Resin infiltrant as a treatment of common changes in dental enamel: narrative literature review

Infiltrante resinoso como tratamento de alterações estruturais comuns do esmalte dental: revisão de literatura narrativa

Infiltrado resinoso como tratamiento de alteraciones estructurales comunes en el esmalte dental: revisión de la literatura narrativa

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Abstract
Minimally invasive dentistry has been considered the most suitable method of choice in order to prevent and treat changes in the tooth surface, such as the initial caries lesions, characterized as white spot. This type of conduction aims to maintain the tooth structure, as long as there is no sign of cavitation on the surface. Thus, in 2009 a material was created based on monomers and additives denominated resinous infiltrant, which has the function of paralyzing this white spot lesion acting through diffusion, where the material fills the microporosities. The only material commercially available is Icon®, which, despite having numerous benefits, has some limitations. Some studies with experimental material have been developed in order to try to minimize the limitations of commercial material. Therefore, this literature review aims to address the characteristics, function, application and indications of the material, as well as its limitations.
Keywords: Caries dental; Composite resins; Dental enamel; Teaching.

Resumo
A odontologia minimamente invasiva tem sido considerada a condução de eleição mais adequada a fim de prevenir e tratar as alterações na superfície dentária como as lesões iniciais de cárie, caracterizadas como mancha branca. Esse tipo de condução visa a manutenção da estrutura dentária, desde que não haja nenhum sinal de cavitação na superfície. Considerando esses aspectos, em 2009 foi desenvolvido um material a base de monômeros e aditivos denominado infiltrante resinoso, que tem como função paralisar essa lesão de mancha branca agindo por meio de difusão, onde as microporosidades são preenchidas pelo material, reforçando sua estrutura. O único material disponível comercialmente é o Icon® que apesar de apresentar inúmeros benefícios tem algumas limitações. Alguns estudos com

material experimental vêm sendo desenvolvidos com intuito de tentar minimizar as limitações do material comercial. Diante disso, essa revisão de literatura visa abordar as características, função, aplicação e indicações do material, bem como suas limitações
Palavras-chave: Cárie dentária; Resinas compostas; Esmalte dentário; Ensino.

Resumen
La odontología mínimamente invasiva ha sido considerada la conducta de elección más adecuada para prevenir y tratar cambios en la superficie dentaria como las lesiones iniciales de caries, caracterizadas como mancha blanca. Este tipo de conducción tiene como objetivo mantener la estructura del diente, siempre y cuando no haya signos de cavitación en la superficie. Considerando estos aspectos, en 2009 se desarrolló un material a base de monómeros y aditivos denominado infiltrante resinoso, cuya función es paralizar esta lesión de mancha blanca actuando por difusión, donde las microporosidades son rellenadas por el material, reforzando su estructura. El único material disponible comercialmente es Icon® que, a pesar de tener numerosos beneficios, tiene algunas limitaciones. Se han desarrollado algunos estudios con material experimental en un intento de minimizar las limitaciones del material comercial. Por lo tanto, esta revisión bibliográfica narrativa tiene como objetivo abordar las características, función, aplicación e indicaciones del material, así como sus limitaciones
Palabras clave: Caries dental; Resinas compuestas; Esmalte dental; Enseñanza.

1. Introduction

The development of tooth structure is considered a dynamic process that can be influenced by external factors such as trauma, infections and diet (Zajac et al., 2020; Ceci et al., 2017; Meyer-Lueckel et al., 2007; Meyer-Lueckel & Paris et al., 2008a; Meyer-Lueckel & Paris et al., 2008b; Paris et al., 2007a). Diet is considered the most common external factor, since it is present daily, during development and after the eruption of the tooth in the oral cavity, and is directly related to caries disease, considered a biofilm-sugar-dependent disease. (Ceci et al., 2017; Meyer-Lueckel et al., 2007; Meyer-Lueckel e Paris et al., 2008a; Meyer-Lueckel e Paris et al., 2008b; Paris et al., 2007a). Such external factors can contribute to the color change in tooth enamel, which is associated with some disorders such as tooth decay, fluorosis, hypomineralization and enamel hypoplasia (Mandava et al., 2017; Aziznezhad et al., 2017; Patel et al., 2019), in addition to dental erosion (Honório et al., 2008a; Honório et al., 2008b). The clinical sign can present itself in a very similar way, being perceived, in most cases, as a white spot (Ceci et al., 2017; Meyer-Lueckel et al., 2007; Meyer-Lueckel & Paris et al., 2008a; Paris et al., 2007a; Dinesh et al., 2017), except for dental erosion where the tooth surface is usually worn and opaque (Honório et al., 2008a; Honório et al., 2008b). However, as they are different disorders, staining can vary from a white spot to a yellow-brown spot or enamel defects, depending on the specificity and degree of each one (Honório et al., 2008b).

Staining on the tooth surface, as well as wear resulting from dental erosion, can promote dissatisfaction in the patient, and may even interfere with their social life, which tends to harm their psychological health (Patel et al., 2019; Honório et al., 2008a; Honório et al., 2008b; Gençer et al., 2019). Considering that teeth with the aforementioned disorders are usually of normal size and shape, more conservative treatments are indicated (Patel et al., 2019). In recent years, efforts have been focused on the development of a Minimally Invasive Dentistry, which aims to prevent and treat it with the least possible removal of healthy dental tissue (Ceci et al., 2017; Meyer-Lueckel et al., 2007; Meyer-Lueckel & Paris et al., 2008a; Paris et al., 2007a; Paris & Meyer-Lueckel 2009). In 2009, a resin material denominate Icon® Resin Infiltrant was launched in the dental market, considered a low viscosity resin material, consisting of a resin matrix based on methacrylate, essentially TEGDMA, initiators and additives (Ceci et al., 2017; Gölz et al. 2016; Inagaki et al., 2016).

Although recently launched on the market, studies in search of such a technique started in the 1970s, when the concept of caries infiltration was first mentioned by Davila et al, 1975 (Davila et al., 1975). From this, other studies were developed using adhesives and/or sealants as infiltrating materials, however, the lack of good results was obtained considering that such infiltrant agents resulted in a superficial or inhomogeneous infiltration, even after conditioning the lesion with hydrochloric acid for confection, the hypermineralized surface layer is more porous and thus facilitates penetration (Paris et al., 2013). However, after some attempts, upon discovering the importance of the penetration coefficient/penetration depth relationship, low viscosity resins were improved, allowing a material with a faster and more effective infiltration, by presenting a considerably higher penetration coefficient (Paris et al., 2013). Thus, in 2009, based on in vitro and in vivo studies carried out in Germany (University Hospital Charité-Berlin) on the penetration of resinous material in incipient caries, the Icon® Resin Infiltrant (DMG America Company, Englewood) showed that if commercially viable (Ceci et al., 2017; Aziznezhad et al., 2017).

Its mechanism of action is based on low-viscosity, hydrophilic and light-curing resins that penetrate and occlude the enamel microporosities, thus inhibiting the diffusion pathways for dissolved acids and minerals within the body of the lesion, preventing the progression of tooth decay in a initial stage of its development (Meyer-Lueckel et al., 2007; Meyer-Lueckel e Paris et al., 2008b; Paris et al., 2007a; Dinesh et al., 2017; Paris et al., 2013). In other words, the principle of resin infiltration is to perfuse the porous enamel with resin by capillary action, thus interrupting the demineralization process and stabilizing the carious lesion (Ceci et al., 2017; Mandava et al. 2017; Aziznezhad et al., 2017; Askar et al., 2018; Anaute-Netto et al., 2017).

The micro-invasive technique of resin infiltrant for incipient caries was added to the surgical techniques in order to change the paradigm of treatment of the initial caries lesion, which went from a strictly restorative intervention to a minimally invasive one, where the lesion is analyzed, its extension and prevention of this extension (Meyer-Lueckel & Paris 2008b; Paris et al., 2007a; Dinesh et al., 2017; Paris et al., 2013). This conservative technique aims at not removing hard tissue, but at infiltrating a low-viscosity resin inside the lesion in order to regress and/or paralyze its extension (Meyer-Lueckel e Paris 2008b; Paris et al., 2007a; Davila et al., 1975; Paris et al., 2013). It's particularly indicated for non-cavitated carious lesions. Compared with remineralization techniques that may require multiple treatment and follow-up sessions, therapy can be performed in a single session, which is interesting for the patient, in particular for children and their parents (Lasfargues et al., 2013).

Currently, the infiltration of carious lesions with low-viscosity resinous material has been used to prevent the progression of the initial carious lesion in a minimally invasive way that is, preserving the healthy tooth structure while treating the lesion (Paris et al., 2013). In addition, recently, this resin material has also been used in cases of fluorosis, hypomineralization, hypoplasia and dental erosion, contributing to the aesthetic improvement of the smile and social inclusion of the affected patient, with a view to maintaining integral health (Patel et al., 2019, Gençer at al., 2019). Therefore, this review article aims to elucidate the application of resinous infiltrates in common structural and dischromic changes in dental enamel, as a minimally invasive option, also explaining its formulations and limitations.

