Development of a disposable (demi)-quantitative colorimetric sensor for the detection of hydrogen sulfide in human breath

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Investigation Monography

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Abbreviatures List

$Bi(HO)^3$ – Bismuth Hydroxide

Bi_2S_3 – Bismuth Sulfide

H_2O – Water

H_2S – Hydrogen Sulfide

NaOH – Sodium Hydroxide

Ppb – part per billion

PSM – Portable Sulfide Monitor

SIM – Sulfide Indole Motility

VOC – Volatile Odorific Compound

VSC – Volatile Sulfur Coumpound

Abstract

Introduction: Halitosis is a condition with more than 50% prevalence. The methods and devices used nowadays are the organoleptic method and the Halimeter (Interscan Corp., Chatsworth, CA, USA), being the last one, one of the most used and sensible devices for measuring volatile odorific compounds, that in the majority of the cases are volatile sulfur compounds, as hydrogen sulfide. This study intends to propose, develop and test a new type of colorimetric disposable sensor with and easy and quick protocol.

Materials and Methods: The sensor development has been done using *Salmonella spp.* inoculated media, inside of 10 tubes and 1 anaerobic jar, and posteriorly, 11 healthy adult volunteers were asked to participate. For the experiment both the sensor and the Halimeter (Interscan Corp., Chatsworth, CA, USA) were used and exposed to air containing hydrogen sulfide produced by the bacterium mentioned. The Halimeter (Interscan Corp., Chatsworth, CA, USA) was utilized as a real time portable sulfide monitor to measure the concentration of hydrogen sulfide on the exposition air.

Results: The results were expressed in colorimetric changes on the sensor and in *part per billion* for the Halimeter (Interscan Corp., Chatsworth, CA, USA). The sensor turned from white to yellow/brown and the values for the portable sulfide monitor were from 74 to 770 when the sensor reacted.

Discussion: The reaction of the sensor was effectively achieved and its application is possible. However, at this point, the tests performed were not enough to produce a functional method, for immediate usage. The volume, concentration of the gas and the sensor protocol and design needs more studies.

Conclusion: The sensor proved that it can be used on the diagnosis of halitosis by reacting with the human bad breath on the clinical trials. More studies and tests are need to have a totally functional sensor.

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1. Introduction

Halitosis or oral malodor is a condition with a prevalence higher than 50%, that varies due to differences in studies' framing and evaluation methods[1, 4]. This disorder has two main groups: delusional and genuine, being the last one divided in physiologic and pathologic halitosis. Pathologic halitosis designated by its origin as oral and extraoral which can be duo to the gastrointestinal, respiratory tracts, among others[1]. For the dentist professional the most important is the oral type, which has its causes in the oral cavity and studies indicate that 85% to 90% of the halitosis cases have this origin[6]. The major causes for this problem are related to bad oral hygiene, food impaction and periodontal diseases. Bacteria is the common leak agent for all of this concepts[6, 8], as it proliferates, consumes the substract deposed specifically on the dorsal surface of the tongue and periodontal pockets, liberating their metabolites to the mucosa, saliva and oral air[1, 5, 6].

The volatile odorific compounds (VOCs) expelled to the oral environment are sensed as an unpleasant odor that exhales from the oral cavity, and that can be scent by the individual that suffers from this condition, and by others, leading to alteration of social behavior[1, 7]. These gases are, mainly, volatile sulfur compounds (VSCs), as hydrogen sulfide and dimethyl sulfide, between others[1, 2, 3, 5].

The awareness-raising of this problem leaded to the necessity of its evaluation to determine whether the concentration of these gas species were indicatives of halitosis, as well as its origin, to prescribe the procedures to treat it. A lot of devices and techniques were created for this effect, being some of these the organoleptic method and the portable sulfide monitor (PSM), Halimeter (Interscan Corp., Chatsworth, CA, USA). The organoleptic method, a subjective measurable registry of the condition, relies on the physician's smell to score on a scale to 0 to 5 the scent coming from the patient's mouth (0 = undetectable; 5 = very malodourous). The portable sulfide monitor, which is the most used method nowadays, provides a numeric measurement on the display of the device in ppb. This method is obtained by an electrochemical reaction by oxidation of a metal component by the sulfide[1, 6].

