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"Solvents Impacts on Microhardness of Dentin"

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“Impacto de solventes na microdureza da dentina”

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Thanks

ABSTRACT

Introduction: Remaining microorganisms in the apical part of the root canal cause failure most of the time, and in these cases the first choice to restore healthy periapical tissue is non-surgical endodontic re-treatment. To obtain resealing and disinfected root canal, it is necessary to remove as many gutta-percha and sealers as possible. There are several methods to remove gutta percha, including the use of solvents, heat, and mechanical instrumentation, purely or in combination. When sealers are in anatomical ramifications, it is not accessible to remove them by applying mechanical methods. In such cases, using solvents is important to clean sealer in combination with gutta-percha and disinfect the root canal system effectively.
Objective: The aim of this study was to review the impact of solvents of gutta-percha on micro-hardness of dentin in non-surgical endodontic re-treatment.
Method materials: This research was done by using a database PubMed, ScienceDirect and EBESCO up to December 2020. The inclusion criteria are full text articles in English and no date limits were imposed. In this review, 49 articles were selected.
Development and conclusion: In endodontic re-treatment, using of several methods simultaneously leads to remove gotta-percha and sealer effectively and completely. Solvents along with other methods are useful to remove filling materials without damaging the root canal system. The toxicity and carcinogenicity of solvents are important to select an ideal solvent. In case of using solvents, the penetration of solvents beyond the canal should be prevented to minimize sever post-treatment pain. Since Orange oil and Eucalyptol have no effect on dental micro-hardness and are safe, in future studies they could be evaluated in terms of other properties of an ideal gutta-percha solvent in compared with Chloroform. Therefore, in case of achieving positive and desired results, they can be alternative for Chloroform.

Key words: solvents, Chloroform, Eucalyptol, Orange oil, Xylene, Halothane, micro-hardness, endodontic re-treatment,

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I. Introduction

The success rate of initial endodontic treatments is between 86% and 96% [1]. Remaining of microorganisms in the apical part of the root canal causes failures most of the time [3]. In these cases, the first choice to restore healthy periapical tissue is non-surgical endodontic retreatment [3]. Gutta-percha combined with various sealers are commonly used as filling materials [4]. In order to obtain resealing and disinfected root canal, it is necessary to remove as much gutta-percha and sealers as possible [5,6]. There are several methods to remove gutta-percha, including the use of solvents, heat and mechanical instrumentation, alone or in combination [7]. When sealers are in anatomical ramifications, it is not accessible to remove them by applying mechanical method [8,9]. In such cases, using of solvents are important to clean sealer in combination with gutta-percha and disinfect the root canal system [9]. Purely using of mechanical methods leads to several hazards such as root perforation, canal straightening, or altering the original canal shape [10]. Therefore, solvents in combination with mechanical methods are safe and effective to get access again to entire root canal system [11]. Solvents can cause physical and chemical changes in surface of dentin, and these alternations can affect the interaction between dentin and fillings materials. So, these alternations are clinically significant [12,13]. Many types of solvents are available, such as, Chloroform, Eucalyptol, Orange oil, Tetrachloroethylene (Endosolv), and Xylene. But none of these solvents have all the properties of an ideal solvent that includes non-toxicity, non-carcinogenicity to the tissue, patients and clinicians and also effective softening of gutta-percha [14]. For example, Chloroform has been the preferred choice for a long time due to its high volatility, but it is the most cytotoxic to periapical tissues, it could be even hepatotoxic, and it has been categorized as a Class 2B carcinogenic material [15,16]. Since there exist various solvents that could alter the physical properties of dentin, in this report it is intended to conduct a review work on the state of art of the solvents impacts on micro-hardness of dentin with the aim of assisting dentist to select the appropriate solvent to remove gutta-percha.

II. Method and Materials

This bibliographic review was carried out based on the reading and analysis of several articles fulfilling the inclusion and exclusion criteria mentioned in table 1.
The research question was based on the PICO (Population, Intervention, Comparison and Outcome) framework. The population was human teeth, the Intervention was the use of Gutta-percha solvents, in comparison with control groups (Phosphoric acid, Normal saline) and the Outcome was the micro-hardness of dentin. Therefore, the aim of research is “The solvents impact on dentin micro-hardness.”
The electronic research was done in three databases (PubMed, ScienceDirect, EBSCO) up to December 2020. No date limits were imposed, and English papers were included. The research strategy included the use of Medical Subject Heading MeSH terms: (Dentin micro-hardness and Solvents).
The organization of bibliographic references was performed by using the EndNote X8.2 software. The articles were selected after reading their abstract in full, resulting in a total of 46 articles.

