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RESEARCH ARTICLE

RESIN INFILTRATION IN PEDIATRIC DENTISTRY- A REVIEW

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ABSTRACT

For a conventional caries treatment generally a high speed hand-piece is used to access the lesion and a low-speed hand-piece for the caries removal, this method is considered predominantly an invasive approach. Through this approach, along with the carious tooth structure there is unintentional removal of non-carious tooth structure. Approaches for the management of dental caries have changed dramatically in recent years, evolving from the traditional, largely restorative treatment approach to a preventive approach, non-invasion or minimal invasion[1]. In order to diminish the amount of destruction of the tooth substance, minimally invasive cavity designs and techniques like air abrasion, atraumatic restorative therapy, chemomechanical caries removal, and lasers have been tried. For a better comprehension on the caries process, the contemporary methods of management must be aimed towards prevention of the disease, managing the caries risk and detecting the carious lesions as early as possible in order to steer clear from invasive treatment, but, when indicated, use the least invasive methods[1]. Various approaches have been suggested for the non-invasive management of non-cavitated caries lesions, which are also known as initial or early caries lesions. These include the remineralisation of the lesion with fluoride[2] and casein phosphopeptide amorphous calcium phosphate[3], or the use of therapeutic sealants for occlusal lesions[4]. Additional to these, a non-invasive alternative treatment was proposed that was based on the experiments conducted by Robinson *et al*.[5] on caries infiltration with resorcinol-formaldehyde resin. The aim of this review was to present the scientific basis, the principles of resin infiltration, resin infiltration technique and to discuss its inherent clinical applications in primary and permanent dentition.

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INTRODUCTION

Dental caries is a vital public health concern that commonly affects children in their early childhood. It has a negative impact on children's' oral as well as general health[6]. Special attention has been devoted to early proximal carious lesions, with maximum preservation of tooth structure[7]. This is mainly as the restorative therapy involving lesions of proximal region requires removal of a considerable amount of sound tooth substance and this brings tooth into a circle of treatment and retreatment[8]. Therefore, invasive treatment of these lesions can be avoided by the early detection and treatment of the same by non-invasive approach. Restoring the tooth structure by dental filling and restoration was the first choice for treating dental caries[9], but in the last years, the treatment has been changed from the large invasive technique to non-invasive or minimal invasive preventive techniques[1]. Several non-invasive techniques have been developed to treat early caries lesions[10].

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Enamel carious lesions are characterized by mineral loss in the body of the lesion, resulting in greater visual enamel opacity due to alteration of the refractive index of the affected area[11]. Great attention has been dedicated to the non-invasive approach of such enamel carious lesions, which includes remineralisation of the lesion with fluoride and casein phosphopeptide-amorphous calcium phosphate, or the use of therapeutic sealants for occlusal lesions. Fluoride and casein phosphopeptide-amorphous calcium phosphate play a major role in the remineralisation of white spot lesions that are present superficially. However, good cooperation of the patient, a change in harmful habits by the patient is required for the success of these treatments along with the hope that the patient does not abandon the treatment before completion. As an attempt to reduce lesion progression on non-cavitated enamel caries, sealants have been used therapeutically. The pores within the body of enamel caries provide diffusion pathways for acids and dissolved minerals[12]. Therefore, an alternative approach for superficial sealing might be based on experiments conducted by Robinson *et al*[5], to arrest carious lesions by the infiltration of these pores with resorcinol-formaldehyde resins.

A technique using resin infiltration has been introduced by Munoz *et al.*[13], the low viscosity resin infiltrant was used to occlude the pores within the hypomineralised lesion. This acts as diffusion pathways for acids and dissolved minerals, thus sealing the pathway. Thus, the caries infiltration can also be used to camouflage aesthetically disfiguring white spot lesions on buccal surfaces[14]. Infiltration Concept (ICON®) is a relatively new resin product developed in Germany and used in the treatment of incipient lesions[15]. It improves the retention and prevents caries on smooth surfaces, but not pit and fissure surfaces[14].