An investigation for the development of a disposable colorimetric chemical sensor to measure the presence and concentration of hydrogen sulfide for some industries, where this gas can cause respiratory problems or worst, and the indication for the possible application of the technology used for the medicine area, were the propellant of this study[10, 11]. An investigation was

assembled to test the viability of the utilization of an alkaline bismuth hydroxide base sensor on the dentistry area for determine the level of hydrogen sulfide on the oral cavity as an easy and quick method. Therefore, the bismuth was utilized because of its non-toxic properties and because is already used at medical area. The studies indicate that the minimum reaction volume is 1,35L and >30ppb concentration of the hydrogen sulfide gas, this is possible because the sensor is used wet and it helps to trap the hydrogen sulfide present. The chemical reaction with the sulfide results on a chance of color of the sensor from white to yellow/brown[10].

The aim of this study was to synthesize a disposable colorimetric sensor capable of detecting the presence of hydrogen sulfide in a demi-quantitative way on human breath with a simplified protocol. Testing the hypothesis of reaction of this method on a pulmonary capacity volume and lower hydrogen sulfide concentrations.

Keywords: detection, colorimetric sensor, volatile sulfur compounds, hydrogen sulfide, halitosis, dental medicine

2. Materials and Methods

2.1. Bacteria and Culture Maintenance

The production of H_2S was obtained using *Salmonella spp.*, cultured on a Sulfide Indole Motility (SIM) medium (BD), incubated at 37°C, during 18 hours. These cultures were conceived in two distinct ways: 1) 10 tubes filled with, approximately, 6ml of the SIM medium were inoculated with *Salmonella spp.*. 1 tube not inoculated was used as a control (Figure 1); 2) 1 petri plaque, filled with the same medium and inoculated with *Salmonella spp., was* placed inside of an anaerobic jar, covered with film, to avoid major air escapes when opened, and the respective lid (Figure 1).

After 18h, both the tubes and the anaerobic jar were used to performed the experiments.

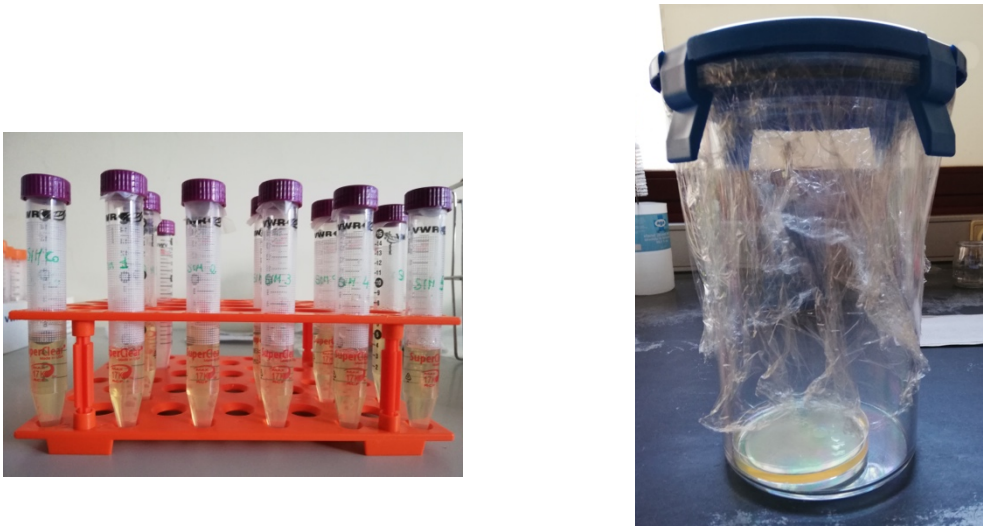

Figure 1 - Tubes and anaerobic jar with one petri plaque media filled inoculated with Salmonella spp.

