

The Use of Resinous Infiltrants for the Management of Incipient Carious Lesions: a Literature Review

Uso de Infiltrantes Resinosos para Tratamento de Lesões Cariósicas Incipientes: uma Revisão da Literatura

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Recebido em: 10/05/2019; Aprovado em: 19/07/2019

Abstract

The objective of this work was to analyze scientific evidence from a literature review pertaining to the effectiveness of resinous infiltrants for minimally invasive treatment of incipient carious lesions. Studies published between 2002 and 2019 were queried from the following databases: Capes, PubMed, Medline, BBO, Lilacs and SciELO. The search keywords included “Dental Caries”, “Tooth Remineralization”, “Dental Leakage”. Most of the studies found resin-infiltrating treatment to be a viable option for the minimally invasive treatment of incipient carious lesions; this treatment was able to fulfill the primary expected effects: inhibition of carious progression and the lesions esthetic improvement. However, some issues need to be clarified to improve the safety of this treatment because it can be recommended in clinical practice. In conclusion, the use of resinous infiltrants has been reported as promising for the treatment of incipient carious lesions. However, there is a need for long-term studies to confirm the effectiveness of this treatment to determine its applicability for clinical use.

Keywords: Dental Caries. Dental Leakage. Tooth Remineralization.

Resumo

O objetivo desse trabalho foi analisar evidências científicas, por meio de uma revisão de literatura, sobre a eficácia do uso de infiltrantes resinosos para o tratamento minimamente invasivo de lesões cariosas incipientes. A seleção do material literário utilizado foi realizada por pesquisa sobre o tema nas bases de dados: portal de periódicos Capes, PubMed, Medline, BBO, Lilacs e SciELO, abrangendo prioritariamente, o período de 2002 a 2019. Para busca nas bases de dados foram utilizadas palavras-chave como “Cárie Dentária”, “Remineralização Dentária”, “Infiltração Dentária”, assim como suas correspondentes na língua inglesa. A maioria dos estudos encontrados aponta o tratamento infiltrante resinoso como uma opção viável para o tratamento minimamente invasivo de lesões cariosas incipientes sendo capaz de cumprir os principais efeitos esperados: inibição da progressão cariosa e melhoria estética das lesões. Entretanto, alguns impasses necessitam ser esclarecidos para que o tratamento seja recomendado com mais segurança na prática clínica. Conclui-se que o uso de infiltrantes resinosos tem sido relatado como promissor para o tratamento de lesões cariosas incipientes, contudo há necessidade de novas pesquisas e estudos a longo prazo para confirmar sua eficácia em todos aspectos desejáveis para seu uso clínico.

Palavras-chave: Cárie Dentária. Infiltração Dentária. Remineralização Dentária. 1

1 Introduction

Caries is a condition often found in the oral cavity and remains a factor of concern in the dentistry area ¹. It has a multifactorial origin and chronic character², and it is associated with an imbalance of the demineralization and remineralization processes²⁻⁴. Successive exposures to bacterial acids with partial mineral replacement leads to an enamel demineralization on the subsurface²⁻⁵, causing the hydroxyapatite crystals dissolution and generating porosity internally⁶.

The clinical manifestation on the dental enamel surface that appears at the beginning of the caries process is the emergence of a whitish, opaque and rough area, called white spot lesion, which tends to be an aesthetic problem for many patients².

When they are in their initial stages, there is a possibility

of remineralization of incipient lesions in the enamel²⁻⁴. Therefore, it is of utmost importance that the diagnosis and treatment of lesions be performed as early as possible to avoid the minerals continuous loss and prevent the cavitation of these lesions, as well as allow the possibility of being treated in a non-invasive or minimally invasive way⁴.

When the carious injury progresses, deepening in the dentin, the restorative treatment is indicated in many cases, and consequently the chances of involvement of adjacent healthy dental structure are higher ⁷. It is known that restorations may undergo substitutions as time goes by, and this process, occurring several times, tends to lead to an increase in the damage to previously intact structure.

