# RESIN INFILTRATION – A NARRATIVE REVIEW OF PROPERTIES

***Abang Ibrahim DF[1,4], Hasmun NN[2], Liew YM[3], and Venkiteswaran A[4].***
*[1]Paediatric Dental Specialist Clinic, Sarawak General Hospital, Ministry of Health Malaysia, 93586 Kuching, Sarawak, Malaysia.*
*[2]Department of Oral Sciences, Faculty of Dentistry, University of Otago, P.O. Box 56, Dunedin 9054, New Zealand.*
*[3]Department of Biomedical Engineering, Faculty of Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia.*
*[4]Centre of Paediatric Dentistry and Orthodontics Studies, Faculty of Dentistry, Universiti Teknologi MARA, 47000 Sungai Buloh Campus, Selangor, Malaysia.*

***Correspondence:***
*Annapurny Venkiteswaran*
*Centre of Paediatric Dentistry and Orthodontics Studies,*
*Faculty of Dentistry,*
*Universiti Teknologi MARA, Sungai Buloh Campus,*
*47000 Selangor, Malaysia*
*Email: annapurny@uitm.edu.my*

***Abstract***
Resin infiltration ICON® has made it possible to treat initial caries lesions in a novel manner that is consistent with the concept of minimal intervention dentistry. Infiltration of caries lesions is a novel technique for treating non-cavitated lesions on the proximal and smooth surfaces of primary and permanent teeth. The greatest benefit of this method is that it is non-invasive, preserves tooth structure and can be completed in a single visit. This narrative review intends to discuss the properties of the material, its clinical applications and its effectiveness in terms of caries inhibition and esthetics effect, surface roughness, microhardness and penetration ability. There are a number of high-quality studies that support the use of ICON® in arresting non-cavitated proximal caries lesions in primary and permanent teeth. However, the masking ability in managing anterior white spot lesions and fluorosis is still doubtful. Among the material limitations were its questionable long-term color and material stability.

***Keywords***: Resin Infiltration, Dental Enamel, Caries, Esthetics, Microhardness

## *Introduction*

In recent years, non-invasive or micro-invasive techniques have supplanted traditional restorative therapy in dental care (1). These therapies aim to minimize pain and costs, restore functionality and aesthetic, and proactively rebuild healthy tooth structure (1). Caries lesions can be treated non-invasively using dietary control, mechanical biofilm removal, or remineralization therapy (2). Although the remineralization of the enamel lesion with fluoride and casein phosphopeptide amorphous calcium phosphate (CPP-ACP) shows promise (1, 2), their effectiveness hinges on adequate patient compliance (2). Due to this, a different strategy for the minimally invasive treatment of demineralized enamel lesions has been developed, known as resin infiltration (1, 2). Currently, the only resin infiltration product on the market is ICON® (DMG, Hamburg, Germany), originally developed to prevent the progression of proximal caries lesions (2).

ICON®, which stands for "Infiltration concept," is the brand name for a resin infiltration product that is available in packages for restoring both proximal and vestibular surfaces (3). ICON® represents a novel treatment option for white spot lesions (WSL), bridging the gap between non-surgical and surgical modalities (1). Its primary characteristics include being non-invasive, preserving tooth structure, and the ability to be performed in a single visit (3). Initially, this approach aimed to slow the progression of non-cavitated caries lesions by preventing cariogenic acid penetration and preserving healthy tooth tissue (2, 3). Its application was subsequently expanded to enhance the appearance of tooth discoloration, fluorosis stains, white spots, and other dental abnormalities such as amelogenesis imperfecta or

molar incisor hypomineralization (3). It is a microinvasive technology that replenishes, reinforces, and stabilizes demineralized enamel without requiring drilling or compromising healthy tooth structure (2). ICON® offers numerous advantages: it preserves tooth structure, preventing caries progression, fills micropores within the lesion, delays the need for restorative treatment, reducing recurrent caries, mitigates risks of pulp inflammation and postoperative sensitivity, lowers the risk of periodontitis and gingivitis, and enhances esthetics outcomes by effecively masking demineralized enamel (1, 4). This review aims to elucidate the scientific basis and principles underlying the ICON® technique and explore its clinical applications, focusing on caries inhibition, esthetics improvements, surface roughness, microhardness, and penetration efficacy — all of which have practical implications in clinical practice.

