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PREVENTIVE DENTISTRY ACCESSIBLE TO ALL.

TiF4 as an alternative fissure sealant.

NICOL GUERREIRO DE NORONHA.
STUDENT Nº:201402426.
MASTER´S ADVISOR: ANA ISABEL PEREIRA PORTELA.

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Abbreviations

APF – Acidulated phosphate fluoride;

ART - Atraumatic restorative treatment;

CaF_2 - Calcium fluoride;

$Ca_{10}(PO_4)6(OH)_2$ - Calcium hydroxyapatite;

CHX- Chlorhexidine;

CPC - Cetylpyridinium chloride;

DC - Developed countries;

EO- Essential oils;

LDC - Developing countries;

HCl - Hydrochloric acid;

HfF4 - Hafnium tetrafluoride;

NaF - Sodium Fluoride;

KOH - Potassium hydroxide;

SnF_2 - Tin fluoride;

TiF_4 - tetrafluoreto de titânio.

Image index

Index

Abstract

In the contemporary world the exploration of the applicability of fluorides in a clinical context has been growing. One of the fluorides that incited curiosity for researchers in the dentistry field is the titanium tetrafluoride (TiF_4) because of its bactericidal effect, its aesthetic characteristics and its strong adhesion to dental structures.

Thus, this monograph aims to review the potential of TiF_4 as a fissure sealant in order to investigate the possibility of suggesting TiF_4 as a material that in a near future could strengthen the presence of preventive dentistry in rural areas of developing countries.

Nevertheless, there are not enough studies yet to prove the clinical benefits of using titanium tetrafluoride, but its chemical and physical reaction with the dental structure allows the creation of a durable protective shield against bacterial proliferation and acid erosion to which the teeth are daily exposed.

Since there are some older articles that could have significance for this study, the search was time restriction-free and based on the search engine PubMed.

In addition, other preventive methods such as the different oral hygiene materials and the ART procedure are discussed. Its relevance in preventive dentistry of the developing countries is put in perspective with respect to the possible benefits of using TiF_4.

Introduction

Demographically, dental caries continues to be the most common childhood disease(1, 2). Oral health is an integral part of an individual's overall health. Poor oral health is associated with several systemic diseases since the oral cavity is one of the major portals of entry, maintenance and development of various diseases affecting the general population. Additionally, it is a direct influence factor of the diet, the type of nutrition, the amount of sleep, the psychological state, the social interaction, the school performance and the work performance of each individual.

For optimal oral health the ADA (American Dental Association) recommends regular dental visits and a daily proper oral hygiene. These practices aim to ensure that the teeth remain healthy, clean and in the dental arches for a long time. However, LDC, developing countries, remain the most affected because of the socio-economic precariousness to which they are subjected.(3)

Thus, if we want to have a positive effect on the oral and general health of the LDC populations it is necessary to focus on the prevention of dental problems rather than fuel the existent tendency towards dental extraction as a solution to all problems (2).

Since most of the developing countries are rural areas without access to the dentist and without favourable clinical environments, it would be of great importance the discovery of an effective preventive method for this lack of preventive dentistry in the LDCs.

What if there was a better dental sealant than the glass ionomer currently used in the ART procedure?

To find a material with a close to the ideal seal capability, that could be easily used in a rural mission context and that could be commercialized in an accessible and responsible way, would be the perfect solution.

Successful prevention of dental disease in developing countries would have a global positive impact on the health and economy of all populations (4).

With an effective method, LDCs would no longer have health complications related to or exacerbated by dental disease. Children could start their adult lives with a good oral health, which would motivate them to become more concerned with dental care. In addition, they would be able to properly contribute to the economy of the country, since they would not waste days of work or even die, due to medical-dental complications that can be prevented (2, 4).

Materials and methods

This study was based in the search engine PubMed ® and Google Scholar. Most of my research was carried out with no time restrictions since some of the articles of interest were published a long time ago.

It was given preference to meta-analyses, systematic reviews and reviews.