The development of less invasive techniques in the restorative procedure with the introduction of new materials promoted treatments with less wear of tooth structure, without

complaints regarding pain and anesthesia, reducing the patient's discomfort and anxiety during the treatment³. Thus, the acquisition of new knowledge on caries has enabled that, for some types of injuries non-operative treatment could be performed⁸.

The remineralization, through the application of remineralizing agents, such as fluorides, is the conventionally indicated treatment for lesions of white spot syndrome^{3,4}. Ideally, it is sought to interrupt the demineralization process and repair the incipient carious lesions. However, the use of this type of treatment seems to have limited success⁸, because these lesions can last a very long time when the body of a superficial lesion becomes mineralized while the body of the underlying lesion remains porous^{5,6,8}.

Thus, aiming at more conservative and satisfactory results, resinous infiltrants were developed. These are hydrophobic materials with low viscosity and high penetration power, able to penetrate the porous body of the caries lesion, filling up the enamel porosities and inhibiting the demineralization progress and possible cavitation^{3, 9 - 12}. Therefore, the infiltration of carious tissue emerged as a micro-invasive alternative to control the caries initial lesions³ being reported as favorable to the goals of minimal intervention.

In addition, the resinous infiltration seems to modify the whitish appearance of carious enamel, by filling its micro porosities with a material that provides optically characteristics more similar to healthy enamel. This leads to a masking of injuries and improves the aesthetic appearance^{3,11}.

Given the above, it is important to broaden the knowledge about the resinous infiltrants and their use in minimally invasive dentistry.

2 Development

2.1 Methodology

The selection of the literary material used in this article was performed on the subject of the data base: journal portal of Capes, PubMed, Medline, BBO, Lilacs e SciELO. The search keywords included "Dental Caries", "Tooth Remineralization", "Dental Leakage", as well as their corresponding words in English language. Available on-line publications covering primarily the period from 2002 to 2019, in Portuguese, Spanish and English, addressing issues related to the topic of this article were considered.

2.2 Minimally Invasive Treatment for Incipient Carious Lesions

Cariou lesions, in the initial phase in enamel, are characterized by mineral loss in the lesion body, while the lesion surface may remain relatively preserved^{5,7}. In the demineralized surface, the increase of the enamel porosity generates a whitish effect and the lesion begins to have a white and opaque appearance. With the increase in opacity, the lesion becomes visible even under wet conditions¹³. Such

a change in coloration of dental enamel causes aesthetic problems, mainly in the buccal surfaces of anterior teeth.

In older concepts of dentistry, the surgical approach for removal of carious tissue and the extension for prevention predominated. However, with the passing of the years, it was realized that there was no need for the removal of healthy tissue aiming at prevention, and that treatment should be more conservative¹⁴, because the restoration did not guarantee, in the long term, that the enamel would remain healthy. On the contrary, it would indicate that, it would possibly start a repetitive restoring cycle. Then, conservative strategies in the caries management began to be recommended¹.

Currently, the goals of modern dentistry for the caries treatment involve procedures that promote the prevention of new lesions, with early lesions detection and minimally invasive treatment^{1,12}. Thus, treatments emerged such as the remineralization treatments by use of topical agents such as fluoride and casein fosfopeptideo - amorphous calcium phosphate (CCP-ACP), micro abrasion, application of conventional resin adhesive, sealants and minimal restoration with composite resin¹⁵. However, these treatments have limitations, which have been stimulating research in the search for new materials or techniques with better results for the treatment of incipient carious lesions.

The most common treatment used in initial carious lesions in enamel is the remineralization through the application of fluoride associated with guidelines for oral hygiene and proper diet⁸. However, the remineralization degree afforded by this type of therapy seems to be limited to the enamel not being able to act completely in lesion already located in the dentin⁸.

In addition, there is the need of the patient's cooperation so that such regimen be successful, and the lack of patient adherence to treatment causes the enamel demineralization remains a challenge¹⁶. Therefore, the results may not be effective in high-risk patients, non-collaborators and there are also greater difficulties in proximal regions⁸. Considering that the greatest part of the lesion detection signal would be related to deeper demineralization, in the body of the lesion, a remineralization only on the superficial lesion layer would not be effective enough in an attempt to halt the caries progression, nor to bring the expected aesthetics improvement^{17,18}.