## *ICON®: Composition, mechanism of action and technique of application*

ICON® contains 15% HCl as an etchant, ethanol as a dehydrating agent, and triethylene glycol dimethacrylate (TEGDMA) resin as an infiltrant (4). This technique involves etching the tooth lesion surface with 15% HCl for two minutes, adequately desiccating the tooth, injecting a low-viscosity resin into the demineralized enamel intercrystallite space via capillary force, and then light-curing the resin (4). HCl gel is applied to the affected areas, including the vestibular and proximal regions, using a specific applicator tip. Prior to ICON® treatment, a latex rubber dam must be placed to prevent salivary contamination, which reduces the treatment's effectiveness, and to protect soft tissues from HCl, which can cause transient bleaching and chemical burn. The manufacturer's protocol recommends applying the etch gel for two minutes, followed by cleaning and drying for thirty seconds using a triple air syringe. Afterward, ICON® Dry (99% ethanol) is applied. Clinicians should monitor the lesions at this stage, as the application of ICON® Dry highlights the areas where the ICON® infiltrant will be effective (2). If the enamel discoloration does not significantly improve after using ICON® Etch and ICON® Dry, the manufacturer suggests repeating the etch, wash, dry, and ethanol application stages twice more (2). The ICON® infiltrant is then applied for three minutes using a light applicator, followed by the application of resin and light cure for three minutes. The resin application may be repeated for an additional minute if necessary. ICON® penetrates demineralized enamel lesions, occluding intercrystalline space via capillary force. It forms a polymer that micromechanically interlocks the remaining enamel prisms, blocking hydrogen ions, thereby preventing further demineralization and caries progression (5).

However, a hypermineralized pseudointact enamel caries surface layer can create a barrier that inhibits the capillary action of the ICON® (6). The use of 15% HCl to remove this surface layer is efficacious and believed to be advantageous for a deeper infiltration of the resin into the body of the lesion (1). According to the manufacturer recommendations, etching cycles are typically conducted in sets of three cycles (6). After the tooth has been etched, it is essential to inspect the lesion to determine if the etching has sufficiently penetrated the lesion substance by applying ethanol. Rewetting the lesions with ethanol appears to be a reliable indicator of the required number of etching cycles (7). If there is no reduction in enamel discoloration after using ethanol, the manufacturer recommends repeating the etching, washing, and ethanol application procedure twice more (6).

Typically, two applications of the ICON® infiltrant are necessary for effective resin penetration (2, 6). Due to the material's tendency to contract after the first application, leaving a gap that the second application of resin can fill, ICON® infiltrant is applied twice (4). In vitro studies have indicated that a second application of ICON® infiltrant can increase the microhardness values by compensating for polymerization contraction, hence promoting a greater filling of the microporosities. Table 1 shows a summary of studies related to ICON®.

## *Caries inhibition properties of ICON®*

The American Dental Association 2018 evidence-based clinical practice guideline endorses the use of ICON® in non-cavitated occlusal and proximal early enamel lesions (7). The guideline recommends the use of ICON® alone or in combination with 5% fluoride varnish for arresting and reversing non-cavitated lesions on the proximal surface, whereas for lesions on the occlusal surface, a combination of ICON® and 5% fluoride varnish can be considered as an alternative to the conventional treatment of using fluoride varnish or fissure sealant (7).