Inclusion criteria	Exclusion criteria
Systematic review	Articles are not covered by inclusion criteria.
Bibliographic review	Articles whose title/abstract were not relevant to the monograph.
Thesis	Individual opinions without a scientific basis
Idiom - English	
Articles in “full text”	
Book	

Table 1

III. Development

III.1 Non-surgical re-treatment of root canal

III.1-1 Obturation of root canal

There are various materials and techniques for filling the root canal system, including Gutta-percha, Carried-based obturator, Silver Point and Paste filler, but Gutta-percha along with sealers is still the most common compound to obturate canals [17]. Although Gutta-percha does not meet all the required characteristics for root canal filling, it is easily removed from root canal in endodontic re-treatment.

III.1-2 The methods of removal of gutta-percha

There are different methods for removing gutta-percha, including:
1. manual method by Stainless Steel files
2. Rotary method by Nickel-Titanium
3. Ultrasonic
4. Heat

In addition, solvents facilitate the removal of gutta-percha by softening [18].

The difficulty of removing the gutta-percha depends on the length of the canal, the diameter, the cross-section shape, and the curvature of the canal [19]. If the root is divided into three equal parts, the removal of gutta-percha is done first from the coronal third, then the middle third, and finally from the apical third. In canals that are large, straight, and gutta-percha has a poor adaptation, the filling materials can be removed with one device and one movement. In other cases, the best technique is selected based on radiography and clinical evaluation after re-entry into the pulp chamber. Using a combination of several methods at the same time causes safe, almost complete, and efficient removal of gutta-percha and sealer from inside the root canal [20].

❖ Heat method:

In the use of the heat, caution must be taken not to overheat the root, because it can injury the periodontal ligament [21]. In teeth where the gutta-percha is well adapted to the canal walls, it is difficult to remove the gutta-percha. In these cases, a heated plugger is used to remove the gutta-percha [20, 22]. One predictable way to remove gutta-percha is to use a thermostatic heated plugger, which does not cool down when it enters the gutta-percha [23]. Electronic Heat Carrier devices remove more soft and heated gutta-percha. In this method, the heated plugger is inserted into the more coronal parts of the gutta-percha. Then the heated plugger is deactivated and removed from the canal, therefore the part of gutta- percha which is attached to the plugger is removed. This process is repeated as far as it is efficient [23].

❖ The technique of using a heat and manual instrument:

Another way to remove gutta-percha is application of heat with a Hedstrom file (H-file). In this method, a hot device is inserted into the canal to warm and soften the gutta-percha and is removed immediately. Then the numbers of 35, 40, or 45 of Hedstrom are rapidly and carefully inserted into soft and warm gutta-percha [24]. When the gutta-percha cools, it hardens on the cutting flutes of the Hedstrom file. In poorly filled canals, a complete mass of gutta-percha is removed with one movement when removing the Hedstrom file [22]. This technique is recommended in canals where the gutta-percha is beyond the apical foramen range. After a large amount of gutta-percha has been removed, the dentist should evaluate the amount of gutta-percha or sealer left inside the canal [25].

❖ Rotary method

Rotary instrumentation has been proposed to remove gutta-percha from a previously treated root canal due to the high adequacy [26]. One of the fastest ways to remove gutta-percha is the rotary method [25]. The recommended instruments in the rotation method include the following [22]:

- Gates Glidden
- Rotary files
- Special burs for removing gutta-percha.

In canals that are not sufficiently prepared, the rotary system should be used with caution. In general, they should not be used in root canals that do not have a direct path and do not allow the instrument to move passively [25]. To soften mechanically the gutta-percha and remove it effectively, rotating devices must be used at speeds between 900-1200 rpm. The rotational speed of the rotary device affects the amount of frictional heat to soften the gutta-percha and remove the coronal gutta-percha. Coronal removal of gutta-percha allows solvents to enter the canal more quickly, thereby facilitating the cleaning and shaping of the canal [25].

❖ Manual method:

When the canal is weakly obturated by gutta-percha and there is space between the gutta-percha and the canal walls, the manual method by Hedstrom files or manual reamers is applied [27].

