp is expected a large percentage of oxygen, essential to maintain the vitality of dental pulp and their metabolic needs (3-13). Pulse oximeters measure arterial oxygen saturation (SaO₂) in the dental pulp through a probe containing two diodes that emit light in two wavelengths (red spectrum, approximately 660 nm; infrared spectrum, approximately 940 nm). These emissions are captured by a photodiode receptor and converted by electronic circuits into SaO₂ and pulse rates (3,4,14-16). The oxygenated hemoglobin (oxyhemoglobin, HbO₂) present in the arterial blood and the deoxygenated hemoglobin (Hb) circulating in the venous blood absorb different amounts of red and infrared light. Oxyhemoglobin absorbs more infrared light than deoxyhemoglobin (15,16).

Various studies to determine the mean of oxygen saturation in healthy dental pulps have been developed in different clinical circumstances (3-5,11-13,17-23). Oxygen saturation for maxillary central incisors varies from 79.31% (19) to 94% (8); maxillary lateral incisors from 78.51% (23) to 87.47% (12); canine from 79.85% (19) to 91% (20); premolars 86.2% (22); and premolars and molars that were determined as an only group, the mean was 92.2% (21).

The knowledge of the oxygen saturation in normal dental pulp is essential for scientific advance about clinical

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Key Words: oxygen saturation, pulp vitality, sensibility test, dental pulp, diagnosis.

decision making process. New information's about oxygen saturation is require particularly involving the efficiency of pulse oximetry. It will enable the establishment of a pattern that can to evaluate and differentiate the healthy pulp tissue from inflamed pulp tissue and necrosis, and to contribute to accurate diagnosis and determination of a treatment suited for the clinical condition of the tooth. Considering the lack of information involving the pulpal compartment in healthy condition of posterior teeth, this study determined the oxygen saturation level in normal pulps of maxillary and mandibular molars using pulse oximetry.

Material and Methods

Patient Selection

This study included 112 normal molars of 22 patients (11 men and 11 women; range 17-40 years old), selected through convenience sampling, treated at the endodontic clinic of the School of Dentistry of the Federal University of Goiás (Goiânia, GO, Brazil). The clinical diagnostic of the molars was made by visual inspection, percussion and palpation tests, periodontal and mobility evaluation. The radiographic exam was done considering the global treatment of the patient, as part of a local attending protocol.

Inclusion criteria were: first and second intact molars (no caries, restorations, fractures or no dental wear); no obliteration and/or calculus in the pulp chamber; no pain; no signs of periodontal disease, absence of periodontal disease, absence of internal/external root obliteration or resorption; positive response to cold test. Smokers, patients with a history of systemic vascular or cardiovascular disease, occlusal or dental trauma, and patients using systemic medications were excluded. Sample size was calculated considering a confidence level, which resulted in a sample (n) of 112 molars.

This study was approved by institutional Research Ethics Committee. All the patients signed an informed consent form prior to the performance of any study procedures.

Cold Sensibility Test

The cold sensibility test by an endodontist using Green Endo-Ice spray (-26.2 °C, Hygienic Corp., Akron, OH, USA) was applied to the middle third of the buccal surface of the teeth using a cotton ball and tweezers. Teeth were isolated with cotton rolls and a saliva ejector. Then, after Green Endo-Ice spray application the patients were asked to rate the intensity of sensitive stimuli (pain) using a 0-10-point scale, where 0 = no pain and 10 = severe pain. Score 0 was defined as a negative response after 15 s of spray application. When this occurred, the test was repeated 2 minutes after the first one. At this moment, the patients were asked to rise their left hand when they felt pain on

the tooth tested. The time of response of the patient to the cold stimulus was registered with digital chronometer (Samsung S4 Mini Cell Phone).