**Table 1**: Summary of study related to ICON®

| Caries inhibition | | |
|---|---|---|
| **Author/ type of study** | **Tooth** | **Main findings** |
| Cebula et al. 2023 (8)/ SR | Non-cavitated proximal carious lesions | ICON® in combination with non-invasive treatments (e.g., oral hygiene and dietary control, topical fluoride, etc.) is more efficacious than non-invasive treatments alone in treating proximal caries lesions in both primary and permanent teeth. |
| Urquhart et al. 2019 (9)/ SRMA | Non-cavitated proximal caries lesions | The combination of ICON® and 5% NaF varnish may be the most effective treatment for non-cavitated carious lesions on the proximal surfaces of permanent and primary teeth (low certainty). |
| Tedesco et al. 2022 (10)/ SRMA | Primary teeth with initial caries lesion | The use of micro-invasive approaches, as ICON® or sealing, are more effective than non-invasive professional treatment or oral hygiene to arrest proximal caries lesion. ICON® is the most effective approach to avoid the progression of initial caries lesions in primary teeth, especially in proximal surfaces. |
| Lin et al. 2022 (11)/ Umbrella review | Primary and permanent teeth with WSL or ICDAS 1 or 2 | ICON® technique was observed to cause a significant reduction in the risk of caries progression for both primary and permanent teeth when compared to the placebo or control groups (fluoridated toothpaste, fluoride varnish, universal self-priming bonding agent, micro-abrasion, oral hygiene instructions and diet counselling or no treatment). |
| Liang et al. 2018 (12)/ SRMA | Non-cavitated proximal caries primary or mixed/permanent dentition | ICON® is effective at halting the progression of non-cavitated proximal caries associated with Dentoenamel junction, whereas the therapeutic effects of resin sealant for varying caries depths require further investigation. |
| Chen et al. 2021 (13)/ SRMA | Primary or mixed/permanent dentition proximal or approximal non-cavitated caries | ICON® and sealing were more efficacious than non-invasive therapies for arresting the progression of proximal carious lesions. In both the primary and permanent dentition, ICON® and sealing was efficacious. |
| Faghihian et al. 2019 (14)/ SRMA | Primary or permanent dentition | ICON® technique is effective in preventing initial caries progression in primary and permanent teeth. |
| Chatzimarkou et al. 2018 (15)/ SRMA | Primary or mixed/permanent dentition with proximal caries lesions, extending at enamel to the outer third of dentin. | Strong evidence indicated that proximal caries lesion progression was less likely to occur in permanent teeth following treatment with ICON® and oral hygiene measures as compared to non-invasive methods (oral hygiene instructions) for 18- to 24-month follow-up. |
| Doméjean et al. 2015 (16)/ SR | Non-cavitated caries lesions | ICON® appeared to effectively halt the progression of non-cavitated caries lesions. |
| Ammari et al. 2015 (17)/ SRMA | Non-cavitated proximal lesions in primary or permanent teeth | ICON® of non-cavitated proximal lesions is effective, as the progression of caries was significantly reduced when this technique was utilized. |
| Dorri et al. 2015 (18)/ SRMA | Proximal carious lesions, extended into enamel or dentin primary and permanent teeth | Microinvasive treatment of proximal caries lesions arrests noncavitated enamel and initial dentinal lesions (limited to outer third of dentine, based on radiograph) and is significantly more effective than noninvasive professional treatment (such as fluoride varnish) or advice (such as flossing). |
| **Esthetic effects** | | |
| Ibrahim et al. 2023 (19)/ SR | Primary and permanent teeth with WSL or ICDAS 1 or 2 | ICON® achieves the best esthetic outcomes compared with microabrasion and remineralization therapy. Color stability was achieved with this material for up to 24 months and no adverse effects were noted. Factors contributing to the esthetic outcomes of the resin include the elimination of the hypermineralized surface layer, the homogeneity of the resin itself, and polishing after ICON® infiltrant. |
| Casaña-Ruiz et al. 2023 (20)/ SR | Hypoplastic or hypomineralized enamel defects | Treatments carried out to date with the ICON™ in pediatric patients provide better results for the treatment of hypoplastic or hypomineralized enamel |

