REVIEW ARTICLE

CONTENTS

ICON infiltration technique as a modern approach to non-invasive caries treatment – A review of the 2018–2024 literature

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ABSTRACT

Non-invasive management of early caries lesions has become a cornerstone of contemporary minimally invasive dentistry. The ICON resin infiltration technique allows for the arrest of non-cavitated carious lesions and significant esthetic improvement, particularly in cases of white spot lesions. This review aims to present current scientific evidence on the effectiveness, indications, limitations, and clinical perspectives of ICON for the treatment of initial enamel caries. Recent systematic reviews, meta-analyses, and clinical studies from 2021–2024 were analyzed. The findings confirm that ICON is highly effective in arresting the progression of early carious lesions, especially on proximal surfaces, and in masking esthetic defects following orthodontic treatment and mild fluorosis. Proper case selection, strict adherence to the clinical protocol, and operator experience are crucial for therapeutic success. Limitations include reduced effectiveness in deep or inactive lesions, high technique sensitivity, and the cost of the procedure. Recent research focuses on combination therapies, novel infiltrant materials, and the application of digital diagnostics and artificial intelligence. ICON has the potential to become the standard for microinvasive treatment of early caries in the future, contributing to patient comfort, esthetic outcomes, and tooth preservation within the framework of preventive dentistry.

KEY WORDS: resin infiltration; early caries; microinvasive treatment; white spot lesions; enamel demineralization

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INTRODUCTION

Dental caries remains one of the most prevalent chronic diseases worldwide, affecting individuals of all age groups despite significant improvements in preventive dentistry [1]. Early enamel lesions are clinically visible as so-called *white spot lesions* (WSLs), which represent subsurface demineralization without cavitation. Their chalky, opaque appearance is an esthetic problem, particularly in anterior teeth, and also indicates the onset of caries progression [2].

Traditional management of these initial lesions includes topical fluoride application, casein phosphopeptide-amorphous calcium phosphate (CPP-ACP), hydroxyapatite-based pastes, bleaching, and microabrasion techniques [3–5]. However, these approaches show limited effectiveness in deeper subsurface lesions, depend on patient compliance, and often fail to completely restore enamel translucency [6].

In recent years, the development of resin infiltration technology (ICON®, DMG, Hamburg, Germany) has provided a micro-invasive alternative between preventive and restorative strategies [7]. The principle of the technique is based on capillary penetration of a low-viscosity resin into the microporosities of demineralized enamel, thereby blocking diffusion pathways for acids and halting caries progression [8]. At the same time, the refractive index of the infiltrated enamel is modified, resulting in an immediate esthetic improvement through masking of WSLs [9].

Several systematic reviews and clinical studies confirm the efficacy of resin infiltration. Meta-analyses have shown that ICON provides superior esthetic masking compared to fluoride or CPP-ACP applications [2, 3]. Recent clinical and laboratory studies further support these findings. An in vitro study demonstrated that ICON resin infiltration increased enamel hardness and sealed prism structures, as evidenced by SEM and AFM analyses [10]. Another laboratory investigation using confocal laser scanning microscopy showed that the resin infiltrant penetrated up to 96% of the lesion depth [11]. In clinical settings, ICON proved effective in managing fluorosis, with a one-year follow-up confirming stable esthetic outcomes and high patient satisfaction [12]. Furthermore, randomized

controlled trials highlighted that ICON was significantly more effective than sodium fluoride varnish in reducing the severity of WSLs after six months [13].

AIM

This review aims to present current scientific evidence on the effectiveness, indications, limitations, and clinical perspectives of ICON for the treatment of initial enamel caries.

MATERIALS AND METHODS

For this narrative literature review, publications from 2018 to 2025 were analyzed. The search was performed in PubMed, Scopus, and Web of Science databases using the keywords *resin infiltration, ICON, white spot lesions, fluorosis,* and *minimally invasive dentistry*. Only articles in English were considered. Priority was given to systematic reviews, meta-analyses, randomized controlled clinical trials, and high-quality in vitro studies directly evaluating the ICON technique.