Pulse Oximeter

The methodology used in this study was the same used previously (22). SaO₂ levels were determined using the BCI 3301 hand-held pediatric pulse oximetry monitoring system (Smiths Medical PM Inc., Waukesha, WI, USA), equipped with 3025 (for teeth) and 3026 (for fingers) sensors. Teeth were isolated with cotton rolls, a saliva ejector, and no dental reflector lamp. The probe was coupled to a device developed specifically for testing maxillary and mandibular molars, considering the necessity of placing the two diodes in parallel, so as to allow correct measuring of pulpal SaO₂. A stainless steel adapter was made specifically for this assay (Fig. 1). SaO₂ levels were measured twice, i.e., the first time 30 s after adapting the probe to the tooth, and the second time 30 s after the first reading; the mean of the two measurements was used as the final result. A third measure was taken by placing the probe on the patient's index finger, to determine SaO₂ levels in their blood. The SaO₂ level of 10 endodontically treated molars and restored with composite resin was evaluated as negative control. All vitality tests were performed by a same endodontist with more 10 years of experience, with previous training in 10% of the sample.

Statistical analysis

Quantitative variables were described by mean and standard deviation when the distribution was symmetric and median and interquartile range when asymmetric. Variables with symmetric distribution were compared between teeth for independent samples and intra-individual for paired samples by Student t test and the asymmetric distribution with the Mann-Whitney. Pearson's correlation coefficient was used to correlate quantitative variables each other. Analysis of variance was used to assess differences in SaO₂ levels between the molar groups, followed by post-hoc Tukey. Significance was set at 0.05.

Results

On the total of 112 molars, 61 were maxillary molars (27 first maxillary molars and 34 second maxillary molars) and 51 were mandibular molars (25 first mandibular molars and 26 second mandibular molars). The mean of SaO₂ for 112 healthy molars pulps was 85.09%. In the 10 endodontically treated molars and restored with composite resin presented 0% SaO₂.

The maxillary molars showed a mean of SaO₂ of 83.59%, and there was a significant difference (p=0.037) between the first (85.76%) and the second molars (81.87%) (Table

1). The mandibular molars had a mean SaO₂ level of 86.89%, and there was no significant difference (p=0.177) between the first (85.58%) and the second mandibular molars (88.15%) (Table 1). The difference in the mean of SaO₂ between maxillary molars (83.59%) and mandibular molars (86.89%) was statistically significant (p=0.018), with a higher mean for the mandibular molars (Fig. 2).

The mean of SaO₂ for the index finger was 92.89%. There was no significant correlation (r=-0.007; p=0.977) between the measurements of SaO₂ for molars (85.09%) and index finger of the patient (92.89%). The median response time of the patient to the cold stimulus was 1.12 s. The maxillary molars had a mean of response time to the cold stimulus of

1.25 s (Table 2), without a significant difference (p=0.052) between the first (0.93 s) and the second maxillary molars (1.40 s) (Table 2). However, the result is on the significance threshold, showing that the second maxillary molars have a higher median.

The mandibular molars had a mean of response time to the cold stimulus of 0.99 s (Table 2). When compared the time response of the patient to the cold stimulus between the first (1.22 s) and the second mandibular molars (0.94 s), there was no significance difference (p=0.158) (Table 2). There was no significant correlation between the time response of the patient to the cold stimulus and the mean SaO₂ for molars (Fig. 3).

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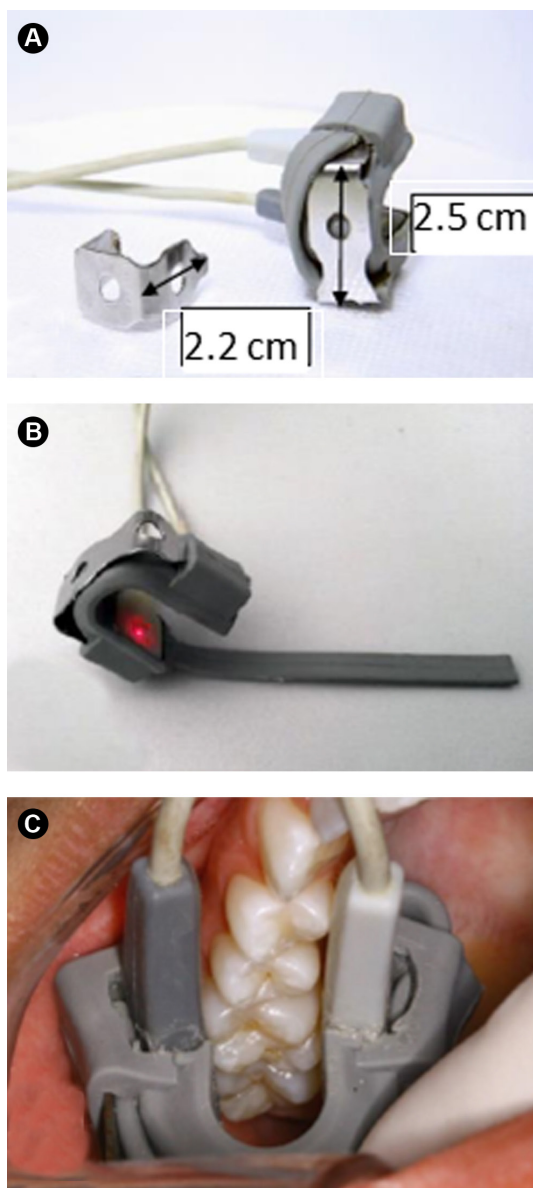