The research began by focusing in understanding how current dentistry is making a difference in developing countries and how preventive dentistry has evolved over these years. After that the search evolved to trying to understand the most common protocol used for fissure sealants in the developing countries: the ART procedure.

Up next the aim of the search shifted to the existing fluorides and the comparison between its characteristics and the titanium tetrafluoride, bringing more focus to the main advantages and disadvantages of the titanium tetrafluoride as a fissure sealant.

The final goal was to compare the current fissure sealants material to the possible use of the titanium tetrafluoride.

The key words used upon this research where the following: “Preventive dentistry”, “titanium tetrafluoride”, “fissure sealants”, “ART”, “atraumatic restorative treatment”, “fluorides”, “developing countries”.

The search resulted in a total of 135 articles. Through the titles and abstract presentations, due to its level of importance for this research, 47 where the final chosen ones.

PREVENTIVE DENTISTRY IN DEVELOPING COUNTRIES

Current situation

In general, most developing countries (LDC) show a weak development of preventive services in dentistry (5, 6). Oral health investments are low and resources are allocated primarily for emergency dental treatment and pain relief (7).

Nevertheless, a good health system must have a strong preventive component (8). To make this possible, it needs an equally distributed number of professionals to guarantee access to the entire population.

In the absence of such an equitable distribution in the LDCs, there is a tendency to consider alternative professionals as people capable of efficiently treating common dental problems, such as, for instance, performing exodontia. With these "associated practitioners", even though these professionals eliminate dental problems without solving the cause, undervaluing due treatment and prevention, they create the possibility of improving access to basic dentistry services effectively (9).

Their lack of training adds a risk to the patient.

Even so, as it is logistically and financially impossible to meet all dental needs in rural areas, prevention should be a major focus of any program whose aim is to improve oral health in developing countries. The promotion of oral health through prevention should be the priority of any oral health care system (10, 11).

There is evidence that increasing the number of dentists is not synonymous of improving the oral health care system (4, 12, 13). Given the exponential growth in the number of students in a largely privatized education (situated in the major urban areas of the LDCs), it would be very important to establish practical teaching programs in rural areas. As it is proven that there is a tendency for the student's preference, once they have graduated, to return to their homeland, it would also be relevant to give more higher education opportunities to the students from rural areas (13).

Preventive methods of the present time

Dental caries are particularly noticeable in developing countries. The best strategy of action against this global pathology is prevention based on information, education and action in the face of the early diagnosis of the conditions that predispose the population to the disease (14).

A study by Van der Weijden compared the efficacy of the preventive methods used in Western LDCs. Comparing the effectiveness of the different methods (toothbrush and toothpaste, miswak branch, dental floss and mouthwash) concluded that, considering the price / effectiveness, the miswak branch (that comes from the Slavadora Persica tree and is still commonly used in the North Africa, Middle East and Central and Southeast Asia) is a better option for dental and interdental hygiene since its use is already rooted in the culture of different populations. Additionally, it is economically accessible to all. The dental floss requires dexterity and instructions for use that are not available in most places and access to manual toothbrushes is dependent on the aids and level of trade at each site. In 2008, the World Health Organization acknowledged the miswak as a healthy alternative to the toothbrush. (15).

Dentifrices and mouthwashes which proved to be more effective in reducing plaque indexes and improving gingival health, mostly as home remedies, contained chlorohexidine (CHX), essential oils (EO) or cetylpyridinium chloride (CPC) as active ingredients (15).

Neutralizing caries-prone cracks and grooves is a preventive measure that has been shown to be quite effective in LDCs through the application of ART sealants (atraumatic restorative treatment) (16).

A study carried out in Syria for children at high risk of caries between the ages of 6 and 7 showed that erupting and erupted first molars, subjected to sealants, were 2.1 times less likely to develop cavitary lesions in dentin 5 years after its application (16). ART sealants are a good method for the preventive treatment of children in the pre-school (17).

Previously the existing solution was the application of silver ammoniacal nitrate and fissurectomy (18), that is, the widening of the narrower and deeper cracks, turning them into cracks that are easy to clean and maintain.