2. Literature Review

2.1 Methodology

This study is a narrative literature review with a descriptive character of resin infiltrants (composition, indications, limitations and prospects). A search for scientific articles was performed, in English, in PubMed, Medline, Lilacs and SciELO databases, during December of 2021 and January of 2022, having as descriptors used in the search "Resin infiltrant" with AND about the subject in topic: "Dental Caries", "White spot lesions", "Enamel defects", "Hypoplasia", "Erosion", "Clinical", "Composition", "Colour stability", "Bioactive", "Follow-up", "Radiopacity". For each theme, summaries were read to verify if the information were relevant to this review and then selected according with studies that showed significant outcomes. Dupplicates and studies with same evaluations were dismiss. The articles were limited during the period of 2001 to 2022. Articles considered gold standard, from previous years, were also considered, mainly to describe basics concepts.

2.2 Current Treatment and its limitation

2.2.1 Incipient caries lesion

Minimally invasive dentistry is a concept that involves the preservation of dental tissue, preferably preventing the disease from occurring or intercepting its progress with as little tissue loss as possible (Inagaki et al., 2016, Sfalcin et al., 2017). In recent years, non-invasive treatment of carious lesions has been the preventive measure of first choice (Meyer-Lueckel and Paris 2008b; Paris et al 2007a; Paris and Meyer-Lueckel 2010, Paris et al 2013). The first treatment for early enamel caries, where cavitations are not yet present, is to control the etiological factor of the disease, promoting remineralization of dental enamel, commonly used methods such as oral hygiene instruction, dietary counseling, remineralization with agents topics containing amorphous calcium fluorides and phosphates (CCP-ACP) and pit and fissure sealants (Ceci et al., 2017, Mandava et al., 2017, Aziznezhad et al., al., 2017).

However, these treatments have some limitations, such as non-immediate results, multiple treatment and follow-up sessions, and the need for patient cooperation for effective results, and because of this lack of adherence/collaboration to the treatment by the patient, many injuries tend to progress (Mandava et al., 2017). In addition, remineralization occurs only superficially, while the lesion body remains porous, which explains the unpredictable results and persistence of whitish discoloration, which also impairs the aesthetics of the smile (Mandava et al., 2017).

2.2.2 Fluorosis, Hypomineralization and Enamel Hypoplasia

Treatment options for teeth with fluorosis, hypomimeralization, and hypoplasia vary greatly according to the degree or depth of the white spot. In recent years, tooth whitening, microabrasion, and direct or indirect restorations have been indicated (depending on the depth and degree of involvement of the tooth) (Reston et al., 2011, Nugroho et al., 2019). Within the concept of Minimally Invasive Dentistry, it is always recommended to start the treatment with more conservative therapies, such as the use of bleaching and microabrasion (Pini et al., 2015). Although tooth whitening and microabrasion, alone or in association, achieve good results in most cases; deeper or moderate-severe fluorotic, hypoplastic or hypomineralized stains may achieve partial results (Habbu et al., 2011, Pini et al., 2015). This depth can be verified through transillumination, where a light-emitting diode (LED) or laser device is placed by the palatine/lingual of the tooth and the potential for blocking the light by the stain is observed, so that the deeper the stain, the darker it will be (Pini et al., 2015). When bleaching and microabrasion are not effective in resolving the stain, direct restorative treatments are chosen, with composite resins, or indirect treatments with ceramic laminates (Habbu et al., 2011, Jain et al., 2016, Pini et al., 2015). The decision of which restorative procedure to follow will be individualized, based on the patient's history, taking into account that, despite being considered conservative treatments, a preparation may be necessary for a satisfactory result (Jain et al., 2016).

2.2.3 Erosion

Methods of protecting dental structures against the effect of erosion may include the use of substances responsible for neutralizing acids and remineralizing dental tissues (Damasceno et al 2019; Zhao et al 2017). In order to prevent erosion, the topical application of fluoride has been used for a long time, as it increases the resistance of the dental hard tissue to acids (Zhao et al 2017). Fluoride in various vehicles such as toothpastes, mouthwashes, gels and varnishes has been shown to be effective in reducing tooth erosion, especially in high concentrations (Ionta et al 2016, Zhao et al 2017). However, the clinical effectiveness of fluoride against erosive challenges remains uncertain due to the nature of acid challenges, as it is necessary to form a protective film over the tooth structure (Ionta et al 2016, Zhao et al 2017). The use of stannous fluoride formulations to prevent erosive wear has been widely discussed in the literature (Viana et al., 2020,Frese et al., 2019, Leal et al., 2020), since greater resistance to acids was observed, when compared to the sodium fluoride formulation; although it is not yet a solution capable of completely inhibiting the loss of tooth tissue exposed to the erosive process (Viana et al., 2020), in addition to presenting some clinical disadvantages such as metallic taste and the possibility of tooth staining (Leal et al., 2020).

Additionally, some studies have tested the use of fluoride and glass ionomer-based sealants as effective surface protectors against the effect of erosion (Damasceno et al 2019; Guedes et al 2018; Hove et al 2008; de Carvalho et al 2007). The authors suggest that they form a protective film on the dental surface and, consequently, because they are a dental biomaterial in which nanotechnology has been applied, they are able to improve the properties of existing materials, filling the gaps and fissures, reducing porosity, as well as increasing wear resistance and maintaining dental integrity. In addition, dietary guidance to the patient who presents erosive wear is essential (Lussi et al., 2007, Lussi et al., 2019); the ingestion of acidic beverages, especially soft drinks and acidic juices, and acidic foods such as citrus fruits should be carefully avoided due to the low pH (Lussi et al., 2007, Lussi et al., 2019). And patients who have gastric disorders, such as gastroesophageal reflux, are commonly referred for medical consultation, as the maintenance of contact with stomach acid to tooth surfaces promotes or increases erosive wear (Lussi et al., 2007, Lussi et al., 2019).

When erosive lesions reach a more advanced stage at the dentin level, it is necessary to carry out a restoration, always emphasizing the concept of minimally invasive dentistry (Lussi et al., 2007). However, considering that the treatment for dental erosion is eminently done in a preventive way, a large part of the success in the treatment is associated with the patient's discipline about following the guidelines, changing habits and going to dental appointments to apply fluoride and control the disorder (Lussi et al., 2007, Ionta et al., 2016).

Given the limitations of the treatments offered for each situation mentioned above, the use of the micro-invasive infiltration technique is promising, being considered an intermediate step between the non-invasive and invasive treatment, within the precepts of Minimally Invasive Dentistry, contributing to the stabilization or postponement of the progression of the incipient caries lesion (Ceci et al 2017; Meyer-Lueckel et al 2007; Meyer-Lueckel e Paris 2008a; Paris et al 2007a; Paris e Mayer-Lueckel 2009).

2.3 Resinous infiltrant indications

The resinous enamel infiltrant was proposed for the treatment of non-cavitated white spot lesions located on smooth dental surfaces, ie, buccal and proximal, with maximum radiographic extension to the outer third of the dentin (Meyer-Lueckel e Paris, 2008a; Borges et al., 2017). However, from the observation of its mechanism and the effectiveness of its application, its use has been investigated in several situations.

2.3.1 Interproximal carious lesions

Conventional restorative treatment of interproximal caries lesions requires prior removal of the teeth, requiring more than one clinical session for treatment, or wearing a healthy tooth structure to gain access to the lesion. Resin infiltrant treatment overcomes these limitations, becoming a more conservative, faster and more effective treatment (Elrashid el al., 2019; Faghihian et al., 2019).

In addition to the wide variety of in vitro and in vivo studies, several clinical studies point to the efficacy of treating resinous infiltration in interproximal caries lesions (Paris & Meyer Lueckel, 2010; Meyer-Lueckel et al 2012; Martignon et al 2012; Meyer-Luckel et al 2016). A placebo-controlled, randomized clinical trial observed 96% efficacy in reducing the progression of infiltrant-treated caries lesions after 3 years of follow-up (Paris & Meyer Lueckel, 2010; Meyer-Lueckel et al 2012). It can also be observed that the relative risk of lesion progression can be up to 11 times lower in infiltrated lesions compared to non-infiltrated ones (Meyer-Lueckel et al., 2012). Another study, also with 3 years of follow-up, reported 68% efficacy of the infiltrant in controlling the progression of lesions, while there was progression in 70% of lesions treated with placebo, despite instruction in oral hygiene using dental floss and local fluoridation and systemic (Martignon et al 2012). Another randomized clinical trial reported, after 18 months of follow-up, a progression of 5% of lesions treated with infiltration, while for non-infiltrated lesions, the rate was 31% (Meyer-Luckel et al 2016).

The most recent data from a longer-follow-up randomized clinical trial (Paris et al 2020) so far reported that after 7 years, treatment with infiltrant significantly reduced the rate of progression of interproximal lesions, which was 7% compared to placebo was 52%, even though all patients were receiving preventive care. The mean rate of treatment failure was 1.3% per year, similar to the rate attributed to composite resin restorations (Opdam et al., 2014). The results support the encouragement of resinous infiltration treatment before opting for a conventional invasive treatment.

When investigated in young children, with a relatively high risk of caries, reports are found comparing lesions in primary molars treated or not with an infiltrant, which indicate that 62% of non-infiltrated lesions exhibited radiographic progression, even with biannual application of fluoride varnish, while among the treated lesions, only 23% progressed (Ekstrand et al. 2010). The most recently published data, from a randomized clinical study with a 2-year follow-up (Jorge et al 2019), report a relative risk reduction of 56% when using the infiltrant, with a progression of 24% of lesions in the test group and 55% in the control, who used dental floss and toothpaste with fluoride. On average, the results of clinical studies of infiltration in primary teeth show a reduction in the relative risk of progression of lesions between 52 and 67% (Ekstrand et al. 2010; Page et al., 2017; Ammari et al. 2018), indicating the treatment efficacy compared to the non-invasive approach alone, even in patients at high risk of caries.