Figure 1. (A-C) Stainless steel probe prepared to adapt the pulse oximeter to molars.

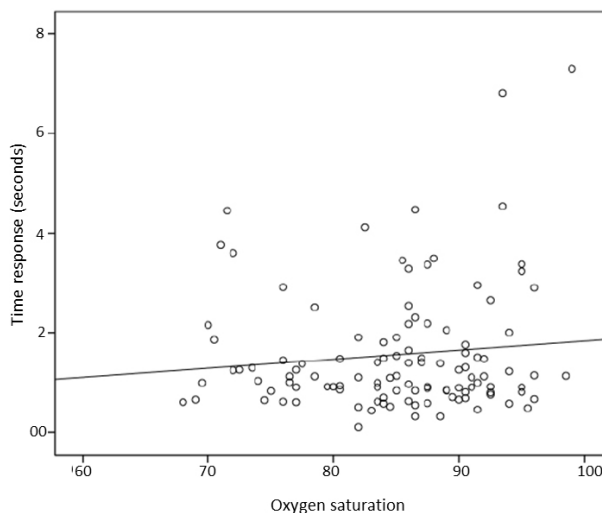


Figure 3. Dispersing points between the oxygen saturation level (%) of sound molars and the time response (s) of the patient to the cold stimulus.

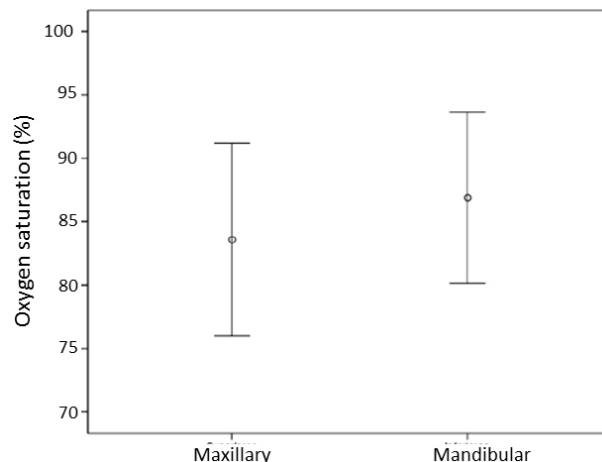


Figure 2. Graphic presentation of the comparison between averages of oxygen saturation levels (%) of maxillary and mandibular molars.

Discussion

Maxillary and mandibular healthy molars pulps presented a mean of SaO₂ of 85.09%. Maxillary molars showed 83.59%, with significant difference between the first (85.76%) and second (81.87%). In mandibular was detected the mean of SaO₂ of 86.89%, with no significant difference between the first (85.58%) and seconds (88.15%). There was found a significant difference between maxillary molars (83.59%) and inferior (86.89%). Setzer et al. (21) found a mean of SaOv of 92.2% in molars and premolars with healthy pulps. The difference between these results can be attributed to the different sets of teeth and to the sample size.

Although, in our study was used adapter of sensors fabricated specifically for these teeth, the appliances used in other studies were not the same. One of the critical factors in the pulse oximeter is associated with the finger sensor format. Studies have emphasized the importance of their adaptation for use in tooth, because of the risk of light beam distortion, due to lack of accommodation of the

same in the tooth structure. There are no specific sensors in the market for different groups of teeth (8,10,20,21,23). Thus, to promote parallelism between the LEDs and the photodetector, in the present study was made a locking device for the sensor, according to the dimensions of the clinical crown of the molar, in order to obtain reliable analysis. Furthermore, the locking device prevents that there is the sensor motion on the tooth surface, contributing to accurate results, since it is necessary that both the sensor and the patient to remain immobile during the use of the oximeter (4,8).