| | | |
|---|---|---|
| | | defects if combined with other Opalustre-type materials or prior remineralization. |
| Bulanda et al. 2022 (21)/ SR | MIH | The ICON® system may be successfully used to infiltrate tooth decalcification in children with MIH. However, the depth of infiltration and the achievement of enamel hardness after such therapy are not precisely defined. |
| Lin et al. 2022 (11)/ Umbrella review | Primary and permanent teeth with WSL or ICDAS 1 or 2 | ICON® can be regarded as an effective treatment modality in minimizing the risk of caries progression and improving the esthetic appearance of WSL. |
| Bourouni et al. 2021 (22)/ SRMA | Post-orthodontic WSL and fluorosis | ICON® has a significantly higher masking effect than natural remineralization or regular application of fluoride varnishes. |
| Shahroom et al. 2019 (23)/ SR | Dental fluorosis | ICON® showed a greater improvement in esthetics in comparison to bleaching. ICON® with additional infiltration time and a combination of ICON® with bleaching is the best treatment options. |
| Somani et al. 2019 (24)/ SR | MIH | ICON® techniques have shown some promise for white opacities. However, incomplete removal of the surface layer with the etchant is known to prevent complete penetration of the resin, thus making it look like the technique has failed. |
| Di Giovanni et al. 2018 (25)/ SR | Fluorosis | The most promising treatment for dental fluorosis appears to be ICON®, followed by bleaching and microabrasion. |
| Saccucci et al. 2022 (27)/ SR | Sound enamel, demineralized enamel, and MIH, Fluorosis | ICON® can be recommended to enhance the appearance of enamel lesions. On a long-term basis, the infiltrated lesions remained chromatically stable, demonstrating no significant color alterations. |
| Borges et al. 2017 (28)/ SR | Post-orthodontic WSL | ICON® technique seems to be a feasible option for color masking of enamel whitish discolorations, resulting both from WSL and enamel development defects. |
| | | **Penetration depth** |
| Ibrahim et al. 2023 (29)/ SR | Human or bovine teeth with sound enamel or lesion confined to enamel | The key to optimal ICON® penetration depth depends on the enamel surface treatment with hydrochloric acid and application technique, infiltration duration, formulation of TEGDMA and ethanol in the resin composition, as well as the type and caries activity of involved teeth. ICON® has superior penetrability compared to fissure sealant, casein phosphopeptide-amorphous calcium phosphate nanocomplexes, flowable composite, adhesive and fluoride varnish. |
| Soveral et al. 2021 (30)/ SRMA | Primary and permanent teeth with WSL or ICDAS 1 or 2 | It was estimated that ICON® penetrated 65.4% of the overall lesion. The average resin penetration depth increases as application time increases. |
| | | **Surface roughness** |
| Soveral et al. 2021 (30)/ SRMA | Primary and permanent teeth with WSL or ICDAS 1 or 2 | The surface roughness of both healthy enamel and WSL decreased by 35% and 54%, respectively, after ICON®. |
| | | **Microhardness** |
| Soveral et al. 2021 (30)/ SRMA | Primary and permanent teeth with WSLs or ICDAS 1 or 2 | ICON® decreased the microhardness of healthy enamel by 24% on average, while it increased the microhardness of enamel with WSL by 68%. |
| Zakizade et al. 2019 (31)/ SR | Untreated WSL | ICON® has a significant advantage in improving the microhardness of WSL; however, it is unlikely that the microhardness of resin-infiltrated WSL can be restored to a level comparable to that of healthy enamel. ICON® was more efficacious than other methods (fluoride application, enamel pro-varnish, ExciTE F adhesive and colloidal silica infiltration) for enhancing microhardness. |

Abbreviation: WSL – white spot lesion; MIH – molar incisor hypomineralization; SR – Systematic review; SRMA – Systematic review and Meta analysis

Published systematic and umbrella reviews on the caries inhibition ability of ICON® on early enamel lesions indicate that the relative risk of caries progression for caries infiltrated lesions is substantially decreased (8, 9, 10, 11, 12, 13, 17, 18). Infiltrating the caries lesion is more effective for both primary and permanent teeth than no treatment or other non-invasive preventive measures like fluoride varnish, fissure sealant, and oral hygiene instruction (11, 12, 13, 14, 15, 18, 19). ICON® has been reported to be particularly successful in primary and permanent teeth when the lesions reach into the enamel and outer third of dentin, according to a meta-analysis evaluating its efficiency in halting the progression of non-cavitated proximal lesions (9, 10, 17, 18).

The majority of the studies discovered that ICON® significantly slowed the progression of WSL compared to the control group (no treatment) and non-invasive interventions (oral hygiene instructions, fluoride varnish, fissure sealants) (8, 9, 10, 11, 12). They observed that the combination of ICON® and 5% sodium fluoride varnish resulted in a five-fold increased likelihood of arresting or reversing lesions in comparison to no treatment (9). Liang et al. (12) discovered that ICON® substantially slowed the progression of white spot or non-cavitated proximal enamel lesions but had no effect on underlying dentinal lesions. Except for individuals with moderate caries risk, Chen et al. (13) observed that ICON® was superior to non-invasive interventions for patients with varying degrees of caries risk.