Systematic reviews with meta-analysis, which are the highest level of scientific knowledge, confirm with a strong level of evidence the effectiveness of the infiltration technique (Elrashid et al., 2019; Faghihian et al., 2019) even pointing out its superiority compared to conventional methods of preventing the progression of non-cavitated proximal lesions (Elrashid et al., 2019). It is suggested that this superiority is due to the fact that the other methods require high patient compliance and, in addition, they are intermittent techniques, and de-remineralization cycles may occur even in adherent patients (Elrashid el al., 2019). The infiltrant, on the contrary, establishes a permanent protective film (Elrashid el al., 2019).

2.3.2 Vestibular face

White spot lesions after orthodontic treatment are very frequent, due to the difficulty in cleaning around the brackets of the appliance (Akin et al. 2012; Sonesson et al. 2016). Demineralization is likely to be reversed by the action of saliva or remineralizing agents (Akin et al. 2012; Huang et al. 2013), however, the whitish appearance of enamel commonly remains (Zantner et al., 2006). The vestibular surfaces can also present whitish lesions resulting from developmental defects. Resin infiltration is able to mask these lesions (Paris & Meyer-Lueckel, 2009; Paris et al. 2013), due to the infiltrant's refractive index (1.52), which is close to that of hydroxyapatite (1.62) (Paris et al., 2013). Once applied, the optical characteristics of the affected enamel are altered and it looks like the surrounding healthy enamel (Paris et al., 2013).

The effectiveness of color masking with resin infiltrant has been demonstrated using artificial caries models (Torres et al., 2011; Paris et al., 2013; Theodory et al., 2019; Aswani et al 2019). It has been shown in vitro that white spot lesions on infiltrant-treated enamel, especially those that were polished, exhibited significantly reduced pigmentation after being subjected to prolonged exposure to tea and wine (Paris et al., 2013). On the other hand, non-infiltrated or non-polished infiltrated lesions exhibited greater pigmentation (Paris et al., 2013). Aswani et al. 2019, evaluated the color stability of infiltrated enamel and observed good stability after 8 weeks, with no significant difference between deciduous and permanent teeth. A comparison between the ability of masking white stains in enamel by the application of resinous sealants or infiltrants showed comparable results between the materials (Theodory et al., 2019).

Clinical reports and case series are also available, showing satisfactory aesthetic results (Paris et al., 2009; Munoz et al., 2013; Feng et al., 2013; Eckstein et al., 2015; Domejean et al., 2015; Torres e Borges, 2015; Joaquim et al., 2021). So far, color follow-up studies of up to one year have been found, which report stability of the aesthetic similarity between infiltrated lesions and the adjacent healthy enamel (Feng et al., 2013; Eckstein et al., 2015; Domejean et al., 2015). It is noteworthy that polishing after the procedure is important to prevent pigmentation in infiltrated areas (Paris et al., 2013), as well as to reverse pigmentation (Leland et al., 2016; Borges et al., 2017). Despite the evidence available so far, clinical trials with longer follow-up periods are needed to strengthen the recommendation for this technique (Borges et al., 2017).

2.3.3 Enamel Developmental Defects

Whitish lesions on enamel may also be due to damage in the formative phase of the tooth, the pre-eruptive defects. These are conditions in which there is a reduction in the mineral phase of the enamel, changing its chemical composition and, therefore, its optical characteristics (Denis et al., 2013; Torres and Borges, 2015). Conditions such as fluorosis, traumatic hypocalcification, and molar-incisor hypomineralization (MIH) are examples of pre-eruptive disorders. The resin infiltrant is also indicated for this type of enamel discoloration (Paris et al., 2009; Munoz et al., 2013; Torres & Borges, 2015; Farias et al., 2022).

In addition to the positive results of in vitro investigations on the penetrability and capacity of masking lesions by the infiltrant (Torres et al., 2011; Paris et al., 2013; Crombie et al., 2014; Theodory et al., 2019). Clinical reports and case series show satisfactory aesthetic results of the treatment (Paris et al., 2009; Munoz et al., 2013; Torres and Borges, 2015). In a series of case reports, Torres and Borges (2015) demonstrated the efficacy of the infiltrant in masking whitish pre-eruptive lesions on vestibular surfaces. However, in some cases the masking was not complete, especially in cases of hypomineralization of traumatic origin, which may be related to the histology of these defects, as their depth and morphology are highly variable (Torres and Borges, 2015). The morphology of carious and fluorotic white spot lesions favor a more efficient infiltration (Araújo et al., 2015).

A technical convenience in the treatment with an infiltrant is that if there is a need to apply composite resin, when hypoplastic defects or cavities are associated, the infiltrant works as a binding agent, dispensing with the additional application of an adhesive system (Wiegand et al., 2011). More recently, high infiltrant penetration has been observed in developmental hypomineralization lesions, with penetration into cavitations and dentinal tubules up to 2mm depth (Schnabl et al 2019). This penetration was greater than that which occurs in normal dental tissue, which is limited to decalcified areas of the enamel (Schnabl et al 2019). Based on the positive results obtained, the infiltration technique was suggested as a routine procedure in the treatment of pre-eruptive hypomineralization (Schnabl et al 2019).

2.3.4 Erosion

The application of resinous infiltrant in early enamel erosion lesions has been suggested, due to its ability to form a mechanical barrier against acid challenges, as well as in early caries lesions (Oliveira et al., 2015; Ionta et al., 2016; Tereza et al., 2016; Zhao et al., 2017; Rios et al., 2019). The infiltrant ability to prevent erosion is related to its mode of application, which influences its thickness (Rios et al 2019). It was also demonstrated that the presence of resin infiltrant only inside the lesion does not inhibit the progression of erosion, that is, the material must remain on the enamel surface (Tereza et al., 2016).

The conditioning of the lesion with HCl for 2min recommended in the infiltrant application protocol, however, is debatable. For erosion lesions, which have a lower surface mineral content, with less mechanical stability, this etching can promote enamel loss (Zhao et al., 2017). To compensate for this deleterious effect, it was suggested that etching with HCl should not be carried out, which, however, reduces infiltrant penetration into the eroded enamel (Tereza et al., 2016; Zhao et al., 2016). Another suggestion is etching with H_3PO_4, which is capable of creating the surface with micro retentions for capillary diffusion and adequate infiltration penetration into healthy enamel (Paris et al., 2007; Yetkiner et al., 2014).

Studies have shown the formation of a 100 µm thick infiltration coating layer on the enamel which, when subjected to erosive challenge, did not show loss of structure (Oliveira et al., 2015; Tereza et al., 2016). In a recent study *in situ* (Rios et al 2019), the infiltrant was compared to resinous adhesive and sealant, all applied to simulated enamel erosion lesions and submitted to erosive (chemical) and abrasive (mechanical) challenges equivalent to 4 months duration. Samples treated with infiltrant showed the least wear and the material was not removed from the enamel, confirming its good performance when applied for this purpose (Rios et al 2019).

2.3.5 Occlusal face

Although this is not yet a frequent clinical application, there are positive reports on the application of resinous infiltrants in carious lesions of occlusal fissures (Paris et al., 2014; Anauate-Netto et al., 2017). It is reported that the higher penetration coefficient of the infiltrant promotes deeper filling of pits and fissures than a conventional sealant (Paris et al., 2014). Reports of a randomized clinical study showed, through analysis by different diagnostic methods, comparable results between infiltrant and sealant in the sealing of pits and fissures (Anauatte-Netto 2017). After 3 years of follow-up, infiltrant and sealant exhibited similar marginal integrity; however, the infiltrant showed wear that is more homogeneous and less progression of caries (Anauatte-Netto 2017). Pre-treatment of the infiltrant technique with 15% HCl promotes more intense erosion of the surface layer compared to phosphoric acid (Eakle et al., 2014). In this way, the infiltrant promotes the filling of the body of the lesion, not just creating a superficial barrier (Meyer-Lueckel e Paris, 2008b).

A recent comparison between different commercial pit and fissure sealants and the resinous infiltrant applied to early carious lesions simulated in human tooth enamel observed the highest values of depth and penetration area between the groups for the infiltrant, in addition to the masking capacity (Theodory et al 2019). This was justified by its chemical composition and, consequently, its favorable properties of surface tension, contact angle, viscosity and wetting capacity, pointing to the infiltrant as a promising material in the control of caries progression in pits and fissures (Theodory et al 2019).

However, answers about the enamel surface microhardness of Icon® resinous infiltrant are still uncertain in the literature. Some authors point out that when compared to other remineralizing materials, Icon® presented lower microhardness values (Dhillon et al., 2020; Chen et al., 2019; Rana et al., 2021). However, unlike this conclusion, Zakizade et al., 2020, after a systematic review, found that when compared to no treatment or other products tested, Icon® was able to increase the microhardness of the demineralized enamel, but without reaching the initial microhardness of the sound enamel. However, more studies are needed to obtain more concrete and assertive results.