2.2. Sensor production

In order to synthetize the sensor two solutions were needed and previously prepared and storaged at room temperature in glass recipients, until further usage. For the Bismuth Nitrate solution, 0,1g of Bismuth Nitrate Pentahydrate [$(Bi(NO_3)_3 \bullet 5H_2O)$, Textron-Limsa Pharma Alliance] was dissolved on 10,0ml of Acetone and mixed for 10 minutes until the formation of a suspension. Then the saturated supernatant was filtered and reserved[9]. The Sodium Hydroxide (NaOH) Solution of 0,1M was prepared from a 5M concentration NaOH solution.

To produce the sensor, 1cm by 1cm squares of filter paper were used. On each one of them, 100µl of the Nitrate Bismuth Solution were impregnated two times, leaving a 2 minutes interval between them, letting it dry at room temperature. After acetone evaporation, 80µl of 0,1 M NaOH Solution were added to the sensor right before its usage [10].

2.2.1. Reaction and Chemical species

The placement of the NaOH solution into the sensor results in a chemical reaction to produce $Bi(OH)_3$, which reacting with the H_2S in the air produces Bi_2S_3 (that is the colorimetric compound) and H_2O (Eq.1)[10].

$$Bi(HO)_3 + H_2S \rightarrow Bi_2S_3 + H_2O \qquad \textit{Eq. 1}$$

2.3. Laboratorial Validation

To test the reactivity of the sensor, the tubes and the anaerobic inoculum with *Salmonella spp.* were used.

The Halimeter (Interscan Corp., Chatsworth, CA, USA) was turned on 30 minutes before the measurements, for calibration. This device has a time display of 180 seconds between measurements[9].

For the tubes' test, the air was extracted, on 5 samples, utilizing a syringe where was, previously, placed, the sensor. The other 5 samples were measured using the PSM. In what concerns the anaerobic jar test, the sensor was placed inside of the jar and at the same time a perforation was made in the film to introduce the straw for the Halimeter (Interscan Corp., Chatsworth, CA, USA). Between samples, the sensor was removed from the jar with minimal air escape and closed with the respective lid to avoid more air leak, once we already had the peripheral leak zone of the film and the perforation for the Halimeter (Interscan Corp., Chatsworth, CA, USA) straw.

For the results validation, a sensor equally produced was left at normal air conditions.

The sensor, in contact with the gas, would change its color from white to a scale of yellow to brown/black, meaning, lower and higher concentrations[10].

2.4. Clinical Validation

In the second stage of the study, 11 healthy adult volunteers were assigned to test, using a morning bad breath model. They were asked not to eat or brush their teeth, as well not to use aromatic cosmetics or fragrances, from the previous night until the morning of the trials. The study was approved for the Ethical Committee of the Faculty of Dental Medicine of the University of Oporto. All the participants were informed about the study and an informed consent was obtained from them prior to study enrollment.

The tests were performed in two distinct days, 4 participants on the first day and 7 on the second day.

The participants were asked to keep their mouths closed for 2 minutes, only using nasal breathing, and blow the air at a balloon, where previously the prepared sensor was placed, and repeating this procedure 2 more times. Each participant had filled 3 balloons at total, leading to 3 sensors exposed to the breath. The color on the sensor was noted on a registration document. All the sensor trials performed had a control sensor on each test.

For comparison, the Halimeter (Interscan Corp., Chatsworth, CA, USA), was used, performing three subsequent measurements, with a time interval of 180 seconds between them, time which the participants had to keep their oral cavities closed, using nasal breathing. During the measurements, the participants were asked to place a disposable straw on the dorsal surface of the tongue with their mouth demi-opened[9].