The inclusion criteria covered studies on early carious lesions, orthodontically induced white spot lesions, dental fluorosis, and molar-incisor hypomineralization. Case reports with long-term follow-up were also included if they provided relevant clinical insights. Studies older than 2018 were excluded unless they presented unique long-term results.

REVIEW AND DISCUSSION

MECHANISM OF ACTION

Resin infiltration works by penetrating the porous structure of early non-cavitated caries lesions with a low-viscosity, light-cured resin. The process begins with gentle etching of the enamel surface, which opens the microporosities and removes the hypermineralized surface layer. After drying with ethanol, the infiltrant resin is applied, allowing capillary action to draw the resin deep into the demineralized enamel. Upon polymerization, the infiltrant occludes the lesion body, blocking further acid diffusion, arresting caries progression, and reinforcing the weakened enamel structure [1, 2].

Recent morphological and in vitro studies confirm that ICON can infiltrate almost the entire body of active white spot lesions, providing a physical barrier to further demineralization and bacterial invasion [5,10]. Confocal laser scanning microscopy investigations demonstrated that the resin infiltrant can penetrate up to 96% of the lesion depth, underlining its potential to seal subsurface demineralization [11]. The success of infiltration depends largely on lesion activity and depth; active, shallow lesions are most effectively treated, while inactive or deeper lesions (such as brown spots) may show incomplete penetration due to surface remineralization or subsurface lesion extension [5,6,11].

Importantly, resin infiltration also leads to optical blending of the lesion with healthy enamel, as the refractive index of the infiltrant closely matches that of sound tooth tissue. This not only halts the disease process but also provides immediate esthetic improvement [2,3].

CLINICAL PROTOCOL FOR ICON RESIN INFILTRATION

Recent guidelines and clinical studies (2018–2024) recommend the following stepwise protocol for the use of ICON resin infiltration in non-cavitated enamel lesions [2,3,5]:

1. **Diagnosis and Case Selection:** Confirm the lesion is a non-cavitated, active (white spot) or early inactive (brown spot) carious lesion, confined to enamel or outermost dentin. Radiographic and clinical assessment are essential for appropriate case selection.
2. **Isolation:** Apply a rubber dam or other isolation technique to prevent moisture contamination during the procedure.
3. **Etching:** Apply 15% hydrochloric acid gel for 2 minutes to remove the hypermineralized surface layer and open enamel microporosities.
4. **Rinsing and Drying:** Thoroughly rinse the etched surface with water, then dry with ethanol (Icon Dry) to achieve optimal dehydration and visual inspection of lesion penetration.
5. **Resin Application:** Apply the low-viscosity resin infiltrant (ICON) onto the lesion surface for at least 3 minutes to ensure deep penetration. Remove excess resin and gently air-dry.
6. **Light-Curing:** Polymerize the infiltrant using an appropriate curing light for 40 seconds.
7. **Repeat (if necessary):** In deeper or more resistant lesions, the infiltration step can be repeated to maximize resin penetration.
8. **Finishing and polishing:** Remove surface excess and polish the treated area to optimize smoothness and esthetics.

Studies confirm that following this protocol yields high rates of lesion arrest and esthetic improvement, particularly for active white spot lesions [2, 5, 10].

INDICATIONS FOR ICON RESIN INFILTRATION

ICON resin infiltration is primarily indicated for the management of non-cavitated enamel lesions, including

early carious lesions (ICDAS 1–2) and certain developmental enamel defects. The main clinical indications supported by recent evidence are:

INITIAL PROXIMAL (CONTACT) CARIES LESIONS

ICON is especially effective for non-cavitated carious lesions located on proximal surfaces of both permanent and primary teeth. A 2021 meta-analysis and subsequent randomized trials confirm that resin infiltration significantly reduces the risk of lesion progression compared to observation or fluoride varnish, with long-term studies reporting 60–80% reduction in progression risk [1, 6, 7, 13]. ICON is therefore recommended as the first-choice micro-invasive approach for radiographically detected early proximal lesions (E1, E2, outer D1), particularly in children, adolescents, and patients at increased caries risk.

