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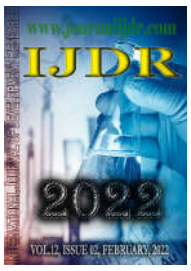

RESEARCH ARTICLE OPEN ACCESS

CAVITY PREPARATIONS PERFORMED WITH PIEZOELECTRIC ASSOCIATED WITH DIAMOND INSERTS

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ABSTRACT

Objective: The present study evaluated the performance of cavity preparations in a group of patients, using piezoelectric associated to diamond inserts. Only posterior teeth were selected, and the restorations performed were of the Class I or II type, without cusp involvement. The aim of this study was relate the depth of cavity to patient's sensitivity presented during preparation. **Materials and Methods:** From a group of 20 patients, 119 posterior teeth were prepared and evaluated about the depth and sensitivity presented during the interventions.All clinical procedures started without anesthesia, in order to measure the sensitivity of using piezoelectric with diamond inserts.The preparations were evaluated from a digital image generated from cast models , showing the depths and their relationship with the sensitivity presented during their execution. **Results:** Statistical analyzes were performed by separating patients into three groups with regard to sensitivity presentedGroups 1 (0 and 1); Groups 2 (2); Group 3(3). Wilcoxon Mann-tests Withney, Test t and Kruskal Wallis were used in each of the sensitive (2 and 3) and non-sensitive (Group 1) groups, with a 95% confidence level ($p \leq 5/ \alpha = 0.05$) and complemented with the Tuckey test of variance to one parameter, where there was no significant difference. **Conclusions:** In all analyses, the results indicate that there were no significant differences between groups, so that in the sample it is not possible to identify correlation between the average depth of interventions and the level of sensitivity. **Clinical Relevance:** This study demonstrate the exclusive use of a oscillatory instrument as piezoelectric with diamond inserts to dental preparation, and its clinical behavior and advantages.

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INTRODUCTION

Minimally invasive dentistry has been modified over time, not only in its operative technique, but also with the use of different instruments, using the less invasive surgical approach with minimal removal of healthy dental tissue.Ultrasound has been introduced in clinical practice since the 50s and 60s,having the first studies a favorable response regarding sensitivity and comfort reported by patients, but with some technical problems such as the use of an aluminum oxide abrasive substance associated with metal tips for dental cutting, lack of operative visibility and high cost of equipment [1,2,3] With the emergence of high rotation in the late 1950s, the use of ultrasound was abandoned, as high rotation brought speed and clinical agility,despite presenting greater sensitivity and excessive cutting of dental tissues [6]. High rotation diamond tips are the most commonly used rotary instruments in clinical dental care and its use requires professional ability, so its high cutting power will not cause excessive cutting, as well as heat generation and consequent increase in intrapulpal temperature. During cavity preparations, an increase of 5.5°C in the intrapulpal temperature can cause irreversible damage to the tooth [9.] The increase in temperature is recognized by the nervous system and expressed as a painful sensation, causing discomfort for the patient. In most cases, this cavity preparation is done with anesthesia, which is the major cause of fear and anxiety in patients regarding dental treatment [24,29]. These disadvantages have led to the search for new technologies, as lasers and ultrasound,turning treatment less uncomfortable. Ultrasound devices can be considered as part of a group of instruments with a micro-traumatic approach, being an alternative to conventional rotary instruments, with less noise and sensitivity, playing an important role in patient's acceptance and cooperation regarding treatment [24,25,29]. Therefore, there was a time gap where ultrasound for cavity preparation was left aside and its other properties were used in other specialties such as periodontics, surgery and endodontics. Diamond inserts that can be coupled to ultrasonic devices were developed by researchers at INPE (National Institute for Space

Research, in São José dos Campos, SP Brazil), and were called CVDentus®(Clorovale Diamantes). According to the technique CVD (Chemical Vapor Deposition) it was possible to obtain a single diamond stone on a molybdenum substrate.It was only with the appearance of CVD-diamond, that inserts could be used with ultrasound that this instrument was once again used in a satisfactory way for dental preparation, offering precise, efficient cutting without the use of abrasive substances, and achieving a clean operative field, clean surfaces and the absence of sensitivity [9,22,25]