To circumvent this problem, the technique of resinous infiltration of incipient caries was developed¹⁴. The knowledge that inside the carious lesion there is increased porosity and these openings act as dissemination paths that allow the demineralization process⁸ motivated the laboratory studies evaluating the possibility to penetrate these lesions with materials that were able to occlude such porosities.

The concept of decay infiltration with resinous material was developed in the decade of 1970, being that in 1975 the first report occurred of the adhesives penetration on artificial and natural lesions of white spot by Davila and collaborators¹⁹. Since then, the penetration of resinous materials with low

viscosity, such as dental sealants and adhesives were investigated as an attempt of treatment for carious lesions that affected the enamel^{9,20}. However, initially, the use of these materials resulted in an incomplete penetration in the depth of the lesion¹³.

Thus, aiming to find materials with improved properties to penetrate in initial carious lesions in enamel, several studies with experimental material (on the basis of triethyleneglycol dimethacrylate - TEGDMA) were carried out^{8,9,21} comparing them to the materials until then available^{9,22,23}. To distinguish these materials from adhesives and sealants, the authors termed the new media “infiltrant”, which showed high infiltration capacity in the carious lesions²².

Based on several studies^{9,22,23}, researchers from the University of Charité (Berlin, Germany) worked on the development of a resin of low viscosity finding a mixture (TEGDMA, BisGMA, camphor quinone, dimethylamine and ethanol) well suited to infiltrate in incipient lesions in enamel, with high penetration coefficient and rigid consistency after polymerization. Thus, it was commercially released in March 2009, the infiltrant Icon® (DMG, Hamburg, Germany)³.

2.3 Mechanism of action and indication of the resinous infiltrant

The resinous infiltrant is a resinous material of low viscosity with potential to penetrate deeply into the porous enamel, due to pressure of capillarity²⁴, and obliterate the pores inside the body of the carious lesion, because these can serve as pathways for dissemination of acids and dissolved minerals, in order to prevent the continuous demineralization⁸. The infiltrant acts by encapsulating the remnants of enamel prisms, which are reduced in diameter by the caries process, and creating a hybrid mixture of prisms of demineralized enamel and a circumfluent polymerized network of resin infiltrant²⁵. In addition, it interacts with the oral environment restructuring the initial demineralized enamel²⁵. Thus, the infiltrating replaces the hard tissues lost by reinforcing the remaining tooth structure¹⁴.

An additional effect on the use of resinous infiltrant is the aesthetic improvement achieved in white spot lesions in anterior teeth^{16,20}. The resinous infiltrants fulfill the pores of the demineralized enamel with a resinous material whose index of refraction ($n_D = 1.52$) is closest to the hydroxyapatite ($n_D = 1.62-1.65$), providing optical characteristics similar to adjacent intact enamel²⁰, positively influencing the aesthetics of this region.

Thus, the resin infiltration technique is mainly indicated for incipient caries lesions in enamel, in the buccal surfaces and in the proximal region, with thin superficial layer more easily penetrated^{20,26}, without cavitation and not prominent, with the possibility of being located in the whole extension of the enamel, up to and including the first and second portions of the enamel, and even those lesions with maximum radiographic extension until the outer third of the dentin¹⁸.

There are also positive reports on the application of resinous infiltrants in caries lesions of occlusal fissures, although this is not a frequent indication^{27,28}.

2.4 Studies on resinous infiltrants

2.4.1 Mechanical properties and depth of the infiltrant penetration

Considering that, after the application of the product, the infiltrant will perform its actions through the penetration in the porosities inside the carious lesion body, the ability to impede the carious progression process would be related to its penetration depth in the lesion⁷. Paris *et al.* mentioned that in order to avoid a greater enamel demineralization in injuries it is important that a full and homogeneous penetration of infiltrating resins be performed²². Thus, the greater the depth of infiltrant penetration into the carious lesion, the better the expected effects would be, mainly in the purpose of inhibiting the progression of the lesion²⁹.