Chatzimarkou et al. (15) concluded that the development of proximal WSL in permanent teeth was less likely after treatment with ICON® and oral hygiene measures compared to other non-invasive interventions, such as oral hygiene instructions. In addition, Doméjean et al. (16) and Ammari et al. (17) discovered that with ICON®, the risk of non-cavitated proximal lesion development in both primary and permanent teeth was significantly reduced. The authors also noted that the comparison of ICON® efficacy and progression of caries lesions on primary and permanent teeth favors the successors, primarily due to the structural difference between the enamel of primary and permanent teeth (16, 17). The enamel structure of primary teeth is less mineralized, more porous, and thinner than that of permanent teeth (11, 14, 18). Therefore, the progression of lesions is more rapid in primary teeth (18). With the incorporation of more recent follow-up reports, the long-term efficacy of the treatment was confirmed, as lesion progression was monitored for at least 36 months in the majority of trials assessing lesions in permanent teeth, and for seven years in one study (8).

### *The esthetics outcomes of ICON®*

Masking enamel lesions with ICON® is based on variations in light scattering within the lesions (1, 6). The refractive index (RI) of healthy enamel is 1.62 (19, 20). The demineralized lesions are filled with either a watery media (RI = 1.33) or air (RI = 1.0) (4). The difference in RI between the enamel crystals and the media within the porosities induces light scattering, which gives these lesions a white, opaque look, particularly when they are dehydrated (3, 6, 21). ICON® infiltrant (RI = 1.52) has an RI that is nearly identical to that of apatite crystals, consequently, the difference in RI between porosities and enamel is minor, and lesions resemble the surrounding healthy enamel, thereby concealing the lesion (6, 21).

A meta-analysis conducted by Bourouni et al. (22) revealed that ICON® resulted in a substantially greater optical improvement than the regular application of fluoride varnish (22). The author also stated that the masking effects of fluoride varnish could take up to six months, unlike the concealing effect of ICON®, which is immediate (22). In addition, Ibrahim et al. (19) concluded that both techniques enhance the esthetics outcome of WSL, but lesions treated with ICON® had better and longer esthetics outcomes. Moreover, ICON® has been found to be the most effective method for enhancing the esthetics of dental fluorosis (22, 23). ICON® yields the most esthetically pleasing results when compared to bleaching and microabrasion (24, 25).

Increasing the etching duration would result in more effective masking of fluorosis. Etching is repeated until there is a discernible change in the color of the tooth surface to ensure deep penetration of the ICON® infiltrant to the depth of the hypomineralized zone. On severe fluorosis, a combination of at-home bleaching with 16% peroxide and carbamide and a later clinic visit using the ICON® method worked best. As opposed to more invasive procedures like direct resin restorations or ceramic veneers, this minimally invasive therapeutic technique proved to be a successful clinical choice. For instance, repeated etching cycles are necessary for deeply seated lesions, and Ibrahim et al. (6) found that five etching

cycles are optimal for concealing demineralized lesions.

The literature demonstrates that molar incisor hypomineralization (MIH) responds differentially to ICON® (22, 23). The success of concealing MIH lesions is contingent on the thickness of the mineralized surface layer (23). These opacities typically extend deep into the enamel, can be localized within the enamel, and can expand throughout its thickness, making the defect volume impermeable (24). ICON® penetrates MIH teeth although not as widely as in caries lesions and does not reach dentinoenamel junction (21, 24). Due to its higher porosity and lower mineral density, severe MIH teeth tend to be more penetrated. Nevertheless, based on a systematic review by Bulanda et al. (21) and Somani et al. (24), ICON® greatly enhanced the esthetics qualities of MIH affected teeth, hence improving the patient's health.

Hasmun et al. (26) examined a combination of management strategies for incisors afflicted by MIH. This pragmatic study utilized a combination of microabrasion, ICON®, at-home tooth whitening, and composite resin restoration, with each participant receiving a tailored treatment plan based on their clinical need. The authors reported an improvement in oral health-related quality of life (OHRQoL) and esthetics in general (26). Bulanda et al. (21) concurred with Somani et al. (23) that repeated etching in MIH cases necessitates a longer etching time. All authors referenced in this systematic review have suggested that ICON® treatment has a chance of failure, hence further research into the ICON® in MIH is needed. They also found a correlation between lesion depth and shade improvement, whereby lesions deeper than the penetration capacity of ICON® may exhibit insufficient esthetics improvement. The findings of the current meta-analyses are also consistent with the findings of several non-controlled trials that ICON® can be a viable option to mask the WSL (22).