WHITE SPOT LESIONS AFTER ORTHODONTIC TREATMENT

Resin infiltration is widely used for esthetic improvement of white spot lesions following multibracket orthodontic therapy. Systematic reviews and meta-analyses show a significant advantage of ICON over remineralizing agents and fluoride varnish, both in esthetic outcomes and lesion stabilization [2, 3].

MILD TO MODERATE DENTAL FLUOROSIS

ICON can successfully mask mild to moderate fluorosis, blending the appearance of affected enamel with healthy tissue. A prospective one-year clinical study demonstrated complete resolution of fluorotic opacities with stable esthetic results and high patient satisfaction [12]. ICON is therefore a valuable micro-invasive alternative to microabrasion or composite restorations in carefully selected cases.

DEVELOPMENTAL ENAMEL HYPOMINERALIZATION (E.G., MIH)

Infiltration has shown esthetic benefit in selected cases of molar-incisor hypomineralization, especially on incisors. However, outcomes remain less predictable for severely affected molars or teeth with extensive structural breakdown [4].

KEY SELECTION CRITERIA

Lesions must be non-cavitated, preferably active or early-inactive, accessible for isolation, and without pulpal or periapical pathology. Proper diagnosis using radiographs and clinical examination is essential [3, 5, 7].

OFF-LABEL AND EMERGING APPLICATIONS

Although ICON resin infiltration is officially indicated for early carious lesions and white spot management, recent studies describe several promising off-label and emerging uses. These include:

Masking of developmental enamel opacities (e.g., Turner's tooth, traumatic hypomineralization)

Camouflage of mild enamel hypoplasia or post-traumatic defects

Management of esthetic disturbances in MIH in anterior teeth not meeting classic inclusion criteria

Blending of localized post-bleaching white marks or superficial post-traumatic stains.

Case reports and pilot clinical trials have demonstrated successful masking of such enamel defects, though current evidence is limited and outcomes less predictable than in classic indications [2, 5, 14]. Patients must be informed that off-label applications may not yield permanent or fully satisfactory esthetic results and may require retreatment. Long-term follow-up, such as the four-year case report presented by Cazzolla et al., shows that infiltration effects may persist, though periodic re-evaluation is recommended [14].

Future research and well-designed clinical trials are needed to clearly establish the safety and long-term efficacy of ICON in these off-label scenarios [2,6].

EFFECTIVENESS AND ESTHETIC OUTCOMES

Recent systematic reviews and clinical studies confirm that ICON resin infiltration is highly effective in arresting the progression of non-cavitated enamel caries lesions. In proximal lesions, multiple meta-analyses demonstrate that resin infiltration reduces the risk of lesion progression by 60–80% compared to no treatment or fluoride varnish, with follow-up extending up to seven years [1,6,7]. ICON is particularly beneficial in children and adolescents, as it helps avoid restorative interventions and preserves sound tooth structure [15].

A key advantage of resin infiltration is its esthetic benefit. ICON provides immediate masking of white spot lesions, post-orthodontic demineralization, and mild dental fluorosis. A 2023 network meta-analysis showed that resin infiltration delivers superior visual improvement compared to remineralizing agents and fluoride varnish, with consistently high patient satisfaction scores [2, 3]. A one-year clinical study further confirmed complete disappearance of fluorotic lesions and stable results [12], while long-term case reports documented

durable esthetic improvement up to four years [14].

For selected cases of molar-incisor hypomineralization (MIH), particularly in anterior teeth, ICON infiltration results in significant color improvement and cosmetic blending, although the outcomes are less predictable in severely hypomineralized or structurally compromised teeth [4].