It is also of clinical interest that the infiltrants, upon penetrating the regions affected by the initial caries, could provide mechanical properties similar to healthy tooth, making these regions less fragile²⁴ and able to withstand tensions of masticatory forces or brushing forces. Another expected feature is that there is a high degree of the material conversion, since it indicates the percentage of monomers conversion in polymer and an adequate rate of polymerization is favorable to the material longevity after its penetration in the tooth structure²⁴.

Studies have been conducted in an attempt to promote the consolidation of this material category - infiltrants - both with the existing trademark (Icon®), as well as through research with experimental products, improving technique and formulations that provide a product capable of generating the expected effects in its use. Regarding the formulation, studies indicate that materials based on resin with high concentrations of TEGDMA have high penetration capacity^{9,22}, although higher concentrations of this monomer seem to reduce the mechanical properties of the photopolymerized resin²⁹. This occurs because it is a very hydrophilic monomer and that generates higher risk of being degraded in the oral environment, due to its high solubility when compared to other monomers³⁰. These factors may impair the clinical efficiency of the resinous infiltrant.

Considering that the commercialized infiltrants today have their composition based on TEGDMA, some studies have tested alternative formulations to remedy the unsatisfactory aspects of this formulation^{24,31}. However, difficulties have been encountered in developing a material that has at the same time a low viscosity capable of providing better product penetration associated with the ideal mechanical resistance. The properties of experimental infiltrating mixtures including: TEGDMA (100%) and formulations combined with BisEMA or UDMA, varying the presence or not of solvent (ethanol

and HEMA) in different percentages, comparing them to the infiltrating trademark Icon®, was evaluated by a study that explored tests related to the degree of conversion, modulus of elasticity and hardness²⁴. This study reported that the addition of solvents was harmful to the final material regarding the assessed properties. Among the associations of monomers, TEGDMA as monomer basis, without the addition of solvents, was the infiltrant with the best properties in all the tests. This was the one that most approached the infiltrant commercially available (Icon®), indicating that can also be used as an infiltrant in incipient lesions in enamel²⁴.

However, in a general way, the influence of the resinous infiltration with the TEGMA-based formulation commercially available, on the mechanical properties of the infiltrated regions seems positive, with increase of the microhardness of infiltrated surfaces³²⁻³⁴. The resinous infiltrant is also able to ensure mechanical benefits to the demineralized enamel to make it more resistant to demineralisation^{9,33}.

Analyzes of surface and morphological aspects of the lesions after resinous infiltration showed improvement in surface stability and good resistance when subjected to abrasion by toothbrushing¹³, resulting in an interesting finding when one thinks about the infiltrant longevity exposed to everyday factors in oral environment.

Regarding the technique, the greatest time of application of the resinous infiltrant is a factor related to greater penetration depth of the same⁷. On the other hand, a complicating factor that seems to be inhibiting to the penetration of the resinous material would be the presence of more mineralized superficial layers of the natural enamel lesions³⁵. Therefore, a pre-treatment of dental surfaces before the infiltration of the resinous product is considered an important step of the technique for removing these layers on the lesion surface and allow better penetration of the infiltrant. The previous preparation with hydrochloric acid to 15% for 120 seconds showed better results in studies that analyzed the different pre-treatments for surfaces to be infiltrated, being recommended by the technique currently used³⁵. In addition, the literature suggests that the use of ultrasonic application with the resinous infiltration can increase the depth of the material penetration in the carious lesions³⁶.

2.4.2 Biocompatibility

Although there is a need for a previous preparation with strong acid on the dental enamel for better infiltrant effectiveness, it is important to consider its biocompatibility in oral environment. However, there are few studies on this context.

Due to the fact of the hydrochloric acid being a corrosive product, this may cause damage to the tissues, such as ulcers on the gums^{25,37}. Thus, in order to avoid contact with the tissues, it is necessary to their protection with absolute isolation³⁷, which may be associated with the use of gingival barrier, as well as posterior aqueous abundant irrigation, being adopted as protocolary precautionary measures.

In spite of the risks of damage to soft tissues due to the use of hydrochloric acid, in a general way, studies have not reported sensitivity due to the use of the product.