The differences in oxygen saturation values of the dental groups can be attributed to anatomical diversity. Each has its peculiarities, both in relation to the structure and thickness of enamel and dentin, as the shape and size of the pulp cavity. Besides these characteristics are similar within the same group, the teeth are not identical (24). The reading of the pulp oxygen saturation can be influenced by diffraction of infrared light by the enamel prisms and dentine surrounding pulp tissue (4,7,17).

Regarding the mineralized tissue surrounding the dental pulp, Stambaugh et al. (24) measured the buccolingual distance of maxillary and mandibular healthy permanent extracted teeth. In a group of 27 molars, the buccolingual distance was 10.74 mm for the first and 11.35 mm for the second molar. Regarding the mandibular, this value was 9.9 mm for the first and 10.08 mm for the second molars. These results showed that, in spite of variations, there were no significant differences. The size of the pulp cavity is also among the anatomical factors that can influence the average level of oxygen saturation. Chandler et al. (25) evaluated coronal pulp size in bitewing radiographs of 225 maxillary and 220 mandibular first molars, healthy and restored, in individuals with aged between 18 and 25 years. The results showed that the mean values of pulp area of the first maxillary molar were 7.5 mm² and 8.67 mm² for the mandibular first molar.

Gradual reductions in oxygen saturation in normal maxillary premolars have been verified with increasing age (22). The 40-44-year age group differed statistically from the 20-24, 25-29, and 30-34-year groups, but showed similar results to the 35-39-year group. The was verified reduction significant in the 40-44-year age group, suggesting that older patients present lower oxygen saturation results even in the absence of pulp tissue injury (22). In anatomical analysis of the coronary chamber volume of molars, the age of patients, the sample size and the image

Table 1. Oxygen saturation level (%) between first and second maxillary and mandibular molars

Teeth	Minimum	Maximum	Mean	Standard deviation	p*
Maxillary first molars	76.0	95.0	85.76	5.63	0.037
Maxillary second molars	69.5	99.0	81.87	8.53	
Mandibular first molars	68.0	98.5	85.58	7.80	0.177
Mandibular second molars	74.5	96.0	88.15	5.45	

Student's t-test for independents samples.

Table 2. Time response (s) of patient to the cold stimulus in maxillary and mandibular molars

Teeth	Medium	Percentil 25	Percentil 75	p*
Maxillary	1.25	0.87	2.03	0.104
Mandibular	0.99	0.64	1.80	
Maxillary first molars	0.93	0.80	1.50	0.052
Maxillary second molars	1.40	0.97	2.34	
Mandibular first molars	1.22	0.64	2.48	0.158
Mandibular second molars	0.94	0.63	1.35	

Mann-Whitney test.

model (radiographic or cone beam computed tomography) constitute factors that may explain the differences between the results of the studies.

The oxygen saturation in healthy and inflamed pulp was evaluated by Setzer et al. (21), who found that oxygen saturation values were decreasing for molars and premolars when healthy (92.2%), with reversible pulpitis (87.4%), irreversible pulpitis (83.1%) and pulp necrosis (74.6%). Karayilmaz and Kirzioglu (12) compared the reliability of laser Doppler flowmetry, pulse oximetry and electric pulp tester on pulpal status of 59 pairs of maxillary anterior teeth in 51 patients with range 12-18 years. Laser Doppler flowmetry showed be effective method compared to pulse oximetry and electric pulp tester to assess the pulpal status of human teeth. Dastmalchi et al. (10) verified that the sensitivity of pulse oximetry, a rubber cup, electric test, and cold spray was 0.93, 0.60, 0.60, and 0.53, respectively. The specificity of these tests was 1.00, 0.55, 0.22 and 0.66, respectively. They concluded that the pulse oximetry is a reliable method in determining the pulp status in endodontics.