3. Results

3.1. Laboratorial Trials

The tests performed on the anaerobic jar were all positive, except the control one. Five trials were made with diminished air escape due to the placement of the sensor inside of the jar. At the same time, both the sensor and the Halimeter (Interscan Corp., Chatsworth, CA, USA) were being used to analyze the content of the jar. The results ranged from 74ppbs to 770ppbs (Table I), measured by the PSM, and in each one of the tests the sensor turned from white to yellow, orange and brown, as the Figure 2 illustrates.

TRIAL	HALIMETER/PPB	SENSOR	SENSOR - COLOR
1ST	770	reacted	Brown
2ND	156	reacted	orange
3RD	131	reacted	orange
4TH	77	reacted	yellow
5TH	74	reacted	yellow
CONTROL	N/A	no reaction	White

Table I - Results of the sensors reaction and respective color/measurements with the PSM (Anaerobic jar tests)

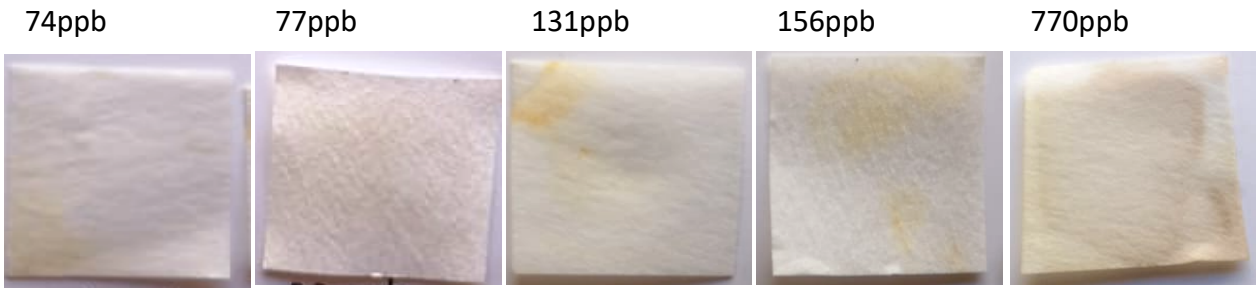

Figure 2 - Sensors exposed to the anaerobic jar air at several concentrations measured with the PSM in ppb

The tubes where the bacteria were seeded, a shift of color of the medium from orange to black indicated the presence of H_2S. Nonetheless, in all of the trials the sensors were white, not reacting. The 5 falcons measured with the Halimeter (Interscan Corp., Chatsworth, CA, USA) gave concentration from 37 to 86 ppb (Table II).

FALCON	HALIMETER/PPB	SENSOR
1	N/A	no reaction
2	N/A	no reaction
3	N/A	no reaction
4	N/A	no reaction
5	N/A	no reaction
6	37	N/A
7	53	N/A
8	86	N/A
9	62	N/A
10	58	N/A
CONTROL	N/A	N/A

Table II - Results on the sensors reaction and measurements with the PSM (tubes test)

3.2. Clinical Trials

The sensor reacted clearly with 4 of the participants, with a visible change of color from yellow to orange maximum, as it shows. For 2 of the participants the reaction of the sensor was not doubtless, so were considered whites. The other 5 participants the not reaction of the sensor was clear and the score was white (Table III).

The measurements performed with the Halimeter (Interscan Corp., Chatsworth, CA, USA) gave us a range from 20 to 190 ppb (Table IV).

The first day of trials the most sensors put at prove reacted to the breath inside of the balloons, but on the second day of trials the reaction didn't occur as predicted.

For both laboratorial and clinical trials the control sensor placed at the time of the study were negative or white, not reacting with the surrounding air.