Ultrasonic energy and dentistry: Ultrasound is a sound where the frequency is above 20 kHz and it is inaudible to the human ear. It is generated by transducers converting electrical energy into ultrasonic waves. Ultrasonic vibration for dentistry devices,ranging from 25 up to 35 kHz, is created in two ways: magnetic (by magnetostriction) or piezoelectricity. The first transforms magnetic energy into mechanical energy through changes in the magnetic field, while piezoelectricity applies an electrical charge that causes dimensional deformations in ceramic discs, of contraction and expansion, thus producing an oscillatory vibration at the tip of the insert. These waves cause a metallic material (magnetostriction) or ceramic (piezoelectricity) to change its dimensions, contracting and expanding, and this movement is transmitted to the active end of the ultrasound device. The vibratory movement resulting from piezoelectricity is of high frequency and low amplitude and its speed is altered by the increase or decrease in the power of the device [6].Another physical property is cavitation, where ultrasonic energy is transmitted to a liquid medium, generating a cold bubbling. This energy when encountering solid particles, causes them to collapse into smaller particles. This justifies surface cleaning of dental tissues after using ultrasound, and despite the fact that preparations were not successful in its early years, this other property continued to be used for the creation of calculus removal, cleaning and disinfection of dental materials, removal of particles adhered to instruments, and removal of cemented fixed prostheses [5].

Piezoelectric and CVD diamond ultrasound: In the late 1970s, it was shown that diamond can be artificially created as a single body and deposited as a film using chemical vapor depositionprocesses (CVD). For the creation of an artificial diamond, by the CVD process, a reactor and a vacuum pump are needed. In this reactor, there is a hot metallic filament of high temperature (2200°C) that causes collision of hydrogen and methane gases , and through these chemical and thermal interactions, in vacuum environment, there is the deposition of a layer of diamond crystals, forming a uniform polycrystalline layer on the substrate[30].On irregular, spherical or edged surfaces, the formation of this diamond had larger grains and sharp edges, where its application could be extended to abrasion cutting instruments,such as ultrasound inserts, without any another surface treatment [8] Molybdenum was chosen as a substrate for the diamond deposition because it had a transformation phase with a temperature close to from that observed in the growth of the diamond [18]. Only with the success in the creation of CVD diamond inserts, the piezoelectric began to be used to carry out coronary cavity preparations, with satisfactory cut in enamel and dentin. And not only made it possible to perform cavity preparations using an oscillating instrument, but also several advantages of using a single CVD-diamond stone, with crystalline integrity, high adhesion to the metallic substrate and a durability 30X greater than diamond tips for high speed preparation [26].

Cavity preparation performed with piezoelectric: The parameters for considering a cavity preparation as ideal are constantly changing throughout the history of restorative dentistry. The concept of minimally invasive dentistry, concerns minimal cutting of tooth structure, preserving enamel and dentin.The success of adhesion also changes the extent of preparation, as the need to achieve the mechanical fit of a prosthetic piece becomes unnecessary. Ultrasound has the difficulty to establish itself in a market where many do not know its mechanism of action, advantages and multiple properties of its clinical use.With piezoelectric and diamond inserts, we choose not only the insert according to the function, but also the power according to each one of them, for best performance in each indication. When using the right power for each insert, the resulting preparation is close to its diameter, whereas when using a power above, the cavities appear to be larger and deeper due to the increase in the amplitude of the diamond tip, and consequently in the cutting skill of instrument [28].The cavitation property occurs due to vibrations above 20kHz that causes cleaning of dentin surface through the implosion of adhered particles,and it can offer different results in adhesion of restorative materials [31,32].Besides tissue preservation, the use of ultrasound and diamond inserts are atraumatic to periodontal tissues,making possible to put end lines inside gingival sulcus with less trauma, less aggression to pulp and adjacent teeth [37.41,42,50]

