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Research Article

ICON in Minimally Invasive Dentistry

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Abstract

Objective: The thesis objective is to evaluate ICON as a restorative material to treat white spot lesions, incipient carious lesions or primary carious lesions.

Material and Methods: To understand the efficiency of ICON in minimally invasive dentistry took help of NCBI PUBMED. The search terms were mainly primary carious lesions, incipient carious lesions, white spot lesions and resin infiltration. Total of 2732 articles found. After de duplication the shortlisted articles were 44. Apart from the NCBI source the DMG website for ICON was taken as reference and an article published in BMJ regarding aesthetic longevity of treated WSL was taken into consideration.

Results: After application of ICON there was good penetration of resin and that increased micro hardness and toughness of the tooth. WSL could be improved aesthetically. Preventing secondary decay with 2 - 3 application of ICON was tested.

Conclusion: Resin infiltration can be used to arrest progression of decay and along with the other adjunctive measures like 'Fluoridation' for prevention of decay. It's also very effective in masking white spot lesions if applied up to 2 - 3 applications.

Keywords: Resin Infiltration; White Spot Lesions; Secondary Decay; Caries and Aesthetics

Abbreviation

BISGMA: Bisphenol ethylene methacrylate; ICDAS: International caries detection and Assessment system; HCR: High caries rate; RI: Resin infiltration; TEGDMA: Tetraethylene glycol dimethacrylate; UDMA: Urethane dimethacrylate; NCPL: Non cavitated proximal lesions; MIH: Molar Incisor Hypomineralisation; WSL: White spot lesions; HEMA: Hexa ethyl methacrylate; HCL: Hydrochloric acid.

Introduction

Incipient or primary carious lesions are difficult to treat non-invasively. This is predominant problem to deal with in children. Another clinical problem to deal with in children as well as adults are white spot lesions present after orthodontic treatment or as enamel defects - posing aesthetic problem. For the treatment of white spots and non-cavitated lesions many modalities are used.

Solutions available today are either invasive (like fillings) or non-invasive ones like Fluoridation, fissure sealants, fluoride Varnishes, etc. These methods are kind of compromise as they do not solve the clinical challenges completely. It's really difficult to restore the decalcified areas non-invasively. Also after fillings there's always a probability of secondary decay progression around the edges of restorative materials in the teeth.

In case of fissure caries it's difficult to restore the tooth structure without being invasive.

WSL shows intact surface structure but it is decalcified area and needs attention. In order to treat such lesions non-invasively, fluorides are used currently in the form of gels or pastes or Varnishes. This doesn't solve the aesthetic problem immediately

and also requires patient compliance. To prevent secondary decay formation or arresting it, Fluoride gels need to be used for prolonged period of time, which again needs patient compliance.

ICON resin infiltrant introduced in 2009, by DMG HAMBURG, GERMANY can solve many problems like incipient caries, primary caries and secondary caries (Taher., *et al*. 2014).

As it's a micro invasive/ noninvasive procedure, breakdown of the enamel structure is avoided which is done while removing decalcified enamel. It has ability to treat WSL aesthetically. It's considered unique in its segment as it shows deeper penetration than currently available resins without actual mechanical intervention (Omar S. I. 2013).

Mixtures of HEMA, TEGDMA and ethanol creates very high coefficient of penetration in the carious dentin. This property helps in deeper penetration (Paris., *et al*. 2007a).

Thesis objective

The thesis objective is to evaluate ICON as a restorative material to treat white spot lesions, incipient carious lesions or primary carious lesions.

Research questions

Research was carried out on few pointers.

1. Is there increase in the micro hardness of the defective enamel after RI?
2. How deep is penetration of resin in one application?
3. Is RI effective in improving resistance to secondary decay?
4. Is RI more efficient than fissure sealant in preventing decay formation?
5. Is ICON efficient enough to treat WSL adequately?

Material and Methods

The search was carried out through NCBI PUBMED and hand search of relevant literature.

Total hits after using patient's intervention terms is 1250 then adding terms related to ICON as resin infiltrate 123 hits. To get relevant articles and to avoid de duplication, both searches combined to get final number of 44 articles.

Search Term	Search Results	Relevant Hits
White spot lesions	1960	
Incipient carious lesions Avoiding Deduplication	1088	
Primary carious lesion	998	
Without adding in previous searches started with only ICON	2091	
Narrow down the search resin infiltration	764	
Now adding ICON to resin infiltration	2732	
Deduplication- adding now to main search	44	24

Table 1: Overview of the articles found after search and articles considered relevant.