❖ Ultrasonic method:

In the sonic or ultrasonic method, the energy at the tip of the device softens the gutta-percha. The softened gutta-percha is then removed by the file [22]. Ultrasonic devices can also be used to remove residues of sealers that adhere to canal walls [25]. Special ultrasonic devices are designed to enter the shaped canal and move the gutta-percha into the pulp chamber so that the gutta-percha can be removed. When this method is used in combination with manual or rotating files, there is a possibility of further removal of gutta-percha [25].

III.1-3 Solvents

Gutta-percha chemical solvents are used to remove filling materials without damaging the teeth [28]. By mechanical method, it is exceedingly difficult to remove the sealer from the anatomical ramifications of the canal, in these case solvents are suitable for cleaning, removing residual materials, effective disinfection and re-sealing the canal [29].
To select the ideal gutta-percha solvent in endodontic re-treatment, the degree of toxicity and solubility should be considered [30]. Since the dentist may not be sufficiently aware of the type of canal filling material during re-treatment, the solvent which be able to dissolve diverse types of canal filling materials is ideal [30]. One of the major concerns in the use of solvents to remove gutta-percha in the re-treatment of the root canal is that they extend beyond the canal and evaporates in the environment [29].

In use of gutta-percha solvents, precaution should be taken to prevent the mixture of gutta-percha and solvent from penetrating beyond the canal range to minimize the possibility of severe post-treatment pain [7]. Gutta-percha solvents are strong fat dissolvers that can cause chemical changes in dentin surfaces [12]. As a result, the bond strength of the restorative material changes. Among the solvents, the most widely used ones in root canal re-treatment include Chloroform, Xylene, Halothane, Eucalyptol, Turpentine, and Orang oil [12,31].

Chloroform:

Many studies have identified chloroform ($CHCL_3$) as the most effective solvent for the removal of root canal filling materials [32,33]. According to these studies, careful and controlled use of chloroform in dentistry can lead to successful removal of filling materials [32]. The Food and Drug Administration (FDA) does not prohibit the use of Chloroform in dentistry and has not set a limit for its carcinogenic feature [34] and there is no risk of toxicity if the minimum amount of Chloroform is used [35]. The high volatility of Chloroform is one of the reasons that they are applied [36]. Although high volatility is a good property of a solvent, it should be considered the exceedingly high volatility is disadvantage because the therapist cannot use its softening properties [34]. The levels of calcium and phosphorus in dentin can change following the use of Chloroform and Halothane, although these changes are not statistically significant [12]. In addition, if Chloroform exit from the canal, it can be harmful to periapical tissues [28].

Halothane:

Halothane is chemically like Chloroform and chemical formula is ($C_2HBrClF_3$). High volatility of Halothane is desirable. Since the dentist is no longer worried about remaining of that in the pericardial tissues and entering the circulatory system [29], several studies have shown the solubility of Halothane is like Chloroform [12,37,33]. However, the time required to remove the filling materials with Halothane is longer than the time required for chloroform [38]. The high price and volatility of Halothane and its potential for idiosyncratic necrosis of the liver are the reasons that have reduced the tendency to use it as a gutta-percha solvent [29].

Xylene:

Xylene is an aromatic organic solvent and is commonly used in the form of dimethyl benzene [36]. It is not carcinogenic but has a histological toxicity [29]. Xylene dissolves gutta-percha more slowly than Chloroform. Therefore, it provides better control and allows softened gutta-percha to be removed better than when gutta-percha is liquefied. The solubility of Gutta-percha by Xylene is weaker than Chloroform and due to this feature and evaporation, the clinical use of Xylene is impractical [35].

Orange Oil and D-limonene:

Orange oil is a solvent of gutta-percha, also it can be a solvent of Eugenol zinc oxide [30]. D-limonene is the fortified Orange oil, and it is obtained in abundance from plants such as citrus family and as an ingredient in many essences. It is also used as a deodorant and insect repellent [39]. Studies show that Orange oil has the highest biocompatibility among solvents [20,40]. Orange oil has a greater effect on thermoplastic gutta-percha than Eucalyptol and Xylene [40]. It has been shown that Xylene can increase the solubilizing impact of Orange oil [30].

Eucalyptol:

Another solvent that has often been used in dentistry is Eucalyptol, which can be a suitable alternative to Chloroform. In general, Eucalyptol dissolves gutta-percha slowly, but it dissolves faster than Halothane and Orange oil, and if it is heated, its effectiveness is equivalent to Chloroform [30]. Tetrachloroethylene also increases the effectiveness of Eucalyptol [32].