Dentin sensitivity and temperature changes: The search for restorative treatments that cause less clinical discomfort, evaluated the techniques and instruments about level of aggression to the pulp tissues where painsensation is originated. Care must be taken so that the temperature does not rise above 5.5°C, a limit temperature to avoid pulp damage [9]. Histological evaluation of some studies demonstrated that use of high rotation presented disorganization of the odontoblastic cells and rupture of the pulp-dentin layer, and with piezoelectric, the cellular structures and their limits appear preserved and under normal conditions [23]. Even in the use of the piezoelectric in other tissues, such as in bone osteotomies, low heat production,less postoperative morbidity and bone healing are reported[64].

MATERIALS AND METHODS

Through the patient selection section of the ICT-UNESP, São José dosCampos –SP, 20 patients aged between 25 and 58 years were selected for replacement of CL I and CL II restorations in posterior teeth, without cusp involvement. Patients were selected through anamnesis involving clinical and radiographic examination and through a questionnaire on general health status and previous history of dental treatment. An odontogram was inserted in the patient's record to sign the teeth being treated, as well as the degree of sensitivity presented and the need of anesthesia during the procedure. The sensitivity level was reported in three stages:

(1) lack of sensitivity during preparation;
(2) poor sensitivity without the need for anesthetic administration;
(3) moderate or severe sensitivity, with the need for anesthetic administration.

The removal of the restorations was performed with the CVDentus® W1 diamond insert until complete removal of the restorative material (amalgam or resin). Caries removal was done with the R4 insert, and the internal walls of the preparation with the CR4 insert, with a wide chamfer profile. The other inserts CR1-U and CR4-U were used to finish the preparation margins and to perform a bevel in the preparation's proximal margins in the case of class II restorations.

Table 1. CVD diamond inserts (CVDentus®) that were used for removal and preparation

CVDentus ®Inserts	Indication	Recommended power level
1)W1	Removal of amalgams and large resins	80%
2) R4	Removalof caries	50%
3)CR4	Finishing preparation with wide prosthetic margin	80%
4)CR1-U	Polishing of narrow prosthetic margin	30%
5)CR4-U	Polishing of wide prosthetic margin	50%

Source: CVDentus® catalog

After the preparations were carried out, the patients were molded by the single-phase technique with silicone polymerized by addition reaction Elite HD+ (Zhermack® - ZhermackSpA), and in these molds type IV Elite Rock plaster (Zhermack® - ZhermackSpA, in the proportion indicated by the manufacturer. From these cast models, each tooth was cut with discs at low rotation for individualized tooth models. Each of them were scanned by the trios® scanner (3Shape

A/S), with 3shape® software (3Shape A/S) generating a virtual model in STL (Figures 1,2,3,4), where the minimum and maximum depths of each restoration were measured in two/three points, using the tools themselves of software measurement in mm:

- Superficial margin to mesial gingival wall
- Cavus-superficial margin to pulp wall
- Cavus-superficial margin to distal gingival wall