There are some systemic (i.e., vascular diseases) and local factors (i.e., changes in the volume of the coronary chamber, restored teeth) related to the patient and to the tooth that can interfere with the readings of oxygen saturation level by pulse oximetry. It has been reported that this technique is not precise in teeth with indirect restorations (3,8,23), with reduced volume of the pulp chamber by physiological changes due to aging and patients with periodontal disorders (9,13).

Thermal tests are used as an indirect method to evaluate the pulp condition. Cold refrigerant gas is the method most used because of the convenience and ease of application. Despite the subjectivity, they are useful in identifying the dental changes when the patient's complaint is widespread pain, relieved or aggravated by thermal agents. In the present study, the mean patient's response time to the cold stimulus was 1.12 s. For the maxillary molars, the time was 1.25 s, without a significant difference between the first (0.93 s) and the second molars (1.40 s), and the latter had a higher median. The mandibular molars showed an average response time to the cold stimulus of 0.99 s, with no significant difference between the first (1.22 s) and the second molars (0.94 s). There was no statistically significant correlation between the patient's response time to the cold stimulus and the oxygen saturation level for molars. Regarding dental pulp sensory responses to cold testing, it is considered that the pulp tissue is healthy when there is no excessive painful response, which ceases few seconds after the stimulus is removed. The lack of response to the sensitivity test may be suggestive of pulp necrosis.

The use of pulp sensitivity tests to evaluate the pulp

condition, although subject to error, can provide valuable diagnostic information in the hands of an experienced clinician. Knowing the limitations of these methods associated with clinical application may contribute to the attainment of more accurate results in endodontic diagnosis (1).

The use of pulse oximetry has been shown to be an important and promising use in dentistry, with the advantages of being non-invasive, reproducible and painless, and good acceptance by patients. Its superiority over sensory tests has been proven by several studies (3,7,10), which has attracted the attention of the endodontic community about changes in the methods used for the diagnosis of the pulp condition. The sensibility and vitality tests seems to be a sensible options to verified clinically the pulpal tissue condition.

In summary, the mean of SaO₂ in normal molars pulps was 85.09%, with 83.59% of SaO₂ for the maxillary molars and 86.89% for mandibular molars. The mean of patient's response time to the cold stimulus was 1.12 s, with no difference between maxillary (1.25 s) and mandibular (0.99 s) molars. There was no correlation between the patient's response time to the cold stimulus and the SaO₂ level for healthy molars.

Resumo

Este estudo determinou o nível de saturação de oxigênio (SaO₂) em polpas dentais hígidas de molares. O nível de SaO₂ foi avaliado em 112 molares superiores e inferiores usando oxímetro de pulso. As variáveis quantitativas foram descritas pela média e desvio padrão. As variáveis com distribuição simétrica foram comparadas pelo teste t de Student e teste de Mann-Whitney. O coeficiente de correlação de Pearson foi utilizado para correlacionar variáveis quantitativas. A análise de variância foi utilizada para avaliar as diferenças nos níveis de SaO₂ entre os grupos de molares, seguido de Tukey pós-hoc. A significância foi estabelecida em 0,05. O nível médio de SaO₂ para as polpas de 112 molares foi de 85,09%, não havendo correlação com a média de SaO₂ do dedo indicador do paciente (92,89%). Houve diferença significativa entre o nível médio de SaO₂ dos primeiros molares superiores (85,76%) e os segundos molares superiores (81,87%) e não foi significativo entre os primeiros e os segundos molares inferiores. Os molares superiores apresentaram menor nível de SaO₂ (83,59%) do que os molares inferiores (86,89%). A média do tempo de resposta do paciente ao estímulo com frio foi de 1,12 s (molares superiores 1,25 segundos e molares inferiores 0,99 segundos). Não houve correlação significativa entre o tempo de resposta do paciente ao estímulo com frio e o nível de saturação de oxigênio para os molares. Em resumo, o nível médio de saturação de oxigênio foi de 85,09%. Os molares inferiores apresentaram maior nível de SaO₂ do que os molares superiores

Acknowledgements

The authors have no conflicts of interest to declare concerning publication of this manuscript. This study was supported in part by grants from the National Council for Scientific and Technological Development (CNPq #306394/2011-1 to C.E.).

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Received February 8, 2016

Accepted July 10, 2017