❖ Use of solvents with the file:

To remove Gutta-percha from small and curved channels, the use of files along with solvents is more appropriate. This method involves filling the pulp chamber with Chloroform and selecting the appropriate size of the K Type file. While softening gutta-percha is removed, the canal is prepared. First, 10 or 15 size of Stainless-Steel file is inserted into the gutta-percha, and then continuous rinsing with Chloroform is done with clockwise movement (Watch-winding), which creates a path and enough space for use the next larger files to remove the gutta-percha in this area. This procedure continues until the gutta-percha is visible on the cutting flutes of files when it exists from the solvent-filled channel. When the gutta-percha is removed from the coronal third of the canal, the dentist must repeat the procedure in the middle third of the canal and finally in the apical third of the canal. This progressive removal of gutta-percha prevents the softened gutta-percha from penetrating to the periapical area [19].

❖ Use of solvents by paper cone

Gutta-percha and most sealers can be soluble in solvents such as Chloroform, which can be absorbed into paper cones of suitable size. Drying the solvent-containing canal with a paper cone is called the Wicking method, which is used in the last step of removing the gutta-percha. Wicking action is necessary to remove the remaining gutta-percha and sealer from the fins, cul-de-sacs, and aberrations of the canal [30]. Flushing of detergents combined with Wicking action is effective to remove the remaining gutta-percha and sealer from the root canal system. This process is continued and repeated until the paper cone comes out clean, dry, and white. Then the canal is flushed with 70% isopropyl alcohol and wicked to remove residues of softened gutta-percha. Removal of residues by this method increases the efficiency of the detergents during cleaning and shaping of canal [19

III.2 Hardness and micro-hardness test:

❖ Hardness:

Hardness test is performed by applying a standard force to an indenter. This creates a symmetrical effect that can be measured under a microscope in terms of depth, area, or width. The dimensions of the indentation are related to the hardness values of the special tables. By applying a constant force to a standard plunger, the dimensions of the indentation change inversely with the penetration resistance of the material. Therefore, light forces are used for softer materials [41].

Micro-hardness:

The number of dentin tubules per unit of root dentin is less than the crown dentin. Inter-tubular dentine is larger in the root area than in the crown [42]. Therefore, the dentin micro-hardness varies according to the different area [43]. There is an inverse relationship between dentin micro-hardness and tubule density [44]. Also, the amount of micro-hardness in dental hard tissue is indirectly affected by the acquisition or loss of minerals [42]. In addition, micro-hardness is affected by the composition and surface changes of the tooth structure. The two most common methods for measuring dentin micro-hardness are the Vickers Hardness Test and the Knoop Hardness Test [44].

Vickers Hardness Test:

The Vickers Hardness Test uses a pyramidal diamond indenter which creates a square indentation. In this method, a 136-degree diamond pyramid is inserted into the material by applying a certain force and creates a square indentation as shown in Figure 1. The diameters of this square are measured. Finally, the size of the diameters is entered into the device and the device measures the numerical value of the micro-hardness [41].

Knoop Hardness Test:

The Knoop Hardness Test was designed to perform micro-indentation. This method of test is suitable for thin sheets of plastic or metal or brittle materials in which the applied force does not exceed 35N (3 /6   kgf). The Knoop method is designed in such a way that different load can be applied to the indenter, so the resulting indentation area varies according to the applied load and the characteristics of the testing material. The advantage of this method is that materials with a wide range of hardness can be evaluated simply by changing the test force. This method is useful for materials that are different in hardness in small regions because the light loads create extremely delicate micro indentation. The main disadvantages of this method are that the test sample must be highly polished and smooth, and the required time to complete the operation of this test is much longer than the time for methods that are not precisely controlled. Knoop Hardness Values (KHN) of some dental materials are listed in Table 2 [41].