CODE	TEST 1	TEST 2	TEST 3	DAY
001	White	Orange	Null	1
002	Yellow	Yellow	White	1
003	Orange	Yellow	White	1
004	White	White Damage	White Escape	1
005	White	White	White/Yellow	2
006	White	White	White	2
007	White	Yellow	White/Yellow	2
008	White	White	White	2
009	White	White	White	2
010	White	White/Yellow	White/Yellow	2
011	White	White	White	2
CONTROL	White	White	White	1/2

Table III - Results on the sensors reaction and respective color change on the clinical trials with the participants

CODE	TEST 1	TEST2	TEST 3	DAY
001	75	73	64	1
002	37	20	29	1
003	41	45	53	1
004	104	100	47	1
005	190	115	133	2
006	59	77	61	2
007	181	132	146	2
008	91	27	71	2
009	40	35	37	2
010	131	53	131	2
011	65	28	45	2

Table IV - Results on the PSM measurements on the clinical trials with the participants

4. Discussion

The application of a bismuth nitrate paper-based sensor on the halitosis is a new concept to improve the speed and facility of its diagnosis[10]. As already said, this type of device is not at this point used on the medical area. Therefore, this study is a pilot approach to develop this kind of sensor.

The usage of the sensor on the medical field as its limitations as discussed on the enrollment of this work, but its application on the dentistry area with the results obtained on this investigation are good indicators of the potential of it. The vision of using a paper like sensor that can be utilized, directly and easily, on a patient is a great perspective of the future of these devices.

The production of the sensor was obtained at a fraction of the costing price of the Halimeter (Interscan Corp., Chatsworth, CA, USA), as well as its maintenance. It's a non-plastic disposable material sensor, the decomposition of it is more ecological than the plastic straw used at the Halimeter (Interscan Corp., Chatsworth, CA, USA) protocol. The space that it takes to storage the device is also, once more, a minimal space compared to the Halimeter (Interscan Corp., Chatsworth, CA, USA).

The calibration needed when the Halimeter (Interscan Corp., Chatsworth, CA, USA) is turned on is avoid by using the sensor developed in this study. Being a quicker and easier way for a *sidechair* usage or a personal one. However, the protocol needs to be improved for medical application.

The original study stipulates that the minimum volume that is needed for the sensor to react is 1,35L and a concentration superior to 30ppb[10]. The two types of laboratory tests performed, the 5 tubes and the anaerobic jar, were made to confirm these values and to test if it was possible to diminish the volume of air, without compromising the reaction. As already referred, the volume of air needed for the reaction to occur is not, at this point, clear. Although the reaction occurred inside of some of the balloons, the volume was not measured. However, on the laboratory trials the volume of air below 100ml, which was the air inside of the syringe and the falcons, was not able to cause a reaction on the sensor, even though the concentrations of H2S, measured by the Halimeter (Interscan Corp., Chatsworth, CA, USA), appear to be enough to turn the sensor's color. Only on the anaerobic jar, we had the first positive sensor, being this method the best one used to test this parameter. This suggests that the volume of air is an important parameter, once the concentration of the gas measured with the Halimeter (Interscan Corp., Chatsworth, CA, USA) inside of the

anaerobic jar, for the last 2 measurements, had approximately the same concentration of H_2S that the tubes.

The minimal concentration of the gas to which the sensor reacts is also a parameter that, because of the methods used, was not possible to establish. The dilution of the air inside of the jar was made by an arbitrary way of uncovering the jar when the sensor was placed and retired, which by itself is an uncontrollable way of air escape. The number of essays made was also low and once more was not sufficient to substantiate this parameter. The usage of the Halimeter (Interscan Corp., Chatsworth, CA, USA), for approximate the concentration of the H_2S to the color change of the sensor has, once more, an error. This problem occurs owing to the fact that the PSM detectable range includes more than the gas on test. The gas species measured by the Halimeter (Interscan Corp., Chatsworth, CA, USA) are H_2S, dimethyl sulfide and methyl mercaptan, as a sum, even though it as more affinity for the H_2S.