According to Saccucci et al. (27), the ICON® composition of TEGDMA, which is a monomer with the capacity to penetrate deeply into the lesion and is very hydrophilic, is the primary cause of the color changes. This composition causes the resin to absorb more water, which transports the pigments deeply into the resin, therefore favoring the color change and reducing the color stability. Furthermore, long-term contact with the oral environment is thought to have an effect on the surface of resin infiltrated teeth and may cause microcracks on the surface, resulting in irregularities into the surface and increasing its susceptibility to staining and discoloration (19, 27). Patients should avoid ingesting colored foods and beverages to prolong the durability of ICON® in visually significant areas (27). Current clinical findings on long-term color stability, as measured with a spectrophotometer, showed stable infiltrates and esthetics assimilation of color and brightness variations between infiltrated lesions and neighboring healthy enamel. If a color change occurs, a polishing or bleaching treatment of the invaded region might be performed.

Polishing infiltrated lesions enhances their resistance to staining and can reduce the staining impact (19, 28). Polishing has resulted in a large reduction in total color difference (ΔE) values, because dyes are absorbed on the surface, with minimal penetration into resin materials or the dental substrate (29). Apart from that, it was discovered that polishing the infiltrating lesion increased the stability of the masking effect, most likely because it reduced the porosity of the surface and maybe removed the oxygen inhibition layer. The ΔE value after ICON® treatment was not statistically significant or clinically important at 6 months, 12 months or 24 months (19). That is, the demineralized camouflage effects obtained through ICON® were found to be color stable and steady over time.

### *Surface roughness and microhardness of ICON®*

The surface roughness of both healthy enamel and WSL decreased by 35% and 54%, respectively, after ICON®, and these findings have clinical significance (19, 30). Soveral et al. (30) indicated that ICON® treatment reduces surface roughness relative to baseline. This demonstrated that the application of ICON® can seal enamel defects, resulting in a seamless enamel surface (30). This disclosed that the enamel surface treated with ICON® exhibited enamel rod blockage, leaving a smooth surface with a uniform topography.

Compared to artificial demineralization and etching cycles, surface roughness values were significantly reduced following ICON®, which is consistent with the findings of Ibrahim et al. (6). Since the HCl applications created microporosities, which were then filled with ICON®, the surface roughness decreased (6). Consequently, after applying resin to the surface, a homogenous layer containing groups of microscopic enamel grains is uniformly distributed,

thereby smoothing the enamel surface and reducing surface roughness (6, 30).

Currently, ICON® is recommended due to its increased microhardness in comparison to untreated or remineralized caries lesions (31). It has been demonstrated that the hardness of restorative materials correlates with other mechanical properties, such as fracture resistance, elasticity, yield and compressive strength and abrasion resistance (31). This can be explained by the fact that, due to its low viscosity, resin fills the pores between the remaining crystals in a porous lesion, forming a diffusion barrier not only on the surface but also within the lesion body, causing the demineralized tissues to reharden and increase their mechanical strength (31).

### *Limitations of ICON®*

Even though ICON® has expanded minimally invasive enamel opacity treatment choices, there are a few factors that may limit treatment outcomes (4). ICON® works on the infiltration principle and requires a particularly dry field by using a rubber dam. Other than keeping the environment dry, extra efforts must be taken to dry the lesion. In order to do this, the lesion area is treated with ethanol, which evaporates the water present in the porosities and may prevent the infiltration process. Also, surface conditioning of the lesion is necessary for ICON® (9). The early caries lesion hypermineralized surface layer prevents resin from penetrating into the demineralized lesion body, necessitating surface treatment with 15% HCl. Aside from that, ICON® has a restricted penetration depth into the caries lesion (11, 28). Despite several systematic reviews describing the efficiency of ICON® penetrating early enamel lesions, low-viscosity ICON® is restricted to the enamel structure and did not perform well in the dentinal lesion (28).

According to Soveral et al. (30), whereas the resin entered 100% of the inner enamel lesion, only 64% of the outer dentine lesion was infiltrated by ICON®. The deeper the depth of the caries lesion, the lesser the likelihood of full infiltration (29). Extensive lesions are also linked to increased polymerization shrinkage and the formation of porosities and fissures (28, 29).

Poor long-term color constancy has been linked to ICON® (19). Numerous in vitro investigations have demonstrated that the infiltrated teeth are unable to maintain the masking effects and are sensitive to discoloration by the coloring chemicals present in the diet (8, 19). Following immersion in coffee, tea, red wine, and grape juice, notable color changes have been documented (1, 8, 19). Additionally, compared to teeth treated with remineralizing agents, the color alterations were more noticeable in teeth with ICON®.