2.4 Resinous infiltrants formulations

Different formulations have been investigated in order to improve the resinous enamel infiltrant properties (Paris et al., 2007a; Paris et al., 2007b; Paris e Meyer-Lueckel, 2010a; Paris e Meyer-Lueckel., 2010b; Araújo et al., 2013; Inagaki et al., 2016; Andrade et al 2016; Sfalcin et al., 2017; Mathias et al., 2019; Flor-Ribeiro et al., 2019; Gaglianone et al 2020; Wang et al 2021). Ideally, the infiltrant should have low viscosity, as well as low contact angle and surface tension, high penetration coefficient, rigid consistency after polymerization and chemical-mechanical properties compatible with the challenges of the oral environment (Araújo et al., 2013). Other properties such as acceptable aesthetics, bacteriostaticity and radiopacity are also desired (Pedreira et al., 2020; Flor-Ribeiro et al., 2019). To reconcile the ideal characteristics of the material, several components have had their influence analyzed in the composition of the infiltrant.

2.4.1 Monomers

The main component of Icon® is the TEGDMA monomer (Gölz et al., 2016). TEGDMA is a low molecular weight monomer, which gives the material low viscosity (Gonçalves et al., 2009). Furthermore, it is also an extremely fluid monomer and its highly flexible chain structure results in materials with a high degree of conversion (Poshusta et al., 2002; Gonçalves et al., 2009). Studies show that the higher concentration of TEGDMA in infiltrants is related to better penetration depth and degree of conversion results (Gonçalves et al 2009; Meyer-Lueckel & Paris, 2010; Araújo et al 2013). However, this monomer has as a limitation a high hydrophilicity, which facilitates degradation in an oral environment, which can compromise the performance of the material (Paris & Meyer-Lueckel, 2010a; Paris & Meyer-Lueckel, 2010b). Its high polymerization shrinkage is also a limiting factor (Gonçalves et al., 2009). In order to overcome these limitations, different monomeric combinations are investigated.

The addition of more hydrophobic and less fluid monomers than TEGDMA was investigated in order to improve the properties and longevity of infiltrants in an oral environment (Araújo et al 2013). In initial investigations, it was observed that the addition of BisGMA and UDMA significantly increased the viscosity and decreased the infiltration coefficient (Paris et al., 2007a; Paris et al., 2007b). Later, other works used UDMA in their formulations (Araújo et al, 2013; Andrade et al., 2016), obtaining improvements in mechanical properties such as degree of conversion, modulus of elasticity and Knoop microhardness. (Araújo et al., 2013). UDMA monomer has a short chain and low viscosity, just like TEGDMA. Furthermore, both have similar chain morphology, with a linear structure.

Several studies use the composition of 75% TEGDMA + 25% BisEMA (Araújo et al., 2013; Inagaki et al., 2016; Sfalcin et al., 2017; Mathias et al., 2019, Gaglianone et al., 2020), obtaining satisfactory and even improved chemical-physical properties. BisEMA has a considerably longer molecular chain than TEGDMA, therefore, it has greater viscosity and is hydrophobic. Increased hydrophobia can help reduce degradation in the oral environment. Inagaki et al (2016) obtained for the formulation of 75% TEGDMA + 25% BisEMA the lowest sorption and solubility averages, as well as superior elastic modulus and flexural strength when compared to pure TEGDMA, TEGDMA + UDMA and chlorhexidine addition formulations. In another investigation, the experimental infiltrant composed of 75% TEGDMA + 25% BisEMA also exhibited several chemical-mechanical properties (degree of conversion, Knoop microhardness, tensile cohesion strength, elastic modulus and sorption and solubility) superior to the Icon® infiltrant (Sfalcin et al., 2016). It was reported that the lower sorption of the infiltrant composed of BisEMA + TEGDMA compared to Icon® may have occurred due to the high degree of conversion and high hydrophobicity of BisEMA (Dickens et al., 2003).

In a more recent report, it was confirmed that the association of BisEMA and TEGDMA is beneficial, as it reconciles the low viscosity required for penetration with satisfactory polymeric properties (Gaglianone et al., 2020). BisEMA increases the hydrophobic characteristics of the infiltrant, which can help to reduce the hydrolytic degradation of the material in the oral environment (Gonçalves et al., 2009; Araújo et al., 2013, Mathias et al., 2019, Inagaki et al., 2016, Sfalcin et al., 2017; Gaglianone et al 2020).

2.4.2 Photoinitiator Systems

In order to improve the polymerization potential of resinous infiltrants and consequently their chemical-mechanical properties, the incorporation of ternary photoinitiators systems has been investigated (Ogliari et al 2007; Ogliari et al 2008; Paris & Meyer-Lueckel 2009). The most commonly used initiator system is the association between camphorquinone (CQ) and the amine dimethylamethyl benzoate (EDAB) (Sfalcin et al., 2016; Andrade et al., 2016; Mathias et al., 2019; Flor-Ribeiro et al., 2019; Gaglianone et al., 2020), which has a high potential for electron donation for CQ in the excited state. Due to the indication of resinous infiltrants for masking white spot lesions in aesthetic regions, CQ should be used with caution, as its yellowish coloration can compromise the aesthetics of the material (Gonulol & Yilmaz, 2012; Ceci et al., 2017).

Another compound associated with this formulation in order to optimize the polymerization reaction is diphenyliodonium hexafluorophosphate (DPI), or onium salt (Mathias et al 2019). Several studies have reported benefits from the association of DPI in monomeric compounds such as resin adhesives and cements (Gonçalves et al., 2013; Andrade et al. 2016; Dressano et al., 2016).

DPI interacts with the radical generated by the reaction between CQ and EDAB, generating a reactive phenyl radical that allows the formation of a greater amount of free radicals, due to its reaction with residual amines. This association would allow to initiate, improve and increase the polymerization reaction of methacrylate (Ogliari et al., 2008; Gonçalves et al., 2013; Andrade et al., 2016; Golz et al., 2016; Song et al., 2016).

It was observed that the presence of 0.5 and 1 mol% DPI as co-initiator in infiltrants containing 10% ethanol in their formulation promoted an increase in the degree of conversion (Mathias et al., 2019). For infiltrants containing 10% ethanol and HEMA, DPI promoted an increase in the cohesive strength of these materials (Mathias et al., 2019). Infiltrants containing HEMA showed higher sorption and solubility compared to commercial infiltrant, except when 0.5 mol% and 1 mol% DPI was added (Mathias et al., 2019). However, despite these benefits observed, DPI acts as a catalyst and is regenerated at the end of the reaction (Ogliari et al., 2007), so after 10s of photoactivation, its radicals would have already been consumed and its concentration would no longer exert influence on the polymerization kinetics, therefore not affecting the degree of conversion (Gonçalves et al., 2013). Another important point is that the acceleration of the polymerization reaction caused by DPI can result in a reduction in the vitrification time, which can hinder the mobility of molecules (Ogliari et al., 2007). At the end of the polymerization reaction, the polymer has a higher crosslinking density and a high rate of residual monomers, which compromises its quality, negatively affecting the material's sorption and solubility (Ogliari et al., 2007).

2.4.3 Solvents and Diluents

In order to optimize infiltration penetration into the capillary structures of the carious lesion body, another strategy investigated is the addition of solvents or diluents (Meyer-Lueckel & Paris, 2010; Araújo et al., 2013). Although initial studies have shown some benefit from this association, (Meyer-Lueckel & Paris, 2010) it has generally been found that the addition of solvents and thinners, such as ethanol and HEMA, negatively affects the mechanical properties of infiltrants (Araújo et al., 2013; Mathias et al., 2019). The addition of hydrophilic monomers is associated with a plasticizing effect, resulting in infiltrants with greater sorption and solubility compared to commercial infiltrant (Mathias et al., 2019). The presence of ethanol can cause low mobility of radicals in the polymerization initiation centers, reducing the efficiency of the monomeric conversion (Araújo et al., 2013). It is reported that once the infiltrant is applied, the ethanol incorporated into the material cannot be clinically evaporated, as well as HEMA. This could compromise the conversion, as these compounds favor the formation of linear chains and the dilution of a polymeric network in formation, respectively (Ye et al., 2007; Gaglianone et al., 2020).

It is reported that HEMA tends to agglomerate before polymerization, forming hydrophilic regions, which result in greater amounts of residual HEMA after photoactivation, increasing sorption and solubility and favoring accelerated material degradation (Collares et al., 2011; Takahashi; et al., 2011). It was observed that this association caused damage to the properties degree of conversion, Knoop microhardness, elastic modulus and softening rate, resulting in polymers with lower properties (Araújo et al., 2013). Damage to the tensile strength property of experimental infiltrants containing ethanol was also observed, regardless of the monomeric composition tested (Araujo et al., 2015). In general, the presence of HEMA and ethanol in infiltrants promotes a reduction in their chemical-mechanical properties, in addition to not promoting greater penetration depth (Araújo et al., 2013; Mathias et al., 2019).

2.4.4 Bioactives particles

In vitro beneficial effects were obtained by adding bioactive materials to infiltrants (Andrade et al., 2016; Sfalcin et al., 2017; Elembaby et al., 2022). Sfalcin et al. (2017) investigated the incorporation of 10% hydroxyapatite (Hap), amorphous calcium phosphate (ACP), zinc-polycarboxylated bioactive glass (BAG-Zn), bioactive 45S5 glass (BAG 45S5) and calcium silicate modified with beta tricalcium phosphate (β-TCP) and, for all these experimental groups, increased chemical-mechanical properties and a reduction in water sorption/solubility compared to the commercial infiltrant were observed. Water sorption can trigger chemical and physical processes that can be detrimental to the performance of polymeric dental materials (Malacarne et al., 2006). In another investigation, enamel samples treated with an infiltrant containing 10% hydroxyapatite exhibited resistance to acid attack, with preservation of the microhardness of the surrounding enamel underlying the infiltrated area after recurrent demineralization (Andrade et al., 2016). Elembaby et al (2022) observed the mineral density, resin tag penetration and surface of demineralized enamel treated with Icon® and Icon® with nanohydroxyapatite particles in 5 and 10%, the groups containing Hap had good results in those avaliations. Based on the data available so far, it can be observed that the presence of biomaterials in the composition of the infiltrant can, in addition to favoring its chemical-physical characteristics, help to establish a local microenvironment less favorable to demineralization (Andrade et al, 2016; Sfalcin et al., 2017; Elembaby et al., 2022).