Exclusion criteria

- Articles older than 10 years
- Language other than English.

Inclusion criteria

- Clinical trials- random, split mouth
- Review
- Meta-analysis
- *In vitro* and *in vivo* studies.

After de duplication 24 relevant articles were found. During Google search, relevant article was included from Research Gate.

Results

Basic principle of ICON use

Icon composition and function

ICON is basically unfilled resin which penetrates porous structure of enamel by property of capillary action. It's available as two variations, proximal and smooth. Proximal is developed for proximal carious lesions and Smooth surface is especially developed for infiltration for post orthodontic decalcified lesions which are non cavitated. ICON kit comes with three main components- etchant, ICON dry and unfilled resin (Taher., *et al*. 2014).

The composition of ICON etching gel is Hydrochloric acid, photogenic silicic acid, and surface active substances. ICON dry has 99% ethanol. ICON infiltrant has methacrylate based resin matrix, initiators, and additives. (www.dmg-dental.com/icon).

Indication and contraindication

Indicated only for early carious lesions (lesion depth up to D1 as shown in (Figure 1) and lesions on smooth surface like white spot lesions limited to enamel. Contraindicated in deeper lesions up to D2, D3 or cavitated enamel. Advised use of 'ICON etch' only on enamel surface and not on exposed dentin or on cementum surface. If the instructions are not followed it can cause pain to the patient.

Other Contraindications are allergy or intolerance to material components (Omar S.I.2013).

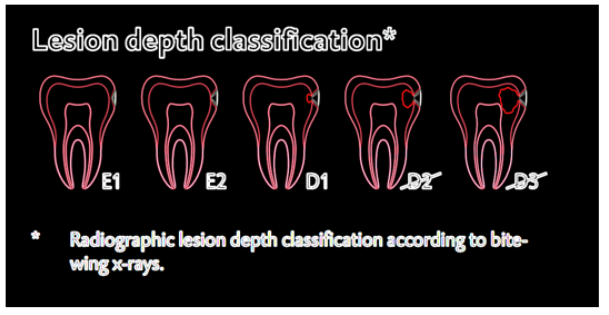

Figure 1: Radiographic lesion depth classification according to viewing x rays (www.dmg-dental.com/icon).

Application regimen

Proximal lesions

For proximal lesions, it is mandatory to use rubber dam - recommended not to use rubber dams made up from thermoplastic elastomer such as Flexidam. Insert the wedges given in the kit between affected teeth. Make sure to achieve sufficient separation. Leave the wedge interdentally for the entire procedure. Screw the proximal top onto ICON etch syringe and Place the application foil interdentally - the green side facing the tooth affected. The material will be dispensed only on green side of the application top.

After etching the surface for 2 minutes remove the foil and rinse of the etchant immediately with water for at least 30 sec. and dry it. Apply ICON dry to the site and dry with oil free and water free air. Apply ICON infiltrate with the new foil in place for 3 min and remove excess with dental floss. Light cure it for 40 sec from all sides. Remove rubber dam and wedges, polish with polishing strips.

Smooth surface treatment

After thorough cleaning of the affected tooth and adjacent teeth, apply rubber dam. ICON etch is used to dispense ample amount of etch on the lesion and let it sit for 2 min. The process is recommended to repeat twice if the WSL is not treated immediately after bracket removal. Rinse ICON etch for at least 30 sec. dry with water free and oil free air. After applying ICON -Dry the whitish opaque appearance should disappear. If not then need to repeat etching step. Etching is advised twice - thrice depending on how recent the white spot appearance is. After rinsing apply ICON dry-sit for 30 sec. Dry. With new smooth surface tip apply an ample amount on etched surface and let sit for 3 min. Remove excess material with a cotton and light cure for 40sec. Remove rubber dam and polish with cups for surface finish. As the material is not radiopaque it's better to record the tooth surface treated and Mark it on the patient's record card [1].

Effect of ICON on teeth

Tooth penetration depth

To evaluate penetration depth of ICON in the enamel of extracted human molars and Pre molars, they were pretreated with HCl, ethanol and acetone and evaluated as different groups. Drying of non cavitated carious lesions is important process in resin infiltration. The experiment concluded that penetration depth increases significantly for lesions ≥ 500 um by either pretreating or with either positive control with acetone or HCl (used twice or more) and drying (Paris., *et al*. 2013).