The dilution by the pulmonary air of the oral air is, again, a criterion that is not in control and varies from a participant to another, reflecting his pulmonary volume capacity. To ensure correct measurements, a mean proportion has to be done to perceive this type of dilution which permits to establish a color from the one concentration that the user can consider Halitosis. A color scale needs to be properly designed with more controlled concentrations of H_2S to ensure that the user can distinguish the lighter colors, which means that the concentration of the gas is not indicative of halitosis, from the color that, in terms of gas concentration, is considered halitosis to more darker ones.

The solutions and its storage could have some influence at the results, being the Nitrate Bismuth Solution made once, at the beginning of the study, at the laboratory trials and used along with the experiment. In the other hand, the Sodium Hydroxide Solution was freshly made on the day of each test took place. The results show us that in the last 7 individuals who participated on the last day of clinical trials the sensor didn´t react as efficiently as the first day. This can be due to the conservation of the Bismuth Nitrate solution or the volume of air obtained from the participants, because as we see at the Halimeter (Interscan Corp., Chatsworth, CA, USA) measurements, the concentration of H_2S was enough to cause a reaction on the sensor, as shown at the laboratory trials and the first clinical ones.

Due to low capital available and the time allowed to carry on the experiments, the paper used for the sensor production is a simple filter paper. As the sensor was produced, it was noticed

that the solute was dragged at the margins of the paper, as the solution spread, mainly when the Sodium Hydroxide Solution was used. Leaving the reacting elements at the peripheral zone of the paper giving us an unperfect vision for the colors post-reaction.

The balloon choice was a simple way of doing the clinical trials in the time available, because the participants could perform the exhalations at the same time leading to a more efficient management of the time. Nonetheless, some of the characteristics of the balloons are poorly a fit for the sensor usage, being its initial resistance to the air entrance one of the main causes for the participants lack of air volume, probably needed for the sensor to react. This difficulty was sensed the most on the first exhalation, causing some of the air to escape, losing on the final volume.

The sensor, as we see it, needs more studies and improvement until it was able to be used in the diagnosis of halitosis. Performing more clinical and laboratorial trials to prefect the protocol and maybe create a device where the sensor is placed inside to be used directly on the patient's oral cavity. It has great potential to be used in this medical scenario or at home, where a person who thinks that is breath is malodorous, as in some psychological condition as approached in this work, can used it. This technology could be used in the future because of its impact, especially on its price, protocol and storage.

5. Conclusion

The study showed that the sensor is, not only, sensible enough to react to the H_2S present on human exhaled air but that it could be easily used as a medical or a personal use device to detect and measure the concentration of the gas to determine if halitosis is present.

More studies are needed for it can be used as it is proposed in this work, as well as, its protocol. The future tests should be more precise and controlled in terms of H_2S concentration, confirm the minimal volume needed for the reaction to occur, the design improved, as well as, develop a color scale to easily compare the sensor with the colors specified. Ensuring that its utilization brings a new and developed concept for a more accurate and quick way of this type of condition diagnosis.

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Appendices

U.PORTO
FACULDADE DE MEDICINA DENTARIA
UNIVERSIDADE DO PORTO

Exmº Senhor
André Gonçalves Soares
Faculdade de Medicina Dentária da U. Porto

000194 02 MAI 2019

(CC à Orientadora Srª. Prof. Doutora Luzia Gonçalves)

Assunto: Parecer relativamente ao Projeto de Investigação nº 19/2019.
(Development of a disposable (demi)-quantitative colorimetric sensor for the detection of hydrogen sulfide in human breath).

Informo V. Exa. que o projeto supracitado foi analisado na reunião da Comissão de Ética para a Saúde, da FMDUP, no dia 2 de maio de 2019.

A Comissão de Ética é **favorável** à realização do projeto tal como apresentado.

Subject: Recommendation on the research project nº 19/2019.
(Development of a disposable (demi)-quantitative colorimetric sensor for the detection of hydrogen sulfide in human breath).

I hereby inform that the aforementioned project was analyzed on the 2nd day of may, 2019 by the Ethics Committee for Health of the Faculty of Dental Medicine,

The Ethics Committee is **favourable** to the project execution.