Nowadays the application of fissure sealants is a preventive solution that creates a physical barrier between the dental structure and the cariogenic bacteria (18), representing one of the good allies of current preventive dentistry.

The ART concept

The ART method arose about 30 years ago and is currently included in the public and private oral health systems of the LDCs and also some developed countries (DCs) (16). The concept ART is divided into two parts: the ART sealants and the ART restorations (19). Given its relevance to the theme, we will focus on the ART sealants.

Most of the ART sealants are composed of high viscosity glass ionomer (Ketac Molar Easymix or Fuji IX, e.g.) applied with finger pressure with the aid of hand instruments as a digger for occlusal adjustment and for excess removal (Fig.1).

Figure 1. Protocol of application of ART fissure sealants with Ketac Molar Easymix (1).

Protocol of application of ART fissure sealants:

1. Insulate the tooth with cotton wool rolls. Keep the treatment area free of saliva (a).

2. Gently remove plaque and food debris from deeper parts of cracks and cracks with an explorer (b).

3. Wash cracks and fissures using wet cotton pellets (c).

4. Apply enamel conditioner to the wells and cracks according to the manufacturer's instructions. Condition for the specified time (d).

5. Immediately wash the holes and cracks, using wet cotton pellets to clean the conditioner. Wash 2 to 3 times.

6. Dry the cracks and cracks with cotton pellets. Do not use the 3-way syringe. The surface of the enamel should not be dehydrated.

7. Mix the glass ionomer and apply it to all holes and cracks with the rounded end of the applicator / ART sculptor instrument or shake the glass ionomer encapsulated in a suitable mixing machine and extrude the mixture into all holes and fissures (e).

8. Rub a small amount of petroleum jelly on the gloved index finger.

9. Press the glass ionomer mixture into the wells and fissures with the index finger (technique of pressing the key). Then remove your finger laterally after 10 to 15 seconds (f).

10. Remove the visible excess mixture with the sculptor or with a large excavator.

11. Check the bite using the pivot paper and adjust until you are comfortable.

12. Remove the upper surface of Vaseline with the sculptor or a large excavator when the mixture is partially adjusted.

13. Apply a new coat of petroleum jelly.

14. Remove the rolls of cotton wool.

15. Ask the patient not to eat for at least an hour.

Since there are no favourable conditions for correct isolation of the targeted teeth in a clinical or mission environment in the LDC field, the glass ionomer is a better bet than the resin sealants because it has a higher hydrophobicity (20).

Advantages and disadvantages of the ART sealants

Some systematic reviews have shown that the preventive effect of glass ionomer and composite resin sealants are comparable. However, glass ionomer sealants have a shorter retention period than resin-based sealants (21).

Since the hydrophobicity of glass ionomer sealants is greater than the hydrophobicity of composite resins, glass ionomer sealants appear to be a better option to use in circumstances where it is difficult to achieve the correct insulation and drying of the aimed site (20). However, glass ionomer sealants still require a conditioned surface, minimally dry and free of bacterial plaque (19, 20).

Despite these drawbacks, high viscosity glass ionomer ART sealants have irrefutable advantages.

The short time required, the simplicity and the minimum material required, makes the concept of ART sealants an economically accessible and easily applicable procedure (52). The cost of acquisition is low (21). And when the teeth are subjected to erosion and conditions prone to cariogenesis, the fluoride release increases (22).

In addition, studies conducted up to a maximum sampling period of 5 years showed that there is an annual development of carious dentin in teeth treated with high viscosity glass ionomer sealants by the ART method of about 2% compared to the 5% treated teeth with the resin composite (23-26).

Since it is not necessary to use electrical or water-based sources, ART sealants can be placed in a clinical and non-clinical environment (20), making them a practical concept for developing countries.

As the effectiveness of a sealant is measured by its ability to prevent the onset and development of carious lesions, which capacity is directly dependent on the level of sealant retention, it can be inferred that although the glass ionomer is a good sealing material, it is not ideal(20).