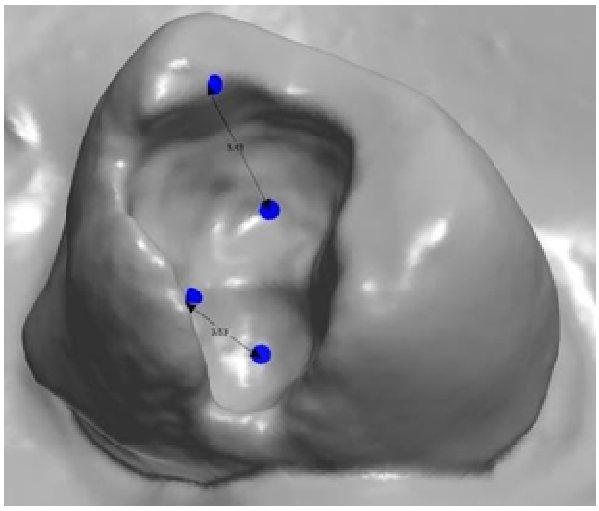

Figure 1. Digitalized image of preparation

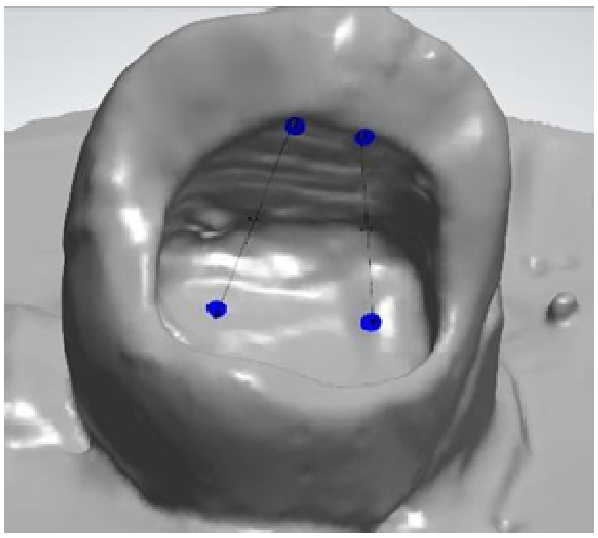

Figure 2. Digitalized image of preparation

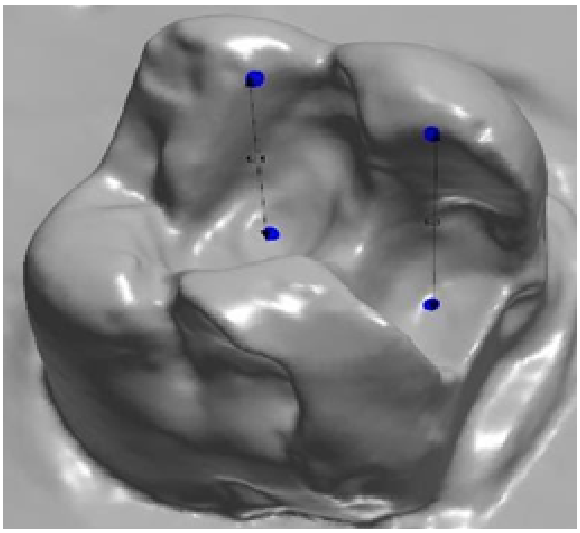

Figure 3. Digitalized image of preparation

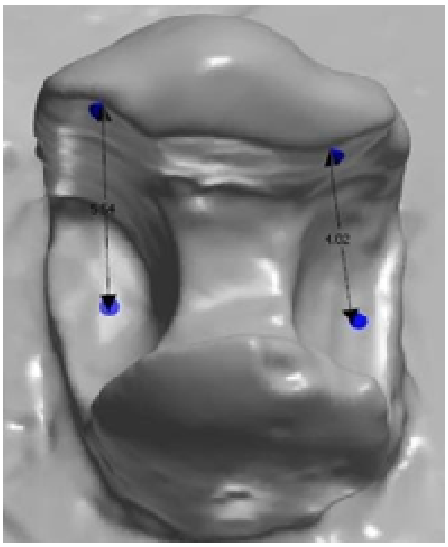

Figure 4. Digitalized image of preparation

The depth at these points was measured (CLI =2 points/CLII=3 points) and an average was obtained, in order to establish a relationship between the depth of preparation and the sensitivity presented by the patient during the procedure. The data obtained used for statistical analysis were:

1. Average depth of all cavities;
2. Table on the sensitivity presented for each preparation;

Other relevant data were collected through the questionnaire, such as: patient acceptance to treatment with ultrasound and diamond tips, noise, comparison with previous dental history and comfort. The time to carry out the preparations was also measured.