RESIN INFILTRATION CONCEPT

DEFINITION

Caries infiltration: A micro-invasive technology that fills, reinforces, and stabilizes demineralized enamel without drilling or sacrificing healthy tooth structure[16]. The micro-invasive infiltration can be used to treat smooth surface and proximal carious lesions up to the first third of dentin. Resin infiltration technique: A novel technology that seems to bridge the gap between noninvasive and minimally invasive treatment of initial dental caries, postponing the need for restoration as long as possible. Resin infiltration technique can camouflage aesthetically disfiguring white lesions on the buccal surface. It is marketed under the name Icon® (DMG America Company, Englewood, NJ). Resin infiltration is a micro-invasive method that fills the incipient lesion pores via capillary action, which blocks further diffusion of the bacteria by creating barriers and stops lesion development, restoring the tooth without anaesthesia and drilling to preserve the natural anatomy of the tooth form[17].

The ICON® infiltrates the lesion, make the bacteria inactive and prevents caries progression[17] compared to the sealant which only work as mechanical barrier between the tooth structure and the oral environment. In the principle of resin infiltration there is perfusion into the porous enamel with resin by capillary action, this arrests lesion progression by occluding the micro-porosities that provide diffusion pathways for the acids and dissolved materials. This technique aims to create a diffusion barrier inside the lesion and not on the lesion surface[18]. Robinson *et al.*[5] reported that about 60 ± 10% of the lesion's pore volume had been occupied by resin. According to Kielbassa *et al*., resin infiltrates into subsurface lesions and produces resin infiltrated parts of the lesion and the depth of resin infiltration was over 100 μm[17]. Enamel lesions lose their whitish appearance when their micro-porosities are filled with the resin and hence look similar to sound enamel; this was a positive side effect of resin infiltration. This masking of enamel lesions by resin infiltration occurs by the principle which is based on changes in light scattering that occurs within the lesions. The refractive index (RI) of Sound enamel is 1.62. The micro-porosities present in the enamel caries lesions contains either a watery medium (RI 1.33) or air (RI 1.0). So this difference in the refractive indices between the enamel crystals and medium inside the porosities causes the light to scatter giving an outcome of whitish opaque appearance of the lesions, especially when they are desiccated[14]. The micro-porosities of infiltrated lesions are filled with resin (RI 1.46) that, in contrast to the watery medium, cannot evaporate[14]. Therefore, the difference in the refractive indices between porosities and enamel is negligible and lesions appear similar to the surrounding sound enamel. As a result, this treatment may be used not only to arrest enamel lesions but also to improve the esthetic appearance of buccal white spots[14].

HISTORY

Meyer – Lueckel *et al*[19]: resin infiltration was used as a method of treating incipient caries either inter-proximally or on the smooth surfaces of teeth. Paris *et al*[14]: The low viscosity resin infiltrant was used to occlude the pores within the hypomineralised lesion. The hypomineralised enamel permits diffusion pathways for acids and dissolved minerals, which continues through the enamel of the affected area. The resin infiltration technique seals these pathways and prevents further deterioration of the area. Thus caries infiltration techniques can also be used to camouflage aesthetically disfiguring white spot lesions on buccal surfaces. Tirlet and Attal[20]: Whilst extensive research has been undertaken on the resin infiltration treatment for caries, a further use of the technique has been explored for the esthetic treatment of white spots. Munoz *et al*[13]: A new technique using resin infiltration has been introduced to treat anterior white marks. Lueckel and Paris[19] emphasized that original aim of this caries infiltration is to arrest the lesion progression by occluding the micro-porosities that provide diffusion pathway for acid and dissolved minerals.

INDICATIONS

- Small white lesions inherent on the tooth.
- Decalcified smooth surface white lesion on the tooth such as stasis of plaque after orthodontic treatment, or early smooth surface caries resulting from poor oral hygiene.
- Larger white marks and bands on the tooth.
- Molar incisor hypoplasia (MIH).
- Hypoplasia stains due to traumatic injuries.
- Mild to moderate fluorosis.
- Large single bands due to fluorosis.
- In a variety of studies it was found that resin infiltration is constructive in arresting of the Non-cavitated Proximal Carious Lesions progression rate. There's a superior efficacy in slowing the Non-cavitated Proximal Carious Lesions' progression rate by proximal resin infiltration when compared to conventional treatment management.

CONTRA-INDICATIONS

- In the case where patient is allergic to any component of the material used during the procedure.
- When the carious lesion has extended beyond the outer third of dentin.