What if there was a biocompatible material, aesthetic, easy to apply and, additionally, with an ideal retention?

TITANIUM TETRAFLUORIDE (TiF_4)

As fluorine varnish - Mechanism of action and compound specifications.

There are relatively extensive studies comparing the properties of TiF4 in the form of fluorine varnish with the properties of other fluorinated compounds. TiF4 has been shown to be a better option in the prevention of dental erosion than the most commonly used fluorides such as sodium fluoride (NaF), tin fluoride (SnF2) and acidulated phosphate fluoride (APF) (1).

Dental erosion consists of localized loss of hard tooth tissue chemically removed from the tooth by an acid or by chelation (sequestration by chemical interaction), without bacterial involvement, in a pathological and chronic manner. For example: Consumption of acidic foods or by an endogenous factor such as recurrent vomiting (e.g., bulimia)(1). This demineralization can be remineralized with the topical application of fluorine which creates the precipitation of (calcium fluoride) CaF2-like compounds on the surface (1, 27).

Demineralized tooth

⇩ Topical fluoride application.

CaF_2 Precipitate (Remineralized Tooth)

Figure 2. Simplified schema of the dental structure remineralization system.

Most topical fluorides dissolve in an acidic environment which gives them limited protection.

In the case of dental erosion, the success of topical fluoride application is greater because (28-30):

1) The organic layer of demineralized dentin serves as a barrier preventing the continuation of the loss of minerals from the deeper layers;

2) The organic layer by its ampholytic nature-like proteins (generalized chemical affinity) can delay / stop the process.

To obtain an intense fluoridation, we need to perform numerous washes and applications, which becomes impractical. With TiF_4 we can create other precipitates besides CaF_2, which are very resistant. This characteristic aroused the interest of researchers.

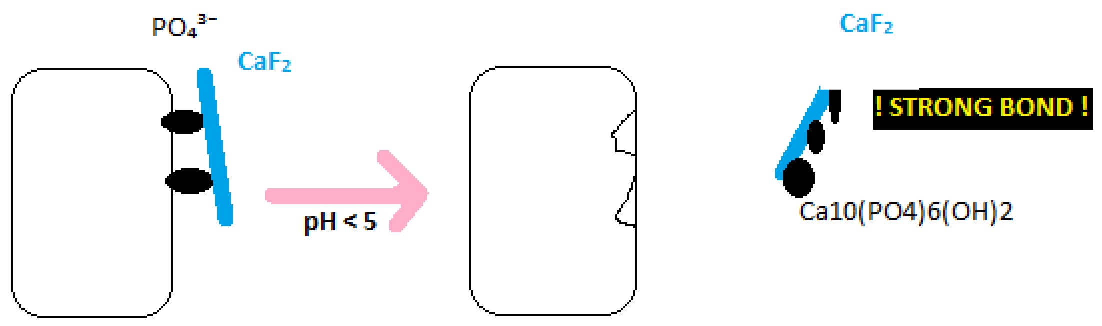
In 2011, it was found that TiF_4 ensures greater protection against tooth erosion (31, 32) and cavities than the fluorides NaF, SnF_2 and APF (1), greatly reducing the loss of minerals until a pH of 1.2 (27, 33).

By microscopic confirmation it was visualized that the 1% and 4% TiF_4-treated enamel is resistant to more than 5 minutes of hydrochloric acid (HCl) application (34) and is also resistant to the application of potassium hydroxide (KOH) (35). In addition, it was observed that teeth treated with 1.5% TiF_4 fluorine varnish presented a stable and extensive granular layer with 5.1 µm ± 0.16 µm thickness which was maintained with a statistically irrelevant difference after application of EDTA / NaOCl (36) and after the application of conditions mimicking the environment, conditions before which the protective layer created by SnF_2 appears largely affected (37).

Nevertheless, there are studies that demonstrate a more effective protection of the enamel submitted to short-term erosive actions when protected by zirconia tetrafluoride and hafnium tetrafluoride (HfF_4) (38).