## *Conclusion*

ICON® is an effective treatment modality for reducing the risk of caries progression and enhancing the esthetics appearance of white spot lesions. This technique is considered microinvasive and bridges the gap between non-invasive and minimally invasive treatment of early caries lesions, effectively delaying the need for more extensive restorative procedures. However, a limitation of ICON® is the unpredictability of esthetics outcomes. To improve this method and achieve a predictable and successful therapeutic strategy for various levels of enamel opacities, further research is essential.

## *Acknowledgment*

We would like to thank the Director General of Health Malaysia for his permission to publish this article.

## *Competing interests*

The authors declare that they have no competing interests.

## *Ethical clearance*

The approval to conduct the study was granted by The Research Ethics Committee (REC) of Universiti Teknologi MARA (UiTM) code REC/08/2020 (MR/220, 15 September 2020).

## *Financial support*

This research did not receive any funding from public, commercial or non-profit agencies.

## *References*

1. Dziaruddin N, Zakaria ASI. Resin Infiltration of Non-Cavitated Enamel Lesions in Paediatric Dentistry: A Narrative Review. Children (Basel). 2022; 9(12):1893.
2. Tavares MI, Saraiva J, do Vale F, Coelho AS, Amaro IF, Marto CM, et al. Resin infiltration in white spot lesions caused by orthodontic hypomineralisation: a minimally invasive therapy. Br Dent J. 2021; 231(7):387-392.

3. Allen DN, Fine CM, Newton MN, Kabani F, Muzzin KB, Reed KM. Resin Infiltration Therapy: A micro-invasive treatment approach for white spot lesions. J Dent Hyg. 2021; 95(6):31-35.
4. Ibrahim DFA, Liew YM, Hasmun NN, Venkiteswaran A. Resin infiltration ICON®: A Guide For Clinical Use. Mal Jour of Paed Dent 2023; 2(1):27-35.
5. Perdigão J. Resin infiltration of enamel white spot lesions: An ultramorphological analysis. J Esthet Restor Dent. 2020; 32(3):317-324.
6. Ibrahim DFA, Hasmun NN, Liew YM, Venkiteswaran A. Repeated Etching Cycles of Resin Infiltration up to Nine Cycles on Demineralized Enamel: Surface Roughness and Esthetic Outcomes—In Vitro Study. Children. 2023; 10(7):1148.
7. Slayton RL, Urquhart O, Araujo MWB, Fontana M, Guzmán-Armstrong S, Nascimento MM, et al. Evidence-based clinical practice guideline on nonrestorative treatments for carious lesions: A report from the American Dental Association. J Am Dent Assoc. 2018; 149(10):837-849.e19.
8. Cebula M, Göstemeyer G, Krois J, Pitchika V, Paris S, Schwendicke F, et al. Resin Infiltration of Non-Cavitated Proximal Caries Lesions in Primary and Permanent Teeth: A Systematic Review and Scenario Analysis of Randomized Controlled Trials. J Clin Med. 2023; 12(2):727.
9. Urquhart O, Tampi MP, Pilcher L, Slayton RL, Araujo MWB, Fontana M, et al. Nonrestorative Treatments for Caries: Systematic Review and Network Meta-analysis. J Dent Res. 2019; 98(1):14-26.
10. Tedesco TK, Calvo AFB, Pássaro AL, Araujo MP, Ladewig NM, Scarpini S, et al. Nonrestorative treatment of initial caries lesion in primary teeth: a systematic review and network meta-analysis. Acta Odontol Scand. 2022; 80(1):1-8.
11. Lin GSS, Chan DZK, Lee HY, Low TT, Laer TS, Pillai MPM, et al. Effectiveness of resin infiltration in caries inhibition and aesthetic appearance improvement of white-spot lesions: an umbrella review. J Evid Based Dent Pract. 2022; 22(3):101723.
12. Liang Y, Deng Z, Dai X, Tian J, Zhao W. Micro-invasive interventions for managing non-cavitated proximal caries of different depths: a systematic review and meta-analysis. Clin Oral Investig. 2018; 22(8):2675–2684.
13. Chen Y, Chen D, Lin H. Infiltration and sealing for managing non-cavitated proximal lesions: a systematic review and meta-analysis. BMC Oral Health. 2021; 21(1):13.
14. Faghihian R, Shirani M, Tarrahi MJ, Zakizade M. Efficacy of the Resin Infiltration Technique in Preventing Initial Caries Progression: A Systematic Review and Meta-Analysis. Pediatr Dent. 2019; 41(2):88-94.
15. Chatzimarkou S, Koletsi D, Kavvadia K. The effect of resin infiltration on proximal caries lesions in primary and permanent teeth. A systematic review and meta-analysis of clinical trials. J Dent. 2018; 77:8-17.
16. Doméjean S, Ducamp R, Léger S, Holmgren C. Resin infiltration of non-cavitated caries lesions: a systematic review. Med Princ Pract. 2015; 24(3):216-221.
17. Ammari MM, Soviero VM, da Silva Fidalgo TK, Lenzi M, Ferreira DM, Mattos CT, et al. Is non-cavitated proximal lesion sealing an effective method for caries control in primary and permanent teeth? A systematic review and meta-analysis. J Dent. 2014; 42(10):1217-1227.
18. Dorri M, Dunne SM, Walsh T, Schwendicke F. Micro-invasive interventions for managing proximal dental decay in primary and permanent teeth. Cochrane Database Syst Rev. 2015; 2015(11):CD010431.
19. Ibrahim DFA, Venkiteswaran A, Hasmun NN. Esthetic Effects and Color Stability of Resin Infiltration on Demineralized Enamel Lesions: A Systematic Review. J Int Soc Prev Community Dent. 2023; 13(4):273-286.
20. Casaña-Ruiz MD, Marqués Martínez L, García Miralles E. Management of Hypoplastic or Hypomineralized Defects with Resin Infiltration at Pediatric Ages: Systematic Review. Int J Environ Res Public Health. 2023; 20(6):5201.
21. Bulanda S, Ilczuk-Rypuła D, Dybek A, Pietraszewska D, Skucha-Nowak M, Postek-Stefańska L. Management of Teeth Affected by Molar Incisor Hypomineralization Using a Resin Infiltration Technique—A Systematic Review. Coatings. 2022; 12(7):964.
22. Bourouni S, Dritsas K, Kloukos D, Wierichs RJ. Efficacy of resin infiltration to mask post-orthodontic or non-post-orthodontic white spot lesions or fluorosis — a systematic review and meta-analysis. Clin Oral Investig. 2021; 25(8):4711–4719.
23. Shahroom NSB, Mani G, Ramakrishnan M. Interventions in management of dental fluorosis, an endemic disease: A systematic review. J Family Med Prim Care. 2019; 8(10):3108-3113.