ADVANTAGES

It is an innovative way of treating initial carious lesions and suits perfectly with the theory of minimal intervention dentistry. It depicts a newer method for the treatment of non-cavitated lesions of proximal and smooth surfaces in primary and permanent teeth up to

the first third of dentin (D-1 level). This resin infiltration technique bears several advantages as follows:

- Non-invasive treatment, preserving tooth structure;
- Achieved in a single visit;
- Mechanical stabilization of demineralized enamel;
- Arrest/retardation of lesion progress;
- Permanent occlusion of superficial micro-pores and cavities
- Obturation of porous, deeply demineralized areas
- Delay of restorative intervention for longer periods
- Minimized risk of secondary caries;
- No risk of postoperative sensitivity and pulpal inflammation;
- Reduced risk of gingivitis and periodontitis;
- Improved esthetic outcome when used as a "masking" resin on demineralized labial surfaces (white spot lesions, i.e. with orthodontic patients);
- High patient acceptance.

While this therapy can rightly be categorized as minimum intervention dentistry, clinical experience is limited and further controlled clinical trials are required to assess its long-term results[17]. The infiltration approach seems to be suitable when early treatment is required; and also for later stages of the caries process.

DISADVANTAGES

- Surface conditioning with 15% hydrochloric acid is necessary because of the presence of hypermineralised surface layer in initial caries lesions that prohibits the resin to penetrate into the demineralized body of the lesion.
- Resin is extremely hydrophobic. Thus, the resin has to be applied in absolutely dry conditions. Wetness within the body of the lesion or surface of the lesion hampers resin infiltration. Thus using a rubber dam is necessary.

RESIN INFILTRATION TECHNIQUE: Icon® is marketed as proximal surface kit and vestibular surface kit. Both the kits are used in a similar method except that in a proximal lesion treatment separation between the teeth is necessary. The lesion body has a higher pore volume when compared to the pore volume of surface layer of enamel caries, this forms a barrier that might disrupt the infiltration of resin into the lesion body. Hence this needs a preparation phase where the surface of the teeth is cleaned and prepared with 15% hydrochloric acid (icon etch) for 2 minutes and stirring the gel from time to time during application with a microbrush (Fig.2). 15% hydrochloric acid gel has been demonstrated to be superior to 37% phosphoric acid gel in removing the mineralized surface layer of natural enamel lesions when applied for 120 seconds[21]. 15% HCL produces a penetration depth of 58 µm, which is more than twice that of phosphoric acid (25 µm), enabling penetration into the deepest part of the lesion, thus eliminating the decalcified areas, preventing further attacks[21]. Ethanol wet bonding technique is used to desiccate the surface by applying 99% ethanol (Icon Dry) for 30 seconds followed by air drying[21] (Fig.3). It is based on the assumption that it will coax hydrophobic monomers to infiltrate into demineralized wet enamel or dentine, and improve the efficacy of penetration of the hydrophobic infiltrate (TEGDMA) to get a well-defined, resin-infiltrated layer[21].

Fig.1. Hypoplastic incisors noted in a patient

Fig.2. Acid etching with 15% Hydrochloric acid for 2 minutes

Fig.3. The result after rinsing and air drying.

This technique involves slowly replacing water within the demineralized collagen matrix with ascending concentrations of ethanol, allowing the latter to penetrate the collagen matrix without causing additional shrinkage of the inter-fibrillar spaces, thus preventing the phase separation of hydrophobic resin monomers[22]. Icon resin, composed of tetraethylene glycol dimethacrylate, is then applied on the surface of the lesion with the help of a microbrush that helps in the penetration of material for about 3 minutes (Fig.4). With the help of cotton roll, the excess material is removed and then light cured. Repeated application for another one minute is performed and then the resin is light cured again. Usually after the first application there is a slight shrinkage of the material that can cause space, hence these are occluded by the applying the resin again and repeating the step. The excess resin is then removed and the surface is polished[23]. The practitioner should select the cases carefully.