Com os melhores cumprimentos,
A Presidente da Comissão de Ética para a Saúde, da FMDUP

Inês Alexandra Costa Morais Caldas

Prof. Doutora Inês Alexandra Costa Morais Caldas

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DECLARAÇÃO DE CONSENTIMENTO INFORMADO

Considerando a "Declaração de Helsínquia da Associação Médica Mundial

Título: Desenvolvimento de sensor descartável (semi)-quantitativo colorimétrico para deteção de sulfureto de hidrogénio no hálito humano

Eu,_____(nome completo), com o nº de CC _____,compreendi o esclarecimento que me foi providenciado, por meio verbal e escrito, relativamente à investigação em curso realizada pelo estudante **André Gonçalves Soares**, com nº de CC **14238391**, na Faculdade de Medicina Dentária da Universidade do Porto, sendo pedida a minha participação. Toda a informação por mim questionada foi respondida, não deixando margem para dúvidas.

Tomei conhecimento de que, de acordo com os enunciados versados na Declaração de Helsínquia, a informação que me foi providenciada tratou os objetivos, os métodos, os possíveis benefícios, os potenciais malefícios e o ocasional desconforto. Foi-me, ainda, dada a liberdade de aceitar ou abandonar o estudo, em qualquer etapa do mesmo, sem que para mim advenham quaisquer prejuízos ou sanções.

Pude despender de todo o tempo que achei necessário para a tomada de decisão para a participação neste estudo.
Por conseguinte, consinto a minha participação neste projeto de investigação, assim como me foi exposto pelo investigador responsável, consciente que a confidencialidade dos participantes bem como dos seus dados se encontra protegida.

Autorizo, ainda, que os dados utilizados neste estudo possam ser reutilizados noutros trabalhos científicos, assumindo que o anonimato é preservado.

Data __/__/__

Assinatura do participante

_____

DECLARAÇÃO DE CONSENTIMENTO INFORMADO

O investigador:

_____

(André Gonçalves Soares, up201304684@fmd.up.pt)

A orientadora:

_____

(Prof. Dra. Luzia da Conceição Martins Mendes Gonçalves, lgonçalves@fmd.up.pt)

A coorientadora:

_____

(Doutora Andreia Sofia Mateus Azevedo, asazevedo@fe.up.pt)

"Desenvolvimento de sensor descartável (semi)-quantitativo colorimétrico para deteção de sulfureto de hidrogénio no hálito humano"

Explicação do Estudo

Contextualização teórica

A halitose é uma condição vulgarmente conhecida como mau hálito e que em 80 a 90% dos casos tem causa e origem na cavidade oral. O odor emanado é atribuído a gases produzidos por bactérias orais, designados de compostos sulfurados voláteis, sendo um dos exemplos o sulfureto de hidrogénio.

O diagnóstico clínico deste tipo de condição é por vezes difícil, sendo conseguido através de equipamento de valores elevados e pouco práticos, pelo que raramente de realiza a quantificação destes compostos.

Objetivos da investigação

Desenvolvimento de um sensor prático e descartável que de forma rápida e eficaz, por métodos de gradiente de cores, detete e quantifique a presença desde compostos sulfurados voláteis no hálito humano. Tendo como método comparativo, o dispositivo médico mais fidedigno existente, o Halimeter. Esta investigação enquadra-se no contexto da unidade curricular, "Monografia de Investigação/Relatório de Atividade Clínica" do 5º ano do Mestrado Integrado em Medicina Dentária da Faculdade de Medicina Dentária da Universidade do Porto (FMDUP).

Metodologia

Os testes serão realizados durante as consultas da unidade curricular de Periodontologia até Fevereiro de 2019 e prosseguirão até Maio de 2019, na unidade curricular de Patologia e Medicina Oral, sempre supervisionadas pelos respetivos docentes.