RESULTS

Data analysis was performed to find out if there is any correlation between the average depth and the sensitivity level, so the survey was carried out in different stages. Ratings 0, 1, 2 and 3 refer to the level of sensitivity, for which the use of anesthetic could be necessary. We present the results as a boxplot, showing the data organized in two different ways: in terms of the median and quartiles, as well as in terms of the mean and extreme values, as can be seen in Figure 5, which presents the distribution broken down for all different sensitivity levels, and in Figure 6, which focuses on sensitivity levels of 0 and 1 only. Visual analysis of the dispersion represented by the interquartile range indicates a concentration of results at low levels of sensitivity (levels 0 and 1).

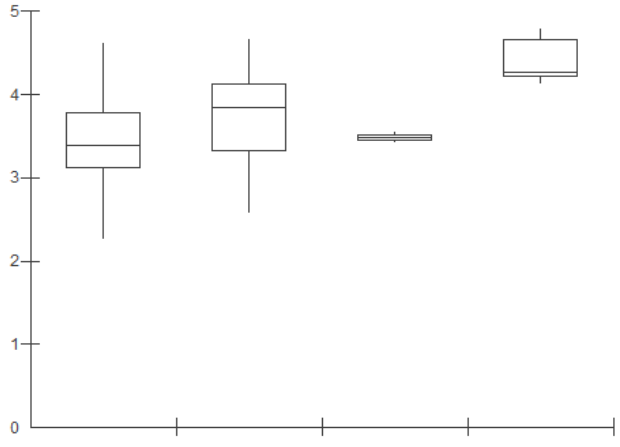

Figure 5

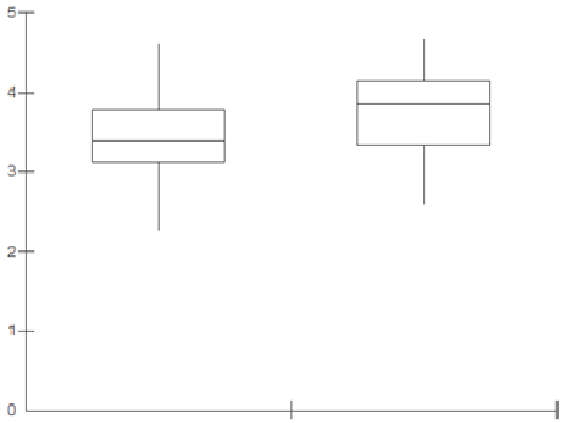

Figure 6.

Two non-parametric tests were performed: the Wilcoxon Mann-Withney Test and the Kruskal Wallis Test. We initially compared the two groups associated with the absence of pain for which the use of anesthetic would be necessary. Statistically there were no significant differences between both groups. It was completed with a t test between both groups to illustrate the result considering a normal distribution. Sensitivity groups with levels 0 and 1, associated with the absence of pain for which the application of analgesics would be necessary, were compared using the Wilcoxon Mann-Withney Test. For the comparison of these three groups, we used a non-parametric analysis of variance: the Kruskal Wallis Test, which allows us to verify if the samples originate from the same distribution, identifying all the associated statistical quantities. The p value suggests that there are no significant differences when we consider the 95% confidence level, that is, when we consider an alpha=0.05. The result of the Kruskal Wallis Test is available in Figure 7. Finally, complementing the information, an analysis was carried out considering the normal distribution between the values of the variables, the Tuckey Test. The results of this analysis are shown in Figure 8.

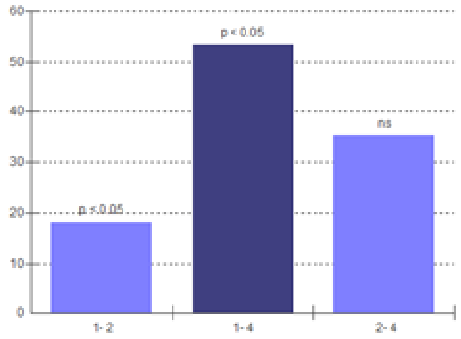

Figure 7.