Fig.4. The resin material is injected with a special applicator

Resin infiltration technique can treat a smaller white mark much easier than a larger patch. If the patches are medium-to-large in size then it may require two treatments. If the lesion is very deep, then it is advisable to sandblast (Fig.5) the white area prior to applying the hydrochloric acid as an etchant to the tooth (Fig.6). The sandblasting helps to open up the enamel tubules so that better penetration of the hydrochloric acid can be achieved[24]. Teeth with brown discoloration may not be good candidates for resin infiltration, since the later will not mask the brown colour and, in fact, it may saturate the colour and make it look worse clinically[25]. Micro-abrasion or conventional resin restorations may be better options for treating teeth with brown discoloration[25].

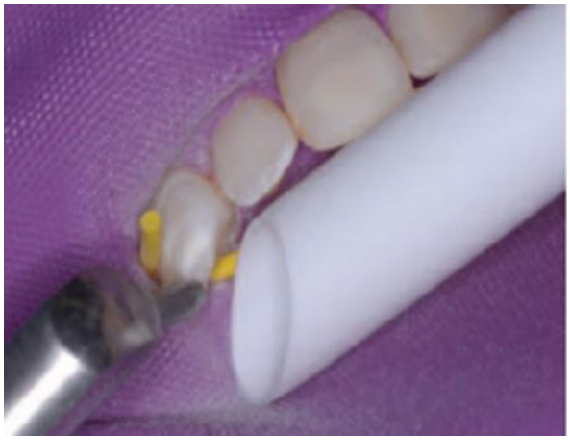

Fig. 5. Deeper lesions sandblasted first before etching

Fig.6. Etching of the tooth after sandblasting process

Fig.7. Immediate result after Resin infiltration technique

Fig.8. 3 Month follow up.

VARYING RESULTS OF THE RESIN INFILTRATION TECHNIQUE

- The resin infiltration technique may not always fade the white spot lesion entirely. This may improve over time. In a study by Kim *et al*[26] 20 teeth with a developmental defect of enamel and 18 teeth with post orthodontic decalcification were selected to have resin infiltration. Standardized photographs were taken before, immediately after and one week after treatment. The results were classified into three different groups: completely masked, partially masked and unchanged. The results showed that 25%of teeth were classified as completely masked whereas 35% were partially masked and 40% unchanged[26].
- In some cases only a partial change of the white area is noticed. Masking effect was dramatic in some cases but not in others.
- No change initially, this may be due to the need of deeper penetration. This can be achieved through a continuous phase of sandblasting, etching with alcohol; and this preparation phase can be done for three to five applications before the placement of the resin. The resin usually continues to work on the tooth over a period of time. Thus it is better to wait between the treatment sessions for the resin to completely work.
- White halo is noticed as incomplete treatment of the white area and can be treated further by sandblasting and applying etchant. Paris *et al.*[27] attempted to test the infiltration pattern in cavitated and non-cavitated proximal lesions. It was concluded that under in vitro

conditions, the infiltrant penetrates in most parts of the demineralized enamel but is not capable of filling up cavities and therefore the efficacy of the resin infiltration technique, particularly in lesions with larger cavitations, might be impaired

- Aesthetic Outcome of Resin Infiltration Therapy: Cosmetics and esthetics is the modern trend in dentistry. With the increase in demand for minimally invasive treatment with cosmetic enhancement without the use anaesthesia and drilling, the demand for the technique of resin infiltration is increased as it may be considered as a micro-invasive treatment of smooth-surface white spot lesions and also recovers back to natural tooth appearance. The initial demineralization caused by the caries process creates porosities that change the refractive index of enamel, thus resulting in a white discoloration in the incipient lesion. The resin infiltration technique has an additional positive effect on esthetics in which the penetration and polymerization of the low viscous resin inside the lesion body allows a change of the lesion's whitish appearance to the natural enamel appearance[28,29]. Knosel *et al*. in a clinical trial with patients with white spot lesions treated after the removal of braces reported that there were no statistically significant differences in the colour of the infiltrated resin during a 6 month follow-up, confirming the aesthetic effect of this treatment[30]. However, Kim S *et al.* in his clinical study on assessing the effectiveness of masking white spot enamel lesions using resin infiltration found that among the 20 teeth with the developmental defect of enamel, 5 teeth (25%) were classified as completely masked, whereas 7 (35%) and 8 teeth (40%) were partially masked and unchanged, respectively[26]. Among the 18 teeth with decalcification, 11 teeth (61%) were completely masked, 6 teeth (33%) were partially masked, and 1 tooth (6%) was unchanged. In some teeth, the result was more improved after 1 week than immediately after infiltration[31].