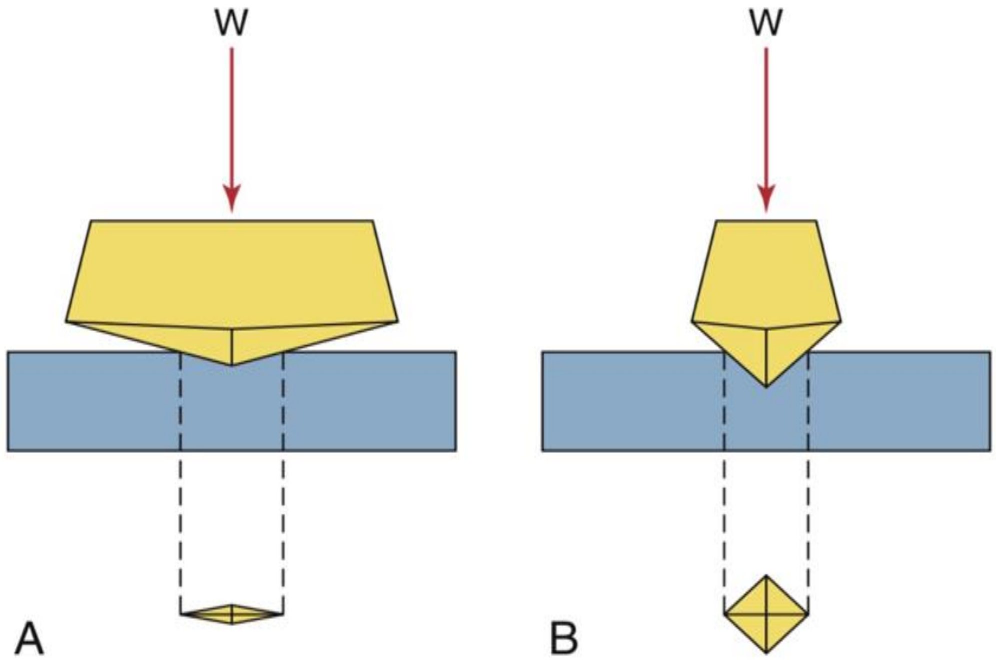

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Figure 1. A1, Principles of Knoop hardness measurement

B1, Vickers Diamond Pyramid indentation Test

Material	KHN(kg/mm2)
Enamel	343
Dentin	68
Cementum	40
Cobalt-chromium partial	391
Denture acrylic	21
Feldspathic porcelain	460
Silicon carbide abrasive	2480
Zinc phosphate cement	38

Table 2.

III.3 The solvents impact on the micro-hardness of dentin:

Four studies met the eligibility criteria and were included in this systematic review.

❖ Root filling materials:

Only in one study the root canals were filled with gutta-percha and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) by means of warm vertical compaction technique [45] and the other studies did not obturate the canals.

❖ Solvents (type, volume, and exposure time):

Three studies in Chloroform were assessed. Xylene, Orange oil, desocclusol and D-limonene were evaluated in one study. Two investigations studied Halothane and Eucalyptol [36,43,46]. The volume used were different between studies from 20 µl to 20 ml.

Study of **Rotstein et al** is the only study in which root canal dentin was exposed to solvents two times (5 and 15 minutes) [36]. Generally, decrease in enamel and dentin micro-hardness was related to increased exposure time by all solvents [36]. Normal saline did not impact on the micro-hardness of enamel or dentin of root canal.

We have reduction in the micro-hardness after 5-minute exposure with phosphoric acidly 13%, chloroform by 13%, Xylene by 9%, Halothane by 8%. The reduction of enamel micro-hardness after 15 min exposure with phosphoric acid, Chloroform, Xylene and Halothane were respectively by 13%, 17%, 13%, 11%.

Chloroform decreased dentin micro-hardness by 29% after 15 minutes. Chloroform decreases the micro-hardness of the dentin after 5 minutes, but it was not significant. Phosphoric acid reduced micro-hardness of dentin 18%. Xylene decreased dentin micro-hardness after 5 minutes by 7% and % after 15 minutes by 10. Halothane reduced dentin micro-hardness by 8% after 5 minutes and by 12% after 15 minutes [36].

According to past studies, Xylene and Chloroform lead to minimal and nonsignificant alternation in levels of phosphorus and calcium of human dentin [12]. Although, study of Rotstein et al presented that Chloroform, Xylene and Halothane decreased the micro-hardness significantly in dentin and enamel. These changes are time related. In addition, in most cases micro-hardness was changed significantly after 5 minutes of exposure. It is assumed that the testing solvents may alter the organic component of dentin and enamel that lead to the enlargement of inter-crystal space. Therefore, the proportion and permeability level increase. It is important to consider the factor of safety and efficiency to select a solvent in in endodontic re-treatment [36].

Khedmat et. al studied 15 minutes exposure of Xylene, Eucalyptol and Orange oil to dentin. Based on results, application of Chloroform, Eucalyptol and Orange oil did not reduce the micro-hardness of root dentin. Therefore, these tested solvents did not have superiority over each other in endodontic re-treatment [46]. The most biocompatibility belongs to Orang oil [40,20]. Since, Orange oil could be an appropriate alternative for the Chloroform [46].