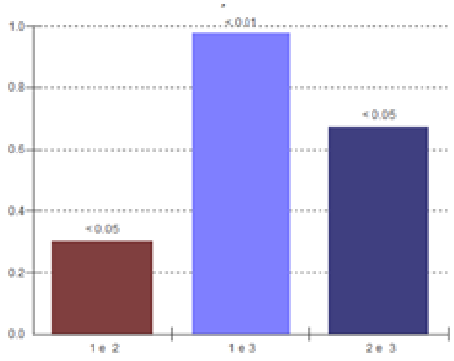

Figure 8.

Finally, complementing the information, an analysis was carried out considering the normal distribution between the values of the variables, the Tuckey Test. The results indicate that there are no significant differences between the groups, so that in the sample it is not possible to identify a correlation between the average depth of interventions and the level of sensitivity.

DISCUSSION

Since the beginning of the discussion and changes about the first surgical techniques to prepare dental tissues, two paths have become clear in this evolution: preventing the recurrence of caries and failure in the margins of restorations, and preserving healthy dental tissue. The awareness that over time, more aggressive cutting techniques would have to be reshaped due to excessive cutting of enamel and dentin, took a prominent place in the face of the need for a standard format for walls and limits for cavity preparations. Some characteristics remained, such as: removal of enamel without dentin support, margins of the preparations, however others have become obsolete or unnecessary such as the preventive extension of sulcular boundaries of restorations. From these changes in techniques, arises what we call minimally invasive dentistry, where within this concept, we can not only choose preparation techniques, but also different rotary or oscillatory instruments.This choice also includes the practical of daily clinical use by the professional, equipment cost, and benefits for the patient in terms of comfort, sensitivity, noise, and treatment compliance. Some of these items, despite not always being questioned by professionals, are important because many patients do not attend the dental office as much as they should, for treatments, maintenance or even prevention of other conditions due to different traumas in face of dental treatment.

Since the beginning of its laboratory and clinical presentation, of the first studies in the 50s and 60s, the introduction of ultrasound as a cutting instrument for performing cavity preparations, brought to light not only the satisfactory cut, but also the absence of sensitivity and better acceptance of patients towards the treatment. However, the lack of adequate technology at the time of its introduction on the market, superseded the existing benefits, in face of high rotation that offered the clinical advantages of accurate and fast cutting, short clinical time and lower cost. This was enough for the use of ultrasound to suffer a clinical and market knockout, which put it in an ostracism for decades in cavity preparation. The existence ofdiamond tips for piezoelectric ultrasound corrected part of the initial problems because they enabled the preparation of teeth, with the advantages of ultrasonic properties, but as they were made in the same way as high-speed diamond tips, with diamond particles aggregated by a galvanic process, this diamond layer was easily detached from the tip, in a delamination process, due to ultrasound vibration. Only with the discovery of CVD-diamond to cut hard tissues,and subsequent studies on which metal could be ideal to avoid the loosening of the diamond layer, is that the ideal union of the piezoelectric and ideal cutting was reached [26].The insert is composed of a single diamond, and therefore does not “loose”, being more stable and 30x more lasting than a conventional high speed diamond tip. Another aspect that has always been observed, even in studies of preparations with CVD-diamond inserts and diamond tips at high speed, is the time to carry out the preparations. In many studies, the time required for piezoelectric ultrasound and diamond tips was longer, compared to high speed. In this study, we measured the time in order to evaluate if clinical time was suitableusing just the piezoelectric from beginning until finishing,however we did not think it was relevant to include this analysis of time, because there were many other variables that influencedthe time required.In all cases where there were already pre-existing restorations and the presence of cracks or carious infiltrations, facilitated or not its removal, influencing the final time result. Another important variable is that piezoelectric has multiple tips with specific indications for its function and for each tip there is a recommended power level to be selected . If a tip that is not for removal of restorations, for example, is used for this function and with lower power, the result will be a much longer clinical time than

when using the right tip at the power indicated by the manufacturer. Correct use favors clinical time by reducing each phase without increasing the time in the subsequent phase. Another characteristic that favors the clinical time is the fact that most restorations performed in this study did not require administration of anesthesia prior to their performance or during the procedure. The time we also use to perform anesthesia is eliminated, as well as in dealing with the patient, who mostly has difficulty in accepting it due to fear of the pain of the puncture and administration of the anesthesia. The piezoelectric and diamond insert technology made the clinical procedure suitable for the professional, and has numerous advantages for the patient, in addition to the benefits for the tooth structure.