2.4.5 Radiopacifying particles

In a previous in vitro study, Pedreira et al., 2021 evaluated the addition of particles of barium and zirconia at concentrations of 25/45% by weight to commercial Icon® and experimental infiltrants in the properties of cohesive resistance, degree of conversion, sorption and solubility, radiopacity and depth of penetration. They found that the groups with the addition of 45% zirconia obtained an increase in radiopacity greater than that of tooth enamel, in addition to improving the cohesive strength of the materials. However, further studies are needed to confirm radiopacity in the resin material. Other radiopacifying elements that can be used in resonant materials are zinc 30, strontium 38, yttrium 39, lanthanum 57, ytterbium 70 and bismuth 83, which vary greatly in concentration in composite resins with different compositions (Yasa et al., 2015, Collares et al., 2010, Dukic, 2017). However, radiopaque particles can have other negative effects, such as increased thermal expansion and hydrolysis of silane bonding agents (Saridag et al., 2015, Pekkan et al., 2016).

2.5 Resinous infiltrants application techniques

2.5.1 Pre-heating

In a recent study, Gaglianone et al., 2020 tested different compositions of experimental infiltrants and their pre-heating. As a result, it was observed that the degree of conversion (DC) was higher for pre-heated materials. The increase in temperature led to a better DC, and according to the authors, this may be due to increased molecular mobility and decreased system viscosity. However, despite the 30% average increase in conversion for groups polymerized at 55ºC, the expected improvement was not observed in all physical properties tested (Collares et al., 2011). The results showed that pre-heating did not influence the elastic modulus (E) and flexural strength (FS) of most groups, corroborating the results of another study with composite resin (Gonçalves et al., 2013). Thus, the pre-heating technique for infiltrants cannot yet be indicated for any specific type of composition.

2.5.2 Modified application

The application protocol of Icon® resinous infiltrant recommended by the manufacturer, with the prior use of hydrochloric acid for 2min, has been followed in several studies as the "gold standard" for performing the technique (Araújo et al., 2013; Borges et al., 2014; Gelani et al., 2014; Araújo et al. 2015; Borges et al., 2017; Ceci et al., 2017; Dinesh et al., 2017; López et al., 2019). However, although prior acid etching promotes greater permeability of the resinous infiltrant, by increasing the porosity of the enamel surface layer, it was observed in some studies that the resinous material exhibited limited permeation in the demineralized area of the enamel (López et al., 2019, Hashimoto et al., 2002). Thus, different times of previous acid conditioning, such as the increase in time, or even the association of 37% phosphoric acid (PA) for 15s with 15% hydrochloric acid (HA) for 2min, were studied at in order to improve the depth of infiltration penetration (López et al., 2019). However, the literature points out that a prolonged time of acid etching can generate more impurities from demineralization on the enamel pores (López et al., 2019, Pini et al., 2017, Meyer-Lueckel et al., 2008), and this can make it difficult to penetrate the material.

In addition, in order to broaden the spectrum of indication of resinous infiltrants, such as filling small cavitated lesions, new approaches to the infiltration technique have been suggested in the literature. Such as the association of resinous infiltrants and subsequent application of a fluid composite resin, or even modifying the resinous infiltrant by inserting filler particles in its composition, in order to promote a consistency similar to a fluid composite resin, aiming both at penetration of lesions and filling cavitations (Askar et al., 2018).

2.6 Resin infiltrants limitations

One of the disadvantages of Icon® is that it is a radiolucent material, which may be a concern for some dentists, as the supposed efficacy of the treatment cannot be evaluated, so the progression of the lesion cannot be monitored in subsequent visits (Lasfargues et al., 2013, Pedreira et al., 2021). In addition, the radiopacity of dental materials is important to distinguish them from dental structures, as well as allowing the clinician to detect secondary caries, defects, under- or over-contouring of restorations, points of contact with the adjacent tooth and failures (Saridag et al., 2015; Pekkan et al., 2016; Hosney et al., 2017; Pedreira et al., 2020). It is also a valuable tool to assess the absorption of materials in dental structures (Pekkan et al., 2016; Collares et al, 2010). There is an in vitro study (Pedreira et al, 2021), however, this can be considered a pioneer study in the analysis of the addition of radiopacifying particles in resinous infiltrants, requiring further studies to confirm the radiopacity in resinous material, without damage to its physical-mechanical properties.

In addition, as the infiltration penetration into the tooth structure is deep, it is permanent and the infiltrated material for being in the oral environment suffers some challenges in this environment, such as toothbrushing (Li et al., 2021). Among these processes, we have the abrasion resulting from the use of dental dentifrices, which wears the resinous material and increases the surface roughness of the material, affecting its performance (Souza et al., 2017). The use of conventional dentifrices in association with acid attacks found in the oral environment cause significant wear on the surface of the infiltrate, when considering its use over the years and this loss of properties can lead to a decrease in its effectiveness on the surface dental applied (Yetkiner et al., 2014). According to previous studies, it is known that brushing with dentifrices, in addition to increasing roughness, also has a direct influence on the change in color of conventional composite resins. The relative abrasiveness of the dentifrice can interfere with the surface smoothness and loss of shine of composites. This is due to the increase in porosity and the loss of mass of the material, thus causing the color change (Amaral et al., 2006; Heintze et al., 2010).

The use of resin infiltrant has shown good potential in some studies to improve the appearance of demineralized areas (Paris & Meyer-Lueckel 2010; Borges et al., 2014; Paris et al., 2010a; Paris et al., 2010b; Hammad et al., 2020). However, although Icon® has an efficient immediate effect to mask the lesion, the durability of its effect as well as its pigmentation is controversial and needs further studies (Silva et al., 2018; Borges et al., 2017). Additionally, a study carried out in 2014 (Rey et al., 2014) that compared Icon® to other materials showed that the commercial infiltrant had a high pigmentation potential for different dyes, and the same was seen in other studies (Ceci et al., 2017; Borges et al., 2014; Araújo et al., 2015; Silva et al., 2018; Rey et al., 2014; Alqahtani et al., 2022). Given the confirmation of pigmentation, then evaluating the possibility of removing the stain caused by the dyes, some authors suggest surface treatments such as polishing (Borges et al., 2014; Paris and Meyer-Lueckel 2009; Leland et al., 2016) and whitening (Araújo et al., 2015b). Furthermore, Icon® is a TEGDMA-based resin material (Chen et al., 2019). This, in turn, is considered a monomer with greater hydrophilicity when compared to other monomers of higher molecular weight, thus promoting greater affinity with water and consequent increase in water sorption and solubility (Chen et al., 2019), or which can generate inferior mechanical properties, in addition to contributing to staining.

3. Final Considerations

Resin infiltrant is an excellent option for treating early caries lesions as well as superficial changes in enamel. Previous studies prove that the de-remineralizing process that occurs in the dental surface, whether or not resulting from a bacterial process, can be easily paralyzed with its application. Since, the resinous infiltrant manages, in addition to penetrating the microporosity, to form a superficial protective layer, preventing the advancement of the lesion. However, because it is a non-radiopaque material and does not have elements in its composition that promote dental remineralization, an end of improved studies has been carried out and/or to develop a material with the desired characteristics, in addition to making it more economically viable, considering that, as it is the only material commercially available, Icon has a high cost, which makes its application in some cases unfeasible.

Therefore, in view of the above, it is suggested that further studies be carried out, especially and additionally, clinical follow-ups, so that the limitations of the material can be resolved and the resin infiltrant achieves a more effective performance than the existing one.

References

Akin M., & Basciftci F. A. (2012) Can white spot lesions be treated effectively? *Angle Orthod*. 82 (5) 770–775.

Alqahtani, S., Abusaq, A., Alghamdi, M., Shokair, N., & Albounni, R. (2022). Colour stability of resin infiltrated white spot lesion after exposure to stain-causing drinks. *Saudi journal of biological sciences*, *29*(2), 1079–1084.

Amaral C. M., Rodrigues J. A., Erhardt M. C., Araujo M. W., Marchi G. M., Heymann H. O., & Pimenta L. A. (2006). Effect of whitening dentifrices on the superficial roughness of esthetic restorative materials. *J Esthet Restor Dent*, 18(2):102-8

Ammari M. M., Jorge R. C., Souza I. P. R., & Soviero V. M. (2018) Efficacy of resin infiltration of proximal caries in primary molars: 1-year follow-up of a split-mouth randomized controlled clinical trial. *Clin. Oral Investig*. 22 (3) 1355–1362.

Anauate-Netto C, Borelli L Neto, Amore R, DI Hipólito V, & D'Alpino P. H. P. (2017) Caries progression in non-cavitated fissures after infiltrant application: a 3-year follow-up of a randomized controlled clinical trial. *J Appl Oral Sci*, 25(4):442-454

Andrade Neto D. M. Carvalho E. V. Rodrigues E. A., et al. (2016) Novel hydroxyapatite nanorods improve anti-caries efficacy of enamel infiltrants. *Dent Mater*, 32(6):784-793

Araujo G., Naufel F., Alonso R., Lima D., & Puppin-Rontani R. (2015) Influence of staining solution and bleaching on color stability of resin used for caries infiltration. *Oper Dent*, 40: E250–256.