Comparing the different TiF_4 varnishes, the 4% TiF_4 varnish looks like a better choice than the 1% TiF_4 varnish because it creates a firmer and thicker layer (34), being demonstrated by Skartveit (39) that the depth of penetration of the fluorides is greater the higher the percentage of TiF_4.

TiF_4 creates a protective layer that allows a high absorption of fluorides throughout the tooth structure (enamel, dentin, root canal).



Ca10(PO4)6(OH)2 = Calcium hydroxyapatite.

Figure 3. Topical fluoride binding mechanism - dental structure (1). The low pH created by the presence of a fluoride allows the creation of a strong bond, difficult to destroy, between the fluorated compounds and the dental structure. This strong bond starts with the creation of the CaF_2 with the calcium that constitutes the dental structure. These compunds will bond directly to the phosphates of the dental structure creating calcium hydroxyapatite crystals. These crystals can only be removed together being very difficult, if not impossible, to separate the fluoride from the dental structure again.

McCann (40) suggested the association of the fluoride with a metal to improve its bond strength to the dental structure. A tooth pre-treated with a polyvalent metal (polyvalent = which can have different loads) creates strong bonds between the fluoride complexes and its apatite crystals becoming less susceptible to pH changes.

Titanium fluoride showed to be the metallic association that guarantees a higher absorption / retention of fluoride. Aluminum proved to be the second-best option.

Skartviet (41) analysed the demineralizing effect of highly acidic TiF4 (pH = 1). It compared SnF2 (pH = 1) with TiF4 (pH = 1) and concluded that TiF4 has a high affinity for O2. The TiF4 hydrolyzes the H2O of the tooth by expelling H+, creating an acidic environment. Simultaneously, it creates complexes of phosphate titanium by reacting with the O2 of the phosphate present in the dental structure.

As the bond is strong and makes it almost impossible to replace the H+ back to its former position, the surface of the tooth becomes more resistant to demineralization.

The acidic environment created by TiF4, unlike the SnF, only creates a slight demineralization (that is remineralized after some weeks). This temporary feebleness facilitates the penetration of the fluorides in the hard tissues of the tooth (39, 41, 42).

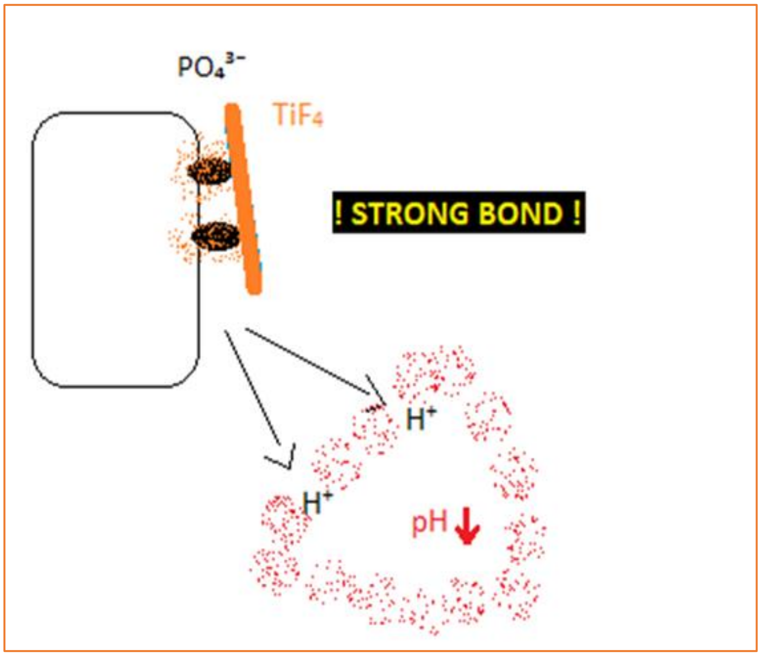


Figure 4. Topical TiF4 binding mechanism - dental structure (1).

With the SnF the bond is easily replaced by H+ because of the weak bonds / complexes it creates with the dental structure. In this case, the tooth loses the protonated phosphates creating a large-scale demineralization.