24. Somani C, Taylor GD, Garot E, Rouas P, Lygidakis NA, Wong FSL. An update of treatment modalities in children and adolescents with teeth affected by molar incisor hypomineralisation (MIH): a systematic review. Eur Arch Paediatr Dent. 2022; 23(1):39-64.
25. Di Giovanni T, Eliades T, Papageorgiou SN. Interventions for dental fluorosis: A systematic review. J Esthet Restor Dent. 2018; 30(6):502-508.
26. Hasmun N, Vettore MV, Lawson JA, Elcock C, Zaitoun H, Rodd HD. Determinants of children's oral health-related quality of life following aesthetic treatment of enamel opacities. J Dent. 2020; 98:103372.
27. Saccucci M, Corridore D, Di Carlo G, Bonucci E, Cicciù M, Vozza I. Assessment of Enamel Color Stability of Resins Infiltration Treatment in Human Teeth: A Systematic Review. Int J Environ Res Public Health. 2022; 19(18):11269.
28. Borges AB, Caneppele TMF, Masterson D, Maia LC. Is resin infiltration an effective esthetic treatment for enamel development defects and white spot lesions? A systematic review. J Dent. 2017; 56:11–18.
29. Ibrahim DFA, Venkiteswaran A, Hasmun NN. The Penetration Depth of Resin Infiltration into Enamel: A Systematic Review. J Int Soc Prev Community Dent. 2023; 13(3):194-207.
30. Soveral M, Machado V, Botelho J, Mendes JJ, Manso C. Effect of Resin Infiltration on Enamel: A Systematic Review and Meta-Analysis. J Funct Biomater. 2021; 12(3):48.
31. Zakizade M, Davoudi A, Akhavan A, Shirban F. Effect of Resin Infiltration Technique on Improving Surface Hardness of Enamel Lesions: A Systematic Review and Meta-analysis. J Evid Based Dent Pract. 2020; 20(2):101405.