Another important consideration is the risk of the conditioning with hydrochloric acid to generate additional demineralization as microcavitations by wear to the undamaged adjacent enamel to the area of the initial bacterial lesion and increase the lesions roughness, which would favor the biofilm accumulation and the recolonization by cariogenic bacteria³⁸, especially in places of difficult access to perform efficient oral hygiene, as in the proximal tooth surfaces below the contact areas of the neighboring teeth²⁵.

2.4.3 Antibacterial property

The literature regarding the presence or absence of the infiltrants antibacterial property is still scarce. What is known is that one of the main components in the commercialized resinous infiltrant formulation, TEGDMA, seems to influence the growth patterns of certain bacterial strains and biomass formation, reducing the oral biofilm adhered on the surface of the tooth enamel, which could inhibit the bacterial growth³⁹. However, these effects were investigated in a few studies, and only under in controlled in vitro conditions in relation to the selective bacterial species, showing contradictory effects depending on the concentration of TEGDMA and pH of the surrounding environment^{39,40}.

Thus, the knowledge about the interaction of oral microflora and infiltrated enamel is still small³⁹. Therefore, further studies evaluating experimental compositions with antibacterial components are necessary in order to affirm the best formulations to achieve this goal.

2.4.4 Effect of inhibition on the progression of the incipient carious lesion: clinical studies

Scientific evidence on the effect of infiltration in the inhibition of carious lesion progression in patients of varying age groups were found in five clinical studies conducted between the years 2010 and 2019, involving the analysis of the different treatments results^{11,28,41-44}.

Evaluating the studies results, the lesions treated by resinous infiltrating material had lower rates of progression than those not treated or which received other types of treatment as sealing with adhesives in proximal cavities⁴⁵, occlusal sealants²⁸ or only the use of conventional non-invasive measures in proximal lesions as instructions to the diet, use of dental floss and fluoride therapy^{11,42,43} and varnish toothpaste *versus* resinous infiltration in combination with fluoride varnish⁴¹.

In a general way, the effectiveness of resinous infiltration was proved in the inhibition of the carious process for both smooth surface lesions (vestibular)⁴³ and occlusal²⁸ and proximal lesions^{11,42,44-45}, with radiographic extension until the outer third of the dentin, for a monitoring period of up to 3 years.

2.4.5 Effect of improvement in the lesions aesthetic aspect of white spot: clinical and laboratory studies

Most of the studies observed that an effect of aesthetic improvement can be obtained after the white spot lesions infiltrations, reported both in laboratory studies^{17,46, 47}, as well as in clinical evaluations^{6,45,48-50}.

However, there is a questioning about the stability of the resinous infiltrant color, in the long term, which could compromise the aesthetics of the infiltrated areas. Before such consideration, some studies analyzed potential changes in the resinous infiltrant color when subjected to the dye solutions for different periods of time^{16,20,33}, as well as the clinical durability of aesthetic improvement achieved after the infiltrant treatment^{45,48,49}.

Laboratory studies that evaluated color changes after the samples immersion in coloring solutions for different periods of time pointed to noticeable changes in color in an average of one week of contact with dye^{15,16,20}. However, some studies have noted that when the samples were subjected to polishing, this had a strong effect on the reversion of coloring, both of the areas treated with infiltrating resin and those not treated^{16,20}. Another laboratory study³³ also pointed out that the polishing performed soon after the resinous infiltration would be an important factor to make the infiltrated lesions more resistant to the staining effects over time.

A clinical study conducted by Altarabulsi *et al.*⁴⁵ accompanied the color stability after resinous infiltration in initial proximal lesions. After a week, aesthetic improvement was noted. However, after one year, the infiltrated surfaces showed a statistically significant increase of discoloration. Whereas other clinical studies that evaluated the durability of the similarity of color among the infiltrated white spot lesions and the undamaged adjacent enamel observed positive results in periods of six months^{48,10} months⁵⁰ and 12 months after the resinous infiltration⁴⁹. In spite of the statements that infiltrating resin has a tendency to discoloration one should consider the need for further *in vivo* studies to assess the real potential of the coloring material in natural conditions, since laboratory investigations carried out with the pure Icon® material, no infiltration¹⁵ or artificially created carious lesions in bovine enamel²⁰ or extracted human teeth¹⁶ subjected to artificially staining procedure, can have very different results than it would be in the oral environment, because they do not take into account factors such as the presence of saliva and the brushing action associated with the use of toothpaste, which could increase the resistance of the infiltrant to discoloration in clinical treatments²⁰.