It is known that TiF4 compared to other topical fluorides allows a greater penetration of the fluorides.

The other fluorides are either not as good (eg NaF) or have high levels of large-scale demineralization (eg acidulated phosphate fluoride) (30, 39, 41).

That is, with TiF4 we obtain a physical protection (the protective layer created) and a chemical protection acquired by the decrease of the solubility of the enamel due to the increase in the concentration of fluorides. In addition, we know that the absorption of fluoride in the enamel is lower in the absence of organic compounds removed by treatment with NaOCl (42, 43), with a higher efficacy of TiF4 in dentin (38) and in biofilm-coated teeth (44).

In 2013 Pragya W. suggests that the importance of the organic matter derives from the great affinity between the Ti and O2 ions of the phosphate group from which a phosphated Ti complex arises. The binding of this phosphate complex is hardly replaced by H+, even at low pH levels, creating a higher resistance to demineralization(45).

To corroborate this hypothesis we have studies that verified that the root canals (with the smear layer present) treated with TiF4 acquired a protective surface with greater thickness (46) and with a hydrophobicity that is largely due to the polymer layer created by the TiF4 (42). A layer that didn´t presented any problem when submitted to the most common irrigators (EDTA 17% and NaOCl 5.25%) (42).

The advantages and disadvantages of using the organic layer of the intracanal smear layer is still debatable (45) and continues to be debatable under the article Use of Titanium Tetrafluoride to alter the smear layer of root canal walls - An in vitro study, de 2013. However, the modification induced by the TiF4, although it lacks a rigorous explanation, seems quite stable and beneficial, becoming a material of interest for the possible application in teeth with greater sensitivity (47). Blocking of the dentinal tubules was shown to be quite effective in the reduction / treatment of dentin sensitivity (47).

In addition, TiF4 has been shown to react easily with animal and human hard tissue, has been shown to have no irritant properties nor toxicity, and a great stability, thus, having also a great potentiality to be used as a preventive method in humans (36).

However, it is also important to mention some features that may be harmful when using topical TiF4. TiF4 has hygroscopic properties (it absorbs water from the surrounding environment with some ease) which may make its handling more difficult (42).

As a channel irrigator there is a high risk since its incorrect application may result in an overdose of fluorides and it is still unclear why the TiF4 treated surfaces present microfractures compared to the control groups that were not cracked even after they had been undergoing the same processes of dehydration(28, 36).

Suggestion of future application of TiF_4 as a fissure sealant.

There are several studies regarding the functionalities of topical TiF4 as a varnish. However, there is only one study, according to the PubMed database and other academic search engines, carried out in 1997, which evaluated the potentiality of TiF4 being used as a fissure sealant. Buyukylmaz and Sean (34) used a solution of topical application of 1% TiF4 and 4% TiF4 for 1 minute on the surfaces of deciduous primary molars expected to exfoliate in the maximum space of 12 months. After application, some of the teeth were subjected to a solution of HCl with a pH of 1.2 for 1 minute or 5 minutes. Although this study aimed to investigate the possibility of using TiF4 as a protector of dental erosion created by endogenous causes (recurrent regurgitation / vomiting by patients suffering from bulimia or some long-term gastroesophageal reflux disease) as the most common prophylactic procedures where proven ineffective in this type of patients, it is important to take into account that in the real life the acid attacks are of shorter duration and discontinued due to the protective work of saliva and surface proteins. The acid attack is usually intermittent and lasts for months and years without ever lasting more than 5 minutes. That is, the tests performed were more severe than what happens in the real context. At the end of the experiment dental surfaces pre-treated with TiF4 and subjected to hydrochloric acid (pH = 1.2) were compared by scanning electron microscopy (SEM) to control teeth. The cracks observed probably arose during the drying of the samples in the preparation for SEM analysis.