Araújo G. S., Sfalcin R. A., Araújo T. G., Alonso R. C., & Puppin-Rontani R. M. (2013) Evaluation of polymerization characteristics and penetration into enamel caries lesions of experimental infiltrants. *J Dent*. Nov;41(11):1014-9.

Askar H., Schwendicke F., Lausch J., Meyer-Lueckel H., & Paris S. (2018) Modified resin infiltration of non-, micro- and cavitated proximal caries lesions in vitro. *J Dent*. 74: 56–60.

Aswani R., Chandrappa V., Uloopi K. S., Chandrasekhar R., & RojaRamya K. S. (2019) Resin Infiltration of Artificial Enamel Lesions: Evaluation of Penetration Depth, Surface Roughness and Color Stability. *Int J Clin Pediatr Dent*. 12(6):520-523.

Aziznezhad M., Alaghemand H., Shahande Z., Pasdar N., Bijani A., Eslami A., & Dastan Z. (2017) Comparison of the effect of resin infiltrant, fluoride varnish, and nano- hydroxy apatite paste on surface hardness and streptococcus mutans adhesion to artificial enamel lesions. *Electron Physician*. Mar 25;9(3):3934-3942.

Borges A. B., Caneppele T. M., Masterson D., & Maia L. C. (2017) Is resin infiltration na effective esthetic treatment for enamel development defects and white spot lesions? A systematic review. *J Den,t* 56:11-18.

Ceci M., Rattalino D., Viola M., et al. (2017) Resin infiltrant for non-cavitated caries lesions: evaluation of color stability. *J Clin Exp Dent*. 9(2):e231-e237

Chen M., Li J. Z., Zuo Q. L., Liu C., Jiang H., & Du M. Q. (2019) Accelerated aging effects on color, microhardness and microstructure of ICON resin infiltration. *Eur Rev Med Pharmacol Sci*. Sep;23(18):7722-7731.

Collares F. M., Ogliari F. A., Lima G. S., Fontanella V. R., Piva E., & Samuel S. M. (2010) Ytterbium trifluoride as a radiopaque agent for dental cements. *Int Endod J*. Sep;43(9):792-

Collares F. M., Ogliari F. A., Zanchi C. H., Petzhold C. L., Piva E., & Samuel S. M. (2011) Influence of 2-hydroxyethyl methacrylate concentration on polymer network of adhesive resin. *J Adhes Dent*. Apr;13(2):125-9.

Crombie F., Manton D., Palamara J., & Reynolds E. (2014) Resin infiltration of developmentally hypomineralised enamel, *Int. J. Paediatr. Dent*. 24 (1) 51–55.

Damasceno, J. E. ; Rodrigues, F. V. ; Dias, L. M. ; Shibasaki, P. A. N. ; Lima, M. J. P. ; Araújo, R. P. C. ; Foxton, R. M. ; & Cavalcanti, A. N. (2019) Effect of Dental Erosion and Methods for its Control on the Marginal and Internal Adaptation of Restorations with Different Adhesive Systems. *Journal of Health Sciences (UNOPAR)*, 21, 437-444.

Davila J. M., Buonocore M. G., Greeley C. B., & Provenza D. V. (1975) Adhesive penetration in human artificial and natural white spots. *J Dent Res*. Sep-Oct; 54(5):999-1008.

de Carvalho Sales-Peres S. H., Magalhães A. C., de Andrade Moreira Machado M. A., & Buzalaf M. A. (2007) Evaluation of the erosive potential of soft drinks. *Eur J Dent*. 1:10–3.

Denis M., Atlan A., Vennat E., Tirlet G., & Attal J. P. (2013) White defects on enamel: diagnosis and anatomopathology: two essential factors for proper treatment (part 1), *Int. Orthod.* 11 (2) 139–165.

Dhillon S. N., Deshpande A. N., Macwan C., Patel K. S., Shah Y. S., & Jain A. A. (2020) Comparative Evaluation of Microhardness and Enamel Solubility of Treated Surface Enamel with Resin Infiltrant, Fluoride Varnish, and Casein Phosphopeptide-amorphous Calcium Phosphate: An In Vitro Study. *Int J Clin Pediatr Dent*. 13(Suppl 1):S14-S25.

Dickens S. H., Stansbury J. W., Choi K. M., & Floyd C. J. E. (2003) Photopolymerization kinetics of methacrylate dental resins. Macromolecules 36:6043–6053

Domejean S., Ducamp R., Leger S., & Holmgren C. (2015) Resin infiltration of noncavitated caries lesions: a systematic review. *Med Princ Pract,* 24: 216–221.

Dressano D., Palialol A. R., Xavier T. A., Braga R. R., Oxman J. D., Watts D. C., Marchi G. M., & Lima A. F. (2016) Effect of diphenyliodonium hexafluorophosphate on the physical and chemical properties of ethanolic solvated resins containing camphorquinone and 1- phenyl-1,2-propanedione sensitizers as initiators. *Dent Mater*. Jun;32(6):756- 64.

Dukic W. (2017) Radiopacity of Composite Luting Cements Using a Digital Technique. *J Prosthodont*. Jan 10.

Eakle W. S., Featherstone J. D., Weintraub J. A., Shain S. G., & Gansky S. A. (2004) Salivary fluoride levels following application of fluoride varnish or fluoride rinse. *Community Dent Oral Epidemiol*. 32(6):462-9.

Eckstein A., Helms H. J., & Knosel M. (2015) Camouflage effects following resin infiltration of postorthodontic white-spot lesions in vivo: One-year follow-up. *Angle Orthod* 85:374–380.

Ekstrand K. R., Bakhshandeh A., & Martignon S. (2010) Treatment of proximal superficial caries lesions on primary molar teeth with resin infiltration and fluoride varnish versus fluoride varnish only: efficacy after 1 year. *Caries Res*. 44(1):41-46.

Elembaby A, AlHumaid J, El Tantawi M, & Akhtar S. (2022) The Impact of Nano-Hydroxyapatite Resin Infiltrant on Enamel Remineralization: An In Vitro Study. Int J Periodontics Restorative Dent. Mar-Apr;42(2): e43-e50.

Elrashid A. H., Alshaiji B. S., Saleh S. A., Zada K. A., & Baseer M. A. (2019) Efficacy of Resin Infiltrate in Noncavitated Proximal Carious Lesions: A Systematic Review and Meta-Analysis. *J Int Soc Prev Community Dent*. May-Jun;9(3):211-218.

Faghihian R., Shirani M., Tarrahi M. J., & Zakizade M. (2019) Efficacy of the Resin Infiltration Technique in Preventing Initial Caries Progression: A Systematic Review and Meta-Analysis. *Pediatr Dent.* Mar 15;41(2):88-94.

Farias, J. O., Cunha, M., Martins, V. L., Mathias, P. (2022). Microinvasive esthetic approach for deep enamel white spot lesion. *Dental research journal*, *19*, 29.

Feng C. H., & Chu X. Y. (2013) Efficacy of one year treatment of icon infiltration resin on post-orthodontic white spots. *J Peking Univ Health Sc*i 45:40–43.

Flor-Ribeiro M. D., Graziano T. S., Aguiar F. H. B., Stipp R. N., & Marchi G. M. (2019) Effect of iodonium salt and chitosan on the physical and antibacterial properties of experimental infiltrants. *Braz Oral Res*. 33: e075.

Foster P. L. A., Beckett D., Ahmadi R., Schwass D. R., Leon de la Barra S., Moffat S. M., Meldrum A., & Thomson W. M. (2017) Resin infiltration of caries in primarymolars in a community setting: 24-month randomized controlled trial findings, *JDR Clin. Trans*. Res. 2 (3) 287–294.

Frese C., Wohlrab T., Sheng L., Kieser M., Krisam J., & Wolf D. (2019) Clinical effect of stannous fuoride and amine fuoride containing oral hygiene products: A 4-year randomized controlled pilot study. *Sci Rep* 9, (7681): 1-10.

Gaglianone L. A., Pfeifer C. S., Mathias C., Puppin-Rontani R. M., & Marchi G. M. (2020) Can composition and preheating improve infiltrant characteristics and penetrability in demineralized enamel? *Braz Oral Res.* 34: e099.

Gelani R., Zandona A. F., Lippert F., Kamocka M. M., & Eckert G. (2014) In vitro progression of artificial white spot lesions sealed with an infiltrant resin. *Operat Dent*. 39-5: 481-8.

Gençer M. D. G., & Kirzioglu Z. (2019) A comparison of the effectiveness of resin infiltration and microabrasion treatments applied to developmental enamel defects in color maskin. Dent Mater J. 1-8.

Gölz L., Simonis R. A., Reichelt J., Stark H., Frentzen M., Allam J-P., Probstmeier R., Winter J., & Kraus D. (2016) In vitro biocompatibility of ICON® and TEGDMA on human dental pulp stem cells. *Dent Mater*. 32: 1052-64.

Gonçalves F., Kawano Y., Pfeifer C., Stansbury J. W., Braga R. R. (2009) Influence of BisGMA, TEGDMA, and BisEMA contents on viscosity, conversion, and flexural strength of experimental resins and composites. *Eur J Oral Sci*. 117:442–6.