2.5 Discussion

It can be assumed that the use of resinous infiltrants for the treatment of incipient carious lesions seems to be a promising alternative within the concepts of minimally invasive dentistry. This method has been reported as able to inhibit the carious

lesions progression in its initial phase, preventing progress and affect even more the healthy dental tissue, evolving to stages where a restorative treatment would be unavoidable. Acting in the initial stages of the carious process, the resinous infiltration is a viable option for dental preservation.

In addition, several studies show that there are more advantages of resinous infiltration when compared to other treatments techniques of the caries initial lesion in enamel such as: increase of the microhardness and greater mechanical stability of the enamel surface^{13,14,32-34}; increased resistance to demineralization of the infiltrated surfaces and ability to stop the progression of carious lesion^{11,27,41-44}, aesthetic improvement of white spot lesions^{6,17,33,46,48,50}, immediate aesthetic results with just a single session, saving clinical time^{6,50}.

The risk of post-operative sensitivity and increased surface roughness due to pre-treatment with hydrochloric acid, with a possible tendency to greater biofilm accumulation in proximal surfaces, favoring future demineralization and secondary caries were mentioned concerns about this technique^{25,38}. However, the clinical studies indicate that the resinous infiltration seems to have high acceptance¹⁴ and patient satisfaction. In general, the treatment was comfortable for patients, painless⁶ and there were no reported cases of post-operative sensitivity¹⁴. In addition, another favorable factor for the patient is that the technique is performed without the need of anesthesia or the dental drill

However, despite the majority of laboratory and clinical studies indicate favorable results for resinous infiltration technique, some issues still need to be clarified, since there are studies with conflicting results concerning the complete inhibition of carious progression, suggesting that a total stabilization of the lesion cannot be reached³⁸.

Considering that the use of resinous infiltrating is unnecessary in collaborating patients seems to be a risky statement, given that favorable results of conventional treatment would be dependent on the patient as one of the main responsible for the treatment success, which may not be the reality of all cases, especially when applied to children who, in general, collaborate the least and are more susceptible to cariogenic risk factors. It is important to consider that the number of studies involving deciduous teeth is limited and, therefore, further studies would be necessary to defend a more concrete idea about the infiltrants in the specific group of teeth.

Uncertainties about the longevity of the obtained results also exist due to the possibility of the resinous material degradation in oral environment and the stability of the improved aesthetics, since studies demonstrate greater susceptibility of resinous infiltrants to discolorations in the long term^{15,16,20,33,45}. However, some studies affirm that the resinous infiltration method can be recommended for an aesthetic improvement of white spot lesions clinically by up

to 12 months⁴⁸⁻⁵⁰.

Given the above, it can be seen that the use of resinous infiltrants has been reported as a viable option for minimally invasive treatment for incipient carious lesions. However, although there are positive evidences about the use of this material, it is still necessary to solve some of the challenges that remain being questioned. Many studies have been carried out with the aim of creating compositions that meet the ideal characteristics of an infiltrant material suitable for clinical use. However, some difficulty in creating a formulation fully effective in all the expected aspects has been found. Thus, alternative formulations have been proposed only experimentally and the commercialized product for clinical use remains Icon[®] (DMG), a product that is a reference for studies on the clinical environment.

It is remarkable the need for further clinical studies with longer patients follow-up, so that it is possible to demonstrate the real effectiveness of resinous infiltration in incipient carious lesions.

3 Conclusion

The use of resinous infiltrants promising in the treatment of incipient carious lesions. Its use is capable of promoting greater preservation of healthy dental tissues due to the porosity filling of these lesions and by inhibiting bacterial progression and paralyzing the demineralization process. However, the amount of in vivo studies is still limited and with some controversial results. Due to that, it is necessary to perform longitudinal clinical studies to prove effectively the resinous infiltration effectiveness with better safety in the clinical context.

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