RESIN INFILTRATION IN PRIMARY TEETH: In primary teeth the progression of proximal caries especially in primary molars is higher when compared to permanent teeth[23]. The mineral composition and the ultra-structure of primary tooth enamel varies with less mineralization and more porous and aprismatic when compares to permanent tooth enamel. Therefore, the diffusion coefficient in primary enamel seems to be greater. The proximal surface layer is less mineralized and thinner in primary molars compared with permanent ones. Thus etching the surface for 120 seconds with 15% hydrochloric acid in primary teeth, showed reliable and considerable erosion of the mineralized surface layer deeper than that seen in permanent teeth.

Smooth Surface: The refractive index (RI) of Sound enamel is 1.62. The micro-porosities present in the enamel caries lesions contains either a watery medium (RI 1.33) or air (RI 1.0). So this difference in the refractive indices between the enamel crystals and medium inside the porosities causes the light to scatter giving an outcome of whitish opaque appearance of the lesions, especially when they are desiccated[14]. The micro-porosities of infiltrated lesions are filled with resin (RI 1.46) that, in contrast to the watery medium, cannot evaporate[14]. These pores when infiltrated with the resin the refractive index increase to 1.52, thus, the difference in the refractive indices between porosities and enamel is negligible and lesions appear similar to the surrounding sound enamel. As a result, this treatment may be used not only to arrest enamel lesions but also to improve the esthetic appearance of buccal white spots[14]. In an *in vitro* study by Paris S *et al*., primary teeth exhibited better infiltrant penetration than permanent teeth, after 1 minute application of resin[32]. On the other hand, 3–5 minutes are required to almost completely infiltrate a natural lesion in permanent teeth with a lesion extended to the inner half of enamel, whereas, one-minute application resulted in only superficial infiltration[33]. Following 5 minute resin application, Liu *et al*. found no significant differences in the overall penetration between primary and permanent molar lesions but the penetration abilities of primary molars were slightly higher than those of permanent teeth in lesions confined to the outer half of enamel[34]. Ekstrand *et al*. conducted a split-mouth study for one year to assess the efficacy of resin infiltrated lesions covered by fluoride varnish vs fluoride varnish treatment only on the proximal lesions of deciduous molars. Lesion progression was assessed clinically and radiographically. Proximal caries in primary molars treated by resin infiltration and fluoride varnish progressed significantly lesser (23%) than those treated with fluoride varnish only (61%) after one year[35].

LIMITATIONS OF RESIN INFILTRATION: Resin infiltration technique has opened up a new range of options for minimal invasive treatment of white spots, yet there are few reasons that may affect the success of the treatment.

- Inefficient isolation;
- Incomplete resin polymerization;
- Depth of the lesion[36,37,38].

ICON works on the principle of infiltration and requires a very dry field. Apart from keeping the environment moisture-free, additional steps must be taken to dry the lesion. This is accomplished by treating the lesion area with alcohol, which evaporates the water within the porosities, which can inhibit the process of infiltration. The greater the depth of the carious lesion, the lower will be the probability of achieving a complete infiltration. Extensive lesions are also associated with higher polymerization shrinkage and the consequent appearance of porosities and cracks[39]. The infiltration of cavitated lesions does not produce satisfactory results, taking into account the weak capillary action of the resin into these lesions[40]. Ekstrand *et al*. evaluated the effectiveness of the treatment of proximal lesions of temporary molars with resin infiltration. The reported rate of failure after one year (23 vs 62% in the control group) was higher than that reported in other studies after the same period of follow up. However, unlike those, the sample used by Ekstrand *et al*. composed of only children with moderate to high risk, which may partially explain the results[35].

Conclusion

Caries resin infiltration is a new trend in modern dentistry and therefore needs a better investigation. From the available studies, it is very convincing the progression of white spot lesion can be reduced or stopped by the use of resin infiltration. This technique is considered to be micro-invasive and bridges the gap between non-invasive and minimally invasive treatment of initial dental caries, postponing, as long as possible, the need for restoration.

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