The study of **Shengnan Li et al**. placed Desocclusol, Eucalyptol and D-limonene for 3 min in three portions of root (coronal, third-middle, third-apical) in Compared with the control group, Eucalyptol did not significantly change the micro-hardness. D-limonene significantly increased the micro-hardness in the coronal third and middle third parts of the root canal and the required time to reach the working length was longer. Desocclusol decreased the micro-hardness, and it has shortest time to reach the working length. In dissolving gutta-percha, Desocclusol showed the highest efficacy compared with two other solvents. Micro-hardness of the apical third of root in all groups were not changed because the organic solvents likely have a brief time contact with the apical part of root canal. [45]. The main component of Desocclusol is Perchloroethylene and it is applied clinically in endodontic re-treatments [47]. D-limonene with the main component of Orange oil (90% to 95%) and Eucalyptol with the main component of 1,8-cineole. For a long time, these solvents have been utilized safely for the human body. Eucalyptol is applied as a cough suppressant and D-limonene is a flavor agent in the food industry. [48]. Applying of solvents in endodontic re-treatment may change the chemical and physical characteristics of teeth [12]. One of the important physical features of dentin is micro-hardness. Loss or deposition of minerals in the hard tissues could alter the micro-hardness. The lower micro-hardness causes lower fracture resistance in the root. Thus, assessing of solvents impact on the micro-hardness of root canal dentin could bring theoretical knowledge for choosing solvents in clinical endodontic re-treatment [45].

Erdemir et al. Studied the impact of 15 min of Chloroform and Halothane on the root canal dentin. The results presented that Chloroform and Halothane did not affect the micro-hardness and the roughness of root dentine, because there is no significant difference between control group and solvents [43]

no.	Author	Location	Solvent	Duration		Test	Main Findings
1	Ilan Rotstein et al.	Root canal dentin and Enamel	Chloroform, halothane, Xylene	5 min	15 min	Micro-hardness Vickers Hardness	Significant reduction in the micro-hardness of both enamel & dentin
2	Sedigheh Khedmat et al.	Root canal dentin	Chloroform, eucalyptol, orange oil	15 min		Micro-hardness Vickers Hardness	No impact on the micro-hardness of dentin
3	Shengnan Li et al.	Root canal dentin	Desocclusol, eucalyptol, D-limonene	3 min		Micro-hardness Vickers Hardness	Desocclusol decreases the micro-hardness while D-limonene has an opposite impact.
4	A. Erdemir et al.	Root canal dentin	Chloroform, halothane	15 min		Micro-hardness Vickers Hardness	No impact on the micro-hardness of dentin

Table 3

IV. Conclusion:

According to the evaluation of these four studies, differences were observed in the results related to Chloroform and Xylene. These inconsistencies of results can be originated from performing unequal methodologies. Results of Eucalyptol and Orange oil show that these two solvents have no effect on the dentin microhardness of the of root and do not change the physical properties of the dentin surface. Eucalyptol and Orange oil are safe and useful essential oils which be able to dissolve gutta-percha [49]. On the other hand, do not have carcinogenic properties. Accordingly, in future studies, these two solvents could be tested in terms of other suitable properties in comparison with Chloroform.Therefore, in case of achieving positive and desired results, Eucalyptol and Orange oil can be replaced with Chloroform. Also, to obtain valuable results, future experiments should be conducted based on standard protocols.

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VI. Attachments

Declaração

Mestrado Integrado em Medicina Dentária

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Identificação da publicação

Dissertação de Mestrado Integrado (Monografia) [✓]

Relatório de Estágio []

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Coorientador: Não possuo

Palavras- chave: solvents, Chloroform, Eucalyptol, Orange oil, Xylene, Halothane, micro-hardness, endodontic re-treatment,

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Monografia de Investigação/Relatório de Atividade Clínica

Declaro que o presente trabalho, no âmbito da Monografia de Investigação/Relatório de Atividade Clínica, integrado no MIMD, da FMDUP, é da minha autoria e todas as fontes foram devidamente referenciadas.

21/05/2021

O/A Estudante

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PARECER
(Entrega do trabalho final de Monografia)

Informo que o Trabalho de Monografia desenvolvido pelo Estudante Alaleh Hashemi, com o titulo: “Solvents Impacts on Microhardness of Dentin”, está de acordo com as regras estipuladas na FMDUP, foi por mim conferido e encontra-se emcondições de ser apresentado emprovas publicas.

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