Gonçalves L. S., Moraes R. R., Ogliari F. A., Boaro L., Braga R. R., & Consani S. (2013) Improved polymerization efficiency of methacrylate-based cements containing an iodonium salt. *Dent Mater*. 29:1251–5.

Gönülol N., & Yilmaz F. (2012) The effects of finishing and polishing techniques on surface roughness and color stability of nanocomposites. *J Dent* 40 (2):64-70.

Guedes A. P. A., Oliveira-Reis B., Catelan A., Suzuki T. Y. U., Briso A. L. F., & dos Santos P. H. (2018) Mechanical and surface properties analysis of restorative materials submitted to erosive challenges in situ. *Eur J Dent*. Oct-Dec; 12(4): 559– 565.

Habbu N., Joshi N., Ramamoorthi M., & Mabrukar V. (2011) Esthetic management of dental fluorosis. *Int J Dent Clin* 3(2): 80-81.

Hammad, S. M., El-Wassefy, N. A., & Alsayed, M. A. (2020). Evaluation of color changes of white spot lesions treated with three different treatment approaches: an in-vitro study. *Dental press journal of orthodontics*, *25*(1), 26–27.

Hashimoto M., Ohno H., Kaga M., Sano H., Tay F.R., Oguchi H., et al. (2002) Over-etching effects on microtensile bond strength and failure patterns for two dentin bonding systems. *J Dent.* 30: 99-105.

Heintze S. D., Forjanic M., Ohmiti K., & Rousson V. (2010) Surface deterioration of dental materials after simulated toothbrushing in relation to brushing time and load. *Dent Mater*. Apr;26(4):306-19.

Honório H. M., Rios D., Francisconi L. F., Magalhães A. C., Machado M. A., & Buzalaf M. A. (2008) Effect of prolonged erosive pH cycling on different restorative materials. *J Oral Rehabil*. Dec;35(12):947-53.

Honório H. M., Rios D., Santos C. F., Magalhães A. C., Buzalaf M. A., & Machado M. A. (2008) Effects of erosive, cariogenic or combined erosive/cariogenic challenges on human enamel: an in situ/ex vivo study. *Caries Res*. 42(6):454-9.

Hosney S., Abouelseoud H. K., & El-Mowafy O. (2017) Radiopacity of Resin Cements Using Digital Radiography. *J Esthet Restor Dent*. May 6;29(3):215-221.

Hove L., Holme B., Øgaard B., Willumsen T., & Tveit A. B. (2008) The protective effect of TiF4, SnF2 and NaF on erosion of enamel by hydrochloric acid in vitro measured by white light interferometry. *Caries Res*. 40(5):440-3.

Huang G.J., Roloff-Chiang B., Mills B.E., Shalchi S., Spiekerman C., Korpak A. M., et al., (2013) Effectiveness of MI Paste Plus and PreviDent fluoride varnish for treatment of white spot lesions: a randomized controlled trial, Am. *J. Orthod. Dentofac. Orthop*. 143 (1) 31–41.

Inagaki L. T., Dainezi V. B., Alonso R. C., et al. (2016) Evaluation of sorption/solubility, softening, flexural strength and elastic modulus of experimental resin blends with chlorhexidine. *J Dent*. 49:40-45.

Ionta F. Q., Boteon A. P., Moretto MJ., Junior O. B., Honorio H. M., Silva T. C., Wang L., Rios D. (2016) Penetration of resin-based materials into initial erosion lesion: A confocal microscopic study *Microscopy Research and Technique* 79(2) 72-80.

Jain A. R., Varma A., & Hemakumar V. (2016) Evaluation of Esthetic Rehabilitation of Teeth with Severe Fluorosis Using Direct and Indirect Laminate Veneer: A Case Report. *Biol Med (Aligarh).* 8(7): 1-3.

Joaquim, B. F., Mansano , T. ., Parreiras, S. O. ., & & Sônego, M. V. . (2021). Esthetic resolution of enamel white spot lesion trough the association of conservative techniques to resin infiltration: Case report. *Research, Society and Development*, *10*(8), e6010817063.

Jorge R. C., Ammari M. M., Soviero V. M., & Souza I. P. R. (2019) Randomized controlled clinical trial of resin infiltration in primary molars: 2 years follow-up. *J Dent*. 2019;90: 103184.

Lasfargues J. J., Bonte E., Guerrieri A., & Fezzani L. (2013) Minimal intervention dentistry: part 6. Caries inhibition by resin infiltration. *Br Dent J*. Jan;214(2):53-9.

Leal I. C., Costa W. K. F., & Passos V. F. (2020) Fluoride dentifrice containing calcium silicate and sodium phosphate salts on dental erosion: In vitro study. *Arch Oral Biol.* 118(104857): 1-6.

Leland A., Akyalcin S., English J. D., Tufekci E., & Paravina R. (2016) Evaluation of staining and color changes of a resin infiltration system. *Angle Orthod* 86(6):900-4.

Li M., Yang Z., Huang Y., Li Y., & Zhou Z. (2021) In vitro effect of resin infiltrant on resistance of sound enamel surfaces in permanent teeth to demineralization. *PeerJ* 9:e12008.

López E. A. L., Dominguez J. Á., Gomes G. M., Mora C. A. P., Bittencourt B. F., Gomes J. C., & Gomes O. M. G. (2019) Effect of conditioning protocols and ultrasonic application of an infiltrant resin in white spot lesions. *Braz Dent J.* 30(1): 58-65.

Lussi A., Buzalaf M. A. R., Duangthip D., Anttonen V., Ganss C., João-Souza S. H. et al. (2019) The use of fluoride for the prevention of dental erosion and erosive tooth wear in children and adolescentes. *Eur Arch Paediatr Dent.* 20: 517–527.

Lussi A., Schaffner M., & Bern T. J. (2007) Dental erosion – diagnosis and prevention in children and adults. *Int Dent J*. 57: 385-398.

Malacarne J., Carvalho R. M., de Goes M. F., Svizero N., Pashley D. H., Tay F. R., Yiu C. K., & Carrilho M. R. (2006) Water sorption/solubility of dental adhesive resins. *Dent Mater* 22:973–980.

Mandava J., Reddy Y. S., Kantheti S., Chalasani U., Ravi R. C., Borugadda R., & Konagala R. K. (2017) Microhardness and Penetration of Artificial White Spot Lesions Treated with Resin or Colloidal Silica Infiltration. *J Clin Diagn Res*.

Martignon S., Ekstrand K. R., Gomez J., Lara J. S., & Cortes A. (2012) Infiltrating/sealing proximal caries lesions: a 3-year randomized clinical trial. *J Dent Res*. 91(3):288-292.

Mathias C., Gomes R. S., Dressano D., Braga R. R., Aguiar F. H. B., & Marchi G. M. (2019) Effect of diphenyliodonium hexafluorophosphate salt on experimental infiltrants containing different diluents. *Odontology*. 107(2):202-208.

Meyer-Lueckel H., & Paris S. (2008) Progression of artificial enamel caries lesions after infiltration with experimental light curing resins. *Caries Res*.42(2):117–24.

Meyer-Lueckel H., Balbach A., Schikowsky C., Bitter K., & Paris S. (2016) Pragmatic RCT on the Efficacy of Proximal Caries Infiltration. *J Dent Res.* 95(5):531-536.

Meyer-Lueckel H., Paris S. (2008) Improved resin infiltration of natural caries lesions. *J Dent Res*. 87(12):1112–7.

Meyer-Lueckel H., Paris S., & Kielbassa A. M. (2007) Surface layer erosion of natural caries lesions with phosphoric and hydrochloric acid gels in preparation for resin infiltration. *Caries Res.* 41(3):223–30.

Munoz M. A., Arana-Gordillo L. A., Gomes G. M., Gomes O. M., Bombarda N. H., Reis A., et al. (2013) Alternative esthetic management of fluorosis and hypoplasia stains: blending effect obtained with resin infiltration techniques, *J. Esthet. Restor. Dent.* 25 (1) 32–39.

Nugroho J. J., & Aco A. H. (2019) Porcelain veneer for a simple and esthetic treatment on anterior teeth with enamel hypoplasia: a case report. *J Conserv*. 9(2): 74-76.

Ogliari F. A., Ely C., Lima G. S., Conde M. C., Petzhold C. L., Demarco F. F., & Piva E. (2008) Onium salt reduces the inhibitory polymerization effect from an organic solvent in a model dental adhesive resin. *J Biomed Mater Res B Appl Biomater.* 86:113–8.

Ogliari F. A., Ely C., Petzhold C. L., Demarco F. F., & Piva E. (2007) Onium salt improves the polymerization kinetics in an experimental dental adhesive resin. *J Dent*. 35(7):583-587.

Oliveira G. C., Boteon A. P., Ionta F. Q., Moretto M. J., Honorio H. M., Wang L., & Rios D. (2015) In vitro effects of resininfiltration on enamel erosion inhibition. *Operative Dentistry* 40(5) 492-502.

Opdam N. J., van de Sande F. H., Bronkhorst E., Cenci M. S., Bottenberg P., Pallesen U., Gaengler P., Lindberg A., Huysmans M. C., & van Dijken J. W. (2014) Longevity of posterior composite restorations: a systematic review and meta-analysis, *J. Dent.Res*. 93 (10) 943–949,

Paris S, Meyer-Lueckel H. (2009) Masking of labial enamel white spot lesions by resin infiltration-a clinical report, *Quintessence Int*. 40 (9) 713–718.