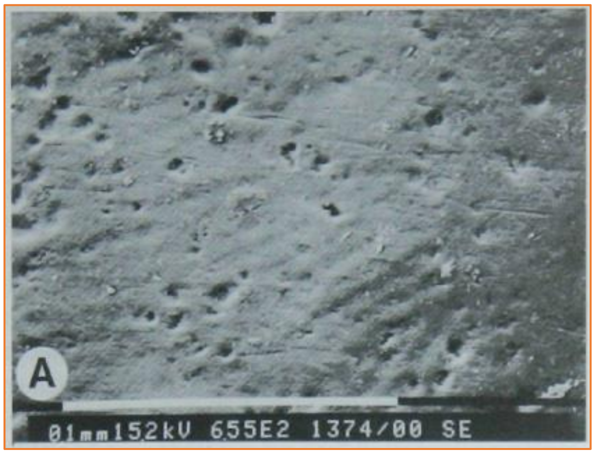


Figure 5. Sound enamel, free of any kind of treatment (1).

Figure 6. Sound enamel subjected to 1min of HCl solution (1).

Figure 7. Sound enamel subjected to 5min of HCl solution (1).

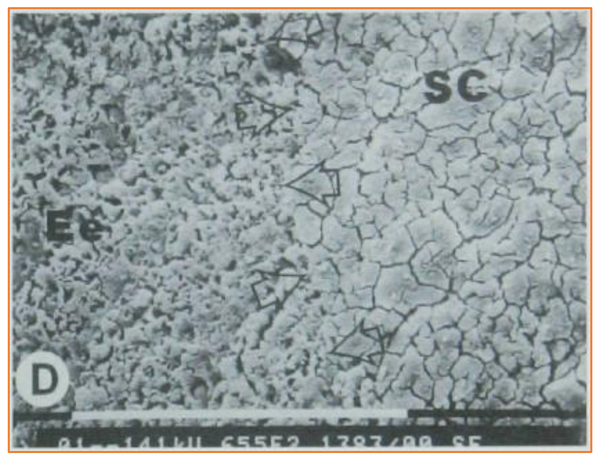


Figure 8. Ee: Sound enamel after acid conditioning. Sc: Enamel protected by TiF4 after acid etching (1).

Figure 9. Enamel treated with 1% TiF_4, submitted to 1min of HCl solution (1).

Figure 10. Enamel treated with 4% TiF_4, submitted to 1min of HCl solution (1).

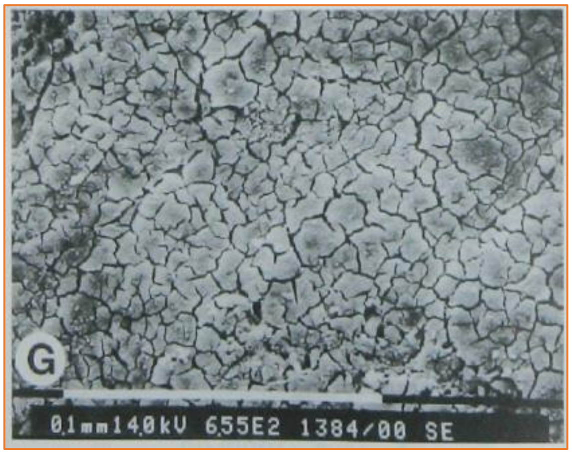


Figure 11. Enamel treated with 1% TiF4, submitted to 5min of HCl solution (1).

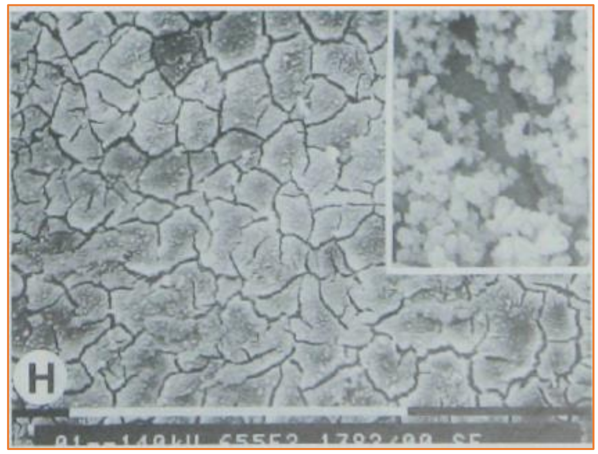


Figure 12. Enamel treated with 4% TiF4, submitted to 5min of HCl solution (1).