O protocolo a levar a cabo será:

1. Seleção dos participantes pela anamnese clínica;
2. Extração com seringa do ar presente na cavidade oral, após fechada por 1 minutos e teste do sensor.
3. Extração do ar da cavidade oral, pela utilização do dispositivo Halimeter, após 1 minuto de boca fechada.

Benefícios esperados para o paciente

Averiguação de possível existência de halitose nos participantes, bem como, caso positivo, métodos de tratamento e controlo da mesma

Desconfortos para o paciente

Não higienização ou alimentação durante 1 hora antes dos testes serem realizados.

Caracter involuntário da investigação

A participação nesta investigação é voluntária, bem como ponderada pelo paciente após ler a explicação do estudo. É assinado um consentimento informado pelo mesmo que assenta nos enunciados versados na Declaração de Helsínquia.

O participante poderá abandonar o estudo em qualquer etapa do mesmo, sem que para este advenham quaisquer prejuízos ou sanções.

Confidencialidade

Toda a informação necessária recolhida durante esta investigação é confidencial e mantida no anonimato.

Características éticas

Este estudo foi submetido à Comissão de Ética da Faculdade de Medicina Dentária da Universidade do Porto.

Declaro que recebi, Ii e compreendi o documento da explicação do estudo

_____

O Participante/O Paciente

Folha de Registo

Código:

Teste Halimeter:

	Concentração de CVS em ppb
Ensaio 1	
Ensaio 2	
Ensaio 3	

Teste sensor:

	Colorimetria	**Concentração de H_2S**
Ensaio 1		
Ensaio 2		
Ensaio 3		

Observações:

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BISMUTH NITRATE PENTAHYDRATE

CODE 000024 **SPECIFICATION Nº** 00002407

PARAMETERS	SPECIFICATIONS	EDITION - 23/09/2016
Description	White powder of transparent crystals, hygroscopic and acid reaction.	
Appearance in solution (HNO3)	Clear, colorless, free of foreign matter.	
Identification	Positive for Bi+3 & nitrates.	
Assay (as Bi(NO3)3.5H2O)	min. 98,0%	
Substance not precipitated by H2S	max. 0,1%	
Insoluble matter in acid	max. 0,005%	
Arsenic (as As)	max. 0,0010	
Chloride (as Cl)	max. 0,0010	
Sulfate (as SO4)	max. 0,0050%	
Calcium (as Ca)	max. 0,0050	
Copper (as Cu)	max. 0,0020	
Iron (as Fe)	max. 0,0010	
Lead (as Pb)	max. 0,0020	
Potassium (as K)	max. 0,0100	
Sodium (as Na)	max. 0,0200	
Silver (as Ag)	max. 0,0010	

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REMARKS

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UNIVERSIDADE DO PORTO

DECLARAÇÃO

Monografia de Investigação

Declaro que o presente trabalho, no âmbito da Monografia de Investigação/Relatório de Atividade Clínica, integrada no Mestrado Integrado em Medicina Dentária, da Faculdade de Medicina Dentária da Universidade do Porto, com o título "Development of a disposable (demi)-quantitative colorimetric sensor for the detection of hydrogen sulfide in human breath", é da minha autoria e todas as fontes foram devidamente referenciadas.

Porto, 15 de Maio de 2019

O investigador

André Gonçalves Soares

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MEDICINA DENTÁRIA
UNIVERSIDADE DO PORTO

PARECER

Entrega do trabalho final de Monografia

Informo que o trabalho de Monografia desenvolvido pelo estudante André Gonçalves Soares, com o título "Development of a disposable (demi)-quantitative colorimetric sensor for the detection of hydrogen sulfide in human breath" está de acordo com as normas e regras estipuladas pela Faculdade de Medicina Dentária da Universidade do Porto, foi por mim referido e encontra-se em condições de ser apresentado em provas públicas.

Porto, 15 de Maio de 2019

A Orientadora

Professora Doutora Luzia da Conceição Martins Mendes Gonçalves