In this study we had few cases where the use of anesthetic was necessary. It should be noted, however, that dentin sensitivity is a multifactorial characteristic and that it does not depend solely and exclusively on the depth of preparation or on the instruments used. Of course, even in a small group of patients, it is already relevant that 80% of them did not have dentin sensitivity during preparation, being these in the same average age group as adult patients. One of the factors would be intrinsic characteristics of each patient, which will exist individually, even if they are in the same group, as they are linked to the individual genetics of each one, and their specific pain threshold. The dentin characteristics of a previously restored tooth, with its variations of secondary and tertiary dentin, are also individual factors, as well as the anatomy of the teeth and the proportion of wear compared to the total size of the tooth and the remaining dentin on the pulp. Several studies present this measurement of preparation depth in different ways, starting from the margin of the superficial cavus angle of the preparation to its pulp wall, as used in this study; but others use a volumetric measure or even consider only the residual dentin layer on the pulp[58,65,66]. Among all of them, none is determinant as to which method would be better or more accurate, simply because there is not only one way to determine if a restoration is deep, as there are anatomical variables of the tooth and internally of the pulp chamber that make this standardization impracticable. We then have an average for both the different dental anatomies and there is no consensus on only one method for measuring depth. Allmeasurements have to be considered within the methodology adopted in each study. The measurements presented in this study are in the form of a digitalized image of the preparation, where 2-3 depth points were chosen to obtain an average. For any clinical observation, a dental element that loses a large part of its crown in a MOD or even MO or OD preparation, there is an agreement that it is a tooth with a medium restoration, or even a deep one, has already lost a good part of its structure. New studies that may consider other variables such as anatomy, various imaging methods and volumetric or residual dentin measurements on the pulp wall can be carried out to address other ways of determining depth, but they will always be associated with the methodology of the work to be performed and cannot be expanded as unique to all clinical works.

CONCLUSION

In this study, it was concluded that the use of piezoelectric associated with diamond inserts, enables satisfactory cavity preparations presents lack of sensitivity and reduction of anesthesia administration in clinical care. No relationships were found between the depth of the preparations and the level of sensitivity reported by the patients. Other future studies will be able to evaluate these and other qualities presented, in a new clinical methodology so that more data can be known or compared.

Compliance with Ethical Standards

Conflict of Interest: Since its first introduction in clinical care to perform dental preparations, ultrasound presented positive results concerning sensitiveness and also other satisfactory technical patterns of dental preparation such as selective cutting and cleaning of dental surface. In this study we wanted to obtain data about sensitiveness during preparations without anesthesia so to observe if it was a pattern concerned to the instrument itself of if there was other related items such as depth of preparations, responsible for the general result of lack of sensitiveness.

Funding: This study received financial aid concerning to instruments and diamond inserts kindly provided by CVDentus® - Clorovale Diamantes, São José dos Campos, SP, Brasil . No other sources of funding were received for this study.

Ethical Approval

This study received ethical approval from:

National Concil of Ethics in Research /CONEP –Brasil https://plataformabrasil.saude.gov.br/login.jsf

Certificate of presentation of ethical appreciation (CAAE) : 10628219.5.0000.0077

Numberofdocument :3.641.361

Informed Consent: (Resolution No. 466, of December 12, 2012 / https://bvsms.saude.gov.br/bvs/saudelegis/cns/2013/res0466_12_12_2012.html)

Me,_____
_____
RG:_____ CPF: _____ , I am being invited to participate in a study called Cavity Preparations made with CVD and Piezoelectric diamond burs, whose objectives and justifications are: to perform cavity preparations with piezoelectric ultrasound and CVDentus® diamond burs, on teeth previously selected in the evaluation that require the replacement of pre-existing restorations in posterior teeth.
My participation in this study will be in the sense of submitting myself to the clinical, radiographic, anamnesis and filling out the questionnaire, in order to carry out clinical care at the Institute of Science and Technology of the Universidade Estadual Paulista, campus of São José dos Campos, São Paulo.
I was advised that, from the research to be carried out, I can expect some direct and indirect benefits such as:

Direct benefits (to the participant)

1) Perform restorative procedures with another technology (piezoelectric ultrasound and CVDentus® diamond tips)
2) Less dental wear during preparation
3) Less sensitivity or even absence of this during the service, in many cases without the prior need for the use of local anesthesia
4) Less noise resulting from the use of the instrument, making the intervention more comfortable.

Indirect benefits (which will be generated from this research)

1) Larger scale use of piezoelectric ultrasound and CVDentus® diamond tips in daily clinical practice, in the performance of cavity preparations by other dental surgeons.
2) Seeking to integrate the use of oscillatory instruments, such as piezoelectric ultrasound, in the clinical learning process within undergraduate and graduate courses in dentistry, aiming to add clinical and biological benefits to patients.
3) Generate data that encourage further clinical research on the subject, which may contribute to new clinical care protocols for different groups of patients.

On the other hand, I received the necessary clarifications about the possible discomforts and risks arising from the study, taking into account that this is a research, and the positive or negative results will only be obtained after its completion. Thus, the procedures for performing and/or exchanging restorations using piezoelectric ultrasound and CVDentus® diamond tips will be started without the use of anesthesia, and in the presence of sensitivity reported by me

during the procedure, it will be interrupted for administration of anesthesia, and later completed until the end of treatment.

The possible risks and/or discomforts arising from the intervention are:

- painful sensitivity during care, from which local anesthesia will be administered.
- postoperative sensitivity (to be informed by the patient to the researcher)
- indication of endodontic treatment in case of pulp exposure, resulting from caries removal in deep restorations.

All possible complications, such as postoperative sensitivity that require:

- new restoration
- associated medication
- endodontic treatment and adequate restoration of the tooth remanescent.

They will be the sole responsibility of the researcher, who is willing to provide the necessary care and treatment, not generating any burden for the patient; as well as insurance against any eventual damage resulting from the research. I am aware that my privacy will be respected, concerning my name or any other data or element that may, in any way, identify me will be kept confidential.I was also informed that I have full freedom of choice, and that I can refuse to participate in the study, or withdraw my consent at any time, without having to justify it, and if I wish to leave the research, I will not suffer any harm to the assistance I have been receiving.

The researchers involved in this project are Renata de Paula Samico (academic master's student, in the discipline of dental prosthodontics, of the Postgraduate Program in Restorative Dentistry, Faculty of Dentistry, São Paulo State University – UNESP / São José dos Campos Campus) and Full Professor Dr. Renato Sussumu Nishioka, Study Advisor, and I can keep in touch with them by phone (12) 99705.0806 /Email: resamico@gmail.com Assistance is guaranteed throughout the research, as well as free access to all additional information and clarifications about the study and its consequences, in short, everything I want to know before, during and after my participation. I also consent to the images of my complementary exams, such as radiographs, CT scans, models, among others, to be used for scientific purposes, publications and classes. I was informed that I will not receive any reimbursement or payment for the use of my images (photos, radiographs) and I also understood that the team of professionals who attend me and will assist me throughout the treatment will not have any kind of financial gain from the exposure of my image . Therefore, I agree with the use of these images for scientific purposes.

Finally, having been oriented as to the content of everything mentioned herein and understanding the nature and purpose of the aforementioned study, I express my free consent to participate, being fully aware that there is no economic value, to be received or paid, for my participation, and that I am receiving a copy of this Informed Consent Form, on this date.

São José dos Campos ,_____de_____ 20__

Patient:

_____

Advised Student:

_____

(Renata de Paula Samico)

Teacher advisor :

_____

(Full Professor Dr. Renato Sussumu Nishioka)

ICT-UNESP - College of Dentistry / São José dos Campos – SP

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