Paris S, Meyer-Lueckel H., Colfen H., & Kielbassa A. (2007) Resin infiltration of artificial enamel caries lesions with experimental light curing resins. *Dent Mater J*. 26:582-588.

Paris S., Bitter K., Krois J., & Meyer-Lueckel H. (2020) Seven-year-efficacy of proximal caries infiltration - Randomized clinical trial. *J Dent*. 93:103277.

Paris S., Dörfer C., & Meyer-Lueckel H. (2010) Surface conditioning of natural enamel caries lesions in deciduous teeth in preparation for resin infiltration. *J Dent*. 38:65-71

Paris S., Hopfenmuller W., & Meyer-Lueckel H. (2010) Resin infiltration of caries lesions: an efficacy randomized trial. *J Dent Res.* 89:823-826.

Paris S., Lausch J., Selje T., Dörfer C. E., & Meyer-Lueckel H. (2014) Comparison of sealant and infiltrant penetration into pit and fissure caries lesions in vitro. *J Dent*.42(4):432-8.

Paris S., & Meyer-Lueckel H. (2010) Infiltrants inhibit progression of natural caries lesions in vitro. *J Dent Res*. Nov;89(11):1276-80.

Paris S., Meyer-Lueckel H., & Kielbassa A. M. (2007) Resin infiltration of natural caries lesions. *J Dent Res.* 86(7):662-6.

Paris S., Schwendicke F., Keltsch J., Dorfer C., & Meyer-Lueckel H. (2013) Masking of white spot lesions by resin infiltration in vitro, *J. Dent*. 41 (Suppl. 5) e28–e34.

Patel A., Aghababaie S., & Parekh S. (2019) Hypomineralisation or hypoplasia? *Br Dent J*. 227(8): 683-686.

Pedreira P. R., Damasceno J. E., Mathias C., Aguiar F. H. B., & Marchi, G. M. (2021) Influence of incorporating zirconium- and barium-base radiopaque filler into experimental and commercial infiltrants. *Operative Dentistry*. 46 (5): 566-576

Pekkan G. (2016) Radiopacity of Dental Materials: An Overview. *Avicenna J Dent Res*. June; 8(2):e36847.

Pini N. I. P., Sundfeld-Neto D., Aguiar F. H. B., Sundfeld R. H., Martins L. R. M., Lovadino J. R., & Lima D. A. N. L. (2015) Enamel microabrasion: An overview of clinical and scientific considerations. *World J Clin Cases*. 3(1): 34-41.

Poshusta A. K., Bowman C. N., & Anseth K. S. (2002) Application of a kinetic gelation simulation to the characterization of in situ crosslinking biomaterials. *J Biomat Sci-Polym* E 13:797–815.

Rana N., Singh N., Thomas A. M., & Jairath R. (2021) A comparative evaluation of penetration depth and surface microhardness of Resin Infiltrant, CPP-ACPF and Novamin on enamel demineralization after banding: an in vitro study. *Biomater Investig Dent*. Jun 11;8(1):64-71.

Reston E. G., Corba D. V., Ruschel K., Tovo M. F., & Barbosa N. A. (2011) Conservative approach for esthetic treatment of enamel hypoplasia. *Oper Dent.* 36(3): 340-343.

Rey N., Benbachirc, Bortolotto T., & Krejci I. (2014) Evaluation of the staining potential of a caries infiltrant in comparison to other products. *Dental Mater J* 33(1): 86–91

Rios D., Oliveira G. C., Zampieri C. R., et al. (2019) Resin-Based Materials Protect Against Erosion/Abrasion-a Prolonged In Situ Study. *Oper Dent*. 44(3):302-311.

Saridag S., Helvacioglu-Yigit D., Alniacik G., & Özcan M. (2015) Radiopacity measurements of direct and indirect resin composites at different thicknesses using digital image analysis. *Dent Mater J.* 34(1):13-8.

Schnabl D., Dudasne-Orosz V., Glueckert R., Handschuh S., Kapferer-Seebacher I., & Dumfahrt H. (2019) Testing the Clinical Applicability of Resin Infiltration of Developmental Enamel Hypomineralization Lesions Using an In Vitro Model. *Int J Clin Pediatr Dent.* 12(2):126-132.

Sfalcin R. A., Correr A. B., Morbidelli L. R., et al. (2017) Influence of bioactive particles on the chemical-mechanical properties of experimental enamel resin infiltrants. *Clin Oral Investig*. 21(6):2143-2151.

Silva S. N., Reich A. M., DeLeon E. Jr, Schafer T, Rueggeberg F. A., & Fortson W. M. Jr. (2018) Staining potential differences between an infiltrative resin and an esthetic, flowable composite. *J Esthet Restor Dent*. 30(5): 457-463.

Sonesson M., Bergstrand F., Gizani S., & Twetman S. (2016) Management of postorthodontic white spot lesions: an updated systematic review, *Eur. J. Orthod*.

Song L., Ye Q., Ge X., Misra A., Spencer P. (2016) Tris (trimethylsilyl) silane as a co-initiator for dental adhesive : Photo-polymerization kinetics and dynamic mechanical property. *Dent Mater*. 32: 102–13.

Souza M. D. B., Pessan J. P., Lodi C. S., Souza J. A. S., Camargo E. R., Souza Neto F. N., & Delbem A. C. B. (2017) Toothpaste with Nanosized Trimetaphosphate Reduces Enamel Demineralization. *JDR Clin Trans Res.* Jul;2(3):233-240.

Swamy D. F., Barretto E. S., Mallikarjun S. B., & Dessai S. S. R. (2017) In vitro evaluation of resin infiltrant case series penetration into white spot lesions of deciduous molars. *J of Clinic and Diag Res*. 11(9): ZC71-ZC74.

Takahashi M., Nakajima M., Hosaka K., Ikeda M., Foxton R. M., & Tagami J. (2011) Long-term evaluation of water sorption and ultimate tensile strength of HEMA-containing/-free one-step self-etch adhesives. *J Dent.* 39:506–12.

Tereza G. P., Oliveira G. C., Andrade Moreira Machado M. A., Oliveira T. M., Silva T. C., & Rios D. (2016) Influence of removing excess of resin-based materials applied to eroded enamel on the resistance to erosive challenge. *Journal of Dentistry* 47 49-54.

Theodory T. G., Kolker J. L., Vargas M. A., Maia R. R., & Dawson D. V. (2019) Masking and Penetration Ability of Various Sealants and ICON in Artificial Initial Caries Lesions In Vitro. *J Adhes Dent*. 21(3):265-272.

Torres C. R., Borges A. B., Torres L. M., Gomes I. S., & de Oliveira R. S. (2011) Effect of caries infiltration technique and fluoride therapy on the colour masking of white spot lesions, *J. Dent.* 39 (3) 202–207.

Torres C. R., & Borges A. B. (2015) Color masking of developmental enamel defects: a case series, *Oper. Dent*. 40 (1) 25–33.

Viana I. E. L., Lopes R. M., Silva F. R. O., Lima N. B., Aranha A. C. C., Feitosa S., & Scaramucci T. (2020) Novel fluoride and stannous -functionalized β-tricalcium phosphate nanoparticles for the management of dental erosion. *J Dent*. 92: 1-6.

Wang, L., Freitas, M., Prakki, A., Mosquim, V., González, A., Rios, D., & Honório, H. M. (2021). Experimental self-etching resin infiltrants on the treatment of simulated carious white spot lesions. *Journal of the mechanical behavior of biomedical materials*, *113*, 104146.

Wiegand A., Stawarczyk B., Kolakovic M., Hammerle C. H., Attin T., & Schmidlin P. R. (2011) Adhesive performance of a caries infiltrant on sound and demineralised enamel. *Journal of Dentistry* 39(2) 117-121.

Yasa E., Yasa B., Aglarci O. S., & Ertas E. T. (2015) Evaluation of the Radiopacities of Bulk-fill Restoratives Using Two Digital Radiography Systems. *Oper Dent*. Sep-Oct;40(5):E197-205. doi: 10.2341/14-074-L.

Ye Q., Spencer P., Wang Y., & Misra A. (2007) Relationship of solvent to the photopolymerization process, properties, and structure in model dentin adhesives. *J Biomed Mater Res A.* Feb;80(2):342-50.

Yetkiner E., Wegehaupt F. J., Attin R., Wiegand A., Attin T. (2014) Stability of two resin combinations used as sealants against toothbrush abrasion and acid challenge in vitro. *Acta Odontologica Scandinavica* 72(8) 825-830.

Zajac J. C., Mantilla-Rivas E., Manrique M., Aivaz M., Ramirez-Suarez K. I., Wang R., Oh A. K., Tate A. R., & Rogers G. F. J Craniofac Surg. 2020; 31(5): 1497-1506.

Zakizade M., Davoudi A., Akhavan A., & Shirban F. (2020) Effect of Resin Infiltration Technique on Improving Surface Hardness of Enamel Lesions: A Systematic Review and Meta-analysis. *J Evid Based Dent Pract.* Jun;20(2):101405.

Zantner C., Martus P., & Kielbassa A. M. (2006) Clinical monitoring of the effect of fluorides on long-existing white spot lesions, *Acta Odontol. Scand*. 64 (2)115–122.

Zhao X., Pan J., Zhang S., Malmstrom H. S., & Ren Y. F. (2017) Effectiveness of resin-based materials against erosive and abrasive enamel wear. *Clinical Oral Investigations* 21(1) 463-468.