Teeth treated with TiF4 are shown to acquire an acid-resistant enamel. The teeth treated with the 4% TiF4 seem better than the 1% TiF4 treated teeth because it presents itself with a firmer and a thicker layer.

According to Tveit and Skartveit. (34, 39) it is proven that the TiF4 is not destroyed nor removed by mechanical agressions such as brushing and chewing harder foods.

Since the effectiveness of a fissure sealant is ascertained by its ability to prevent the onset and development of carious lesions, sealant retention is a crucial point (20).

In this study the TiF4 remained in the grooves for up to 12 months, but the teeth chosen for the experiment exfoliated in that same amount of time. Therefore, it is suggestive that to accredit the benefits of TiF4 as a fissure sealant further studies are needed to demonstrate the benefits of TiF4 in comparison to the other materials used in preventive dental medicine in the LDCs.

In addition, the economic accessibility of the material must be assessed. Since TiF4 has a long history of use in the industry, it is possible that it is economically more affordable than the glass ionomer. However, the material requires increased care by having a slightly exothermic reaction when reacting with dental structure.

However, instead of the glass ionomer used in the ART technique, TiF_4 is readily applicable over the organic layer created by the bacterial plaque, not requiring its removal. And the fact that it does not create gingival irritation or tooth coloration, allows the application of the material in an aesthetic and worry-free way.

Conclusion

The most common clinical preventive protocol in LDCs is the ART protocol that uses bisphenol A-free (BPA-free) high viscosity glass ionomer. Although this method is quite effective, it demonstrates some weaknesses that could be overcome by the substitution or even association with a material such as TiF_4. However, there are few studies that can prove the ability of TiF_4 to overlap the benefits of glass ionomer.

Therefore, in a near future it would be interesting to deepen the knowledge about the behaviour of this material as a fissure sealant and, simultaneously, improve the characteristics of the currently used materials while exploring new materials which may have a potential that could help us to aid where it really hurts the most, in the rural areas of the developing countries.

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Attachments

Attachment 1

Declaração

Monografia de Investigação

Declaro que o presente trabalho, no âmbito da Monografia de Investigação integrado no Mestrado integrado em Medicina Dentária, da Faculdade de Medicina Dentária da Universidade do Porto, é da minha autoria e todas as fontes foram devidamente referenciadas.

Porto, 17 de Maio de 2018

(Nicol Guerreiro de Noronha)

Attachment 2

Parecer do Orientador

Informo que o Trabalho de Monografia desenvolvido pela estudante Nicol Guerreiro, com o título "Medicina dentária preventiva acessível a todos. TIF_4 como selante de fissuras.", está de acordo com as regras estipuladas na FMDUP, pois foi por mim conferido e encontra-se em condições de ser apresentado em provas públicas.

Porto, 17 de Maio de 2018

A orientadora

(Professora Doutora Ana Isabel Pereira Portela)

ERRATA

Page 1, 4th paragraph:
Where you can read “PubMed” it should be read “PubMed ® and Google Scholar”.

Page 2, 2nd paragraph:
Where you can read “subjected.(3)” it should be read “subjected (3).”.

Page 4, 1st paragraph:
Where you can read “Most of my research” it should be read “My research”.

Page 6, 2nd paragraph:
Where you can read “concluded” it should be read “it was concluded”.

Where you can read “Slavadora Perisca” it should be read “*Slavadora Perisca*”.

Where you can read “the toothbrush. (15).” It should be read “the toothbrush (15).”.

Page 9, 6th paragraph:
Where you can read “holes” it should be read “fissures”.

Page 9, 7th paragraph:
Where you can read “cracks and cracks” it should be read “cracks and fissures”.

Figure 3. Corrected.