LIMITATIONS

While ICON resin infiltration has revolutionized micro-invasive caries management, several limitations and challenges remain. The technique is most effective in early, non-cavitated, and active white spot lesions. Inactive or deeper lesions (e.g., brown spots or those extending into outer dentin) frequently show incomplete resin penetration due to a hypermineralized surface or lesion depth [5,6,11]. Systematic reviews highlight that effectiveness significantly decreases when lesions extend beyond the outer third of dentin or present with a thick, remineralized surface layer [1,6,7].

Esthetic outcomes may also vary. Although ICON achieves impressive masking of white spot lesions and mild fluorosis, results are less predictable in severe developmental opacities, deep post-traumatic defects, or extensive MIH [2,3]. The degree of color blending and long-term stability can vary, and in some cases repeated infiltration or adjunctive procedures are necessary [14].

The procedure is also technique-sensitive and requires strict isolation, careful surface conditioning, and adherence to the protocol. Inadequate etching or incomplete drying may limit resin penetration, while operator experience has been shown to significantly affect both clinical and esthetic results [7].

ECONOMIC ASPECTS

An additional limitation of ICON therapy is its cost. The average price per tooth in European private practice ranges from 300–600 PLN, which is considerably higher than topical fluoride varnish (<100 PLN) or remineralizing agents (50–150 PLN). Nonetheless, ICON is less invasive and less costly compared to esthetic alternatives such as veneers or extensive microabrasion procedures. From a long-term perspective, successful infiltration can reduce the need for restorative interventions, potentially lowering future treatment costs [13].

ADVERSE EFFECTS

Although ICON resin infiltration is generally considered a safe and well-tolerated microinvasive technique, some side effects have been reported. The use of 15% hydrochloric acid during the etching step may cause transient gingival irritation if gingival tissues are not adequately protected [10]. Laboratory studies also indicate that infiltrated enamel surfaces may become rougher, which could theoretically favor plaque accumulation [10]. Furthermore, long-term clinical observations and case reports suggest that repeated applications may be required to maintain esthetic results in certain lesions, particularly in fluorotic or hypomineralized teeth [14].

FUTURE DIRECTIONS AND RESEARCH

The field of resin infiltration is evolving rapidly, with several promising developments on the horizon. Combination therapies are being explored, such as infiltration following partial microabrasion or in conjunction with remineralizing agents, to further enhance both caries arrest and esthetic outcomes [9]. Advances in diagnostic technologies, including digital caries detection and artificial intelligence-based imaging, may improve lesion selection, monitoring, and treatment planning, potentially increasing the success rate of ICON therapy [10].

Another area of research focuses on next-generation infiltrants, incorporating bioactive components such as hydroxyapatite nanoparticles or fluoride-releasing matrices. These modified formulations aim not only to seal enamel porosities but also to provide antibacterial properties and promote remineralization [15]. Preliminary laboratory studies suggest that such infiltrants may enhance long-term durability and broaden clinical indications.

Finally, further high-quality randomized controlled trials are needed to confirm the long-term stability of esthetic outcomes, assess cost-effectiveness in broader populations, and validate ICON use in off-label applications, such as developmental enamel defects and severe MIH [2,6,12].

CONCLUSIONS

Resin infiltration with ICON represents a micro-invasive and effective approach for managing early carious lesions and enamel opacities. Current evidence confirms its ability to arrest lesion progression and provide immediate esthetic improvement, particularly for orthodontic white spot lesions and mild fluorosis. Randomized clinical trials demonstrate superior outcomes compared to fluoride varnish, while long-term reports highlight durability of esthetic results.

Despite these advantages, ICON is not universally applicable. Its effectiveness is limited in deep or inactive lesions, and costs may restrict accessibility. Minor adverse effects, such as transient gingival irritation

or the need for repeated applications, should also be considered.

Overall, ICON remains a valuable treatment option within minimally invasive dentistry, bridging the gap between preventive and restorative strategies. With ongoing research and development, resin infiltration may gain an even broader role in contemporary caries management.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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