Another study on molar incisor hypomineralisation concluded that the penetration depth of RI in these cases is erratic. They applied ICON by standard protocol and adding a step of sodium hypochlorite irrigation. The lesions were studied under scanning electron microscope. This increased the penetration depth up to 0.67 ±0.39 mm and 23.1 ± 15.2% of the area of the lesion [2].

Effect on micro hardness of the defective enamel

As the penetration of resin gets deeper, weakened structure of enamel does gain hardness as it penetrates the demineralized area.

According to studies conducted by Paris S. And associates; Compared to unfilled enamel, RI ×1 time and repeating RI ×2times, the micro hardness had increased significantly but did not reach the micro hardness of sound enamel. The composition of used

resins did not affect the results whereas application frequency did affect significantly (Paris., *et al*. 2013).

MIH lesions were infiltrated using standard protocol or with addition of sodium hypochlorite (NaOCl) irrigation. The lesions were examined under light microscope. Vickers micro hardness increased, relative to the immediately adjacent hypomineralised enamel, where visible infiltrate penetration had occurred 3.0 ± 1.8 GPa vs. 1.8 ± 1.2 GPa (control 4.4 ± 1.0GPa) [2].

RI was compared with colloidal silica to assess penetration depth. RI was carried out in artificially created white spots and was compared with Colloidal Silica penetration. The surface micro hardness was measured at baseline using Vickers micro hardness tester with a diamond indented fitted with 300g load. They observed significant difference in values between the groups-showing higher values for resin infiltration Group. The baseline was showing 118.79 mean whereas after RI, the mean was 101.77 on the micro hardness scale. Which is closer value to sound enamel than colloidal silica [3].

Efficiency of ICON in arresting secondary decay

ICON was primarily developed so that there is arrest of secondary decay. Many studies were conducted on primary and permanent teeth to gather data to understand if it is efficient enough to arrest secondary decay.

Four studies are included here and summarized in table 2.

Study	Number of teeth	Age group	Type of study	Time period	Region of lesion	Progression of lesion	Diagnostic methods used
Peters., *et al*. 2018	32 proximal lesion pairs		Split mouth randomised placebo controlled trial.	2 years	Varying between E2 and D1	Less caries progression in RI lesions 97% versus 74% progression in control lesions.	Digital standardised radiographs McNamara's test.
Arthur., *et al.* 2017	36 pairs	26 -41 years old		1 year	Most lesions E2	6.25% E2⍰D1 Control lesions 33% E1⍰E2 6.6%E2⍰D1 33% D1⍰D2	
Martignon., *et al.* 2012	39 lesions		split mouth Randomised trial	1,2 and 3 years	ICDAS 2	Group A ICON 90% ,Group B sealing 87% Group C Placebo 87% stabilised to ICDAS score 2. 5% progressed to score 3.	Visual assessment Digital subtraction technology of scanned images
Bagher., *et al*. 2018	90 lesions	5-8 years old	Split mouth randomised prospective clinical trial	2 years 12 months 18 months 24 months	Most lesions E2	Test group RI +5%topical NaF. 40% progression Control group 5%NaF 72% progression	Radiographic assessment

Table 2: Efficiency of ICON in arresting secondary decay.

One study by Matilda Peters., *et al*. (2018) found that over 2 years 97% of the lesions infiltrated with ICON did not progress further whereas 74% of the control group showed progression. Most of the lesions selected were either existing in E2 or D1.

In another study with 27 lesions where the efficiency of ICON in arresting secondary decay was compared against a placebo group, only four subjects were caries active at follow up. Only 7.4% of the lesions had progressed, compared to 18.5% in the control group (Arthur., *et al*. 2017).

RI of non cavitated carious lesions (NCPL) is particularly very effective and it was assessed in a three year follow up study. Seventeen subjects were chosen (27pairs), at the end of three years only four subjects were caries active. 2/27(7.4%) lesions showed progression in the test group whereas 5/27 (18.5%) in placebo group had progressed. But as there was no significant difference in the number of lesions, the study remained inconclusive. RI was proven to have limited clinical significance [4].

Yet another study compared the efficiency of ICON in combination with sodium fluoride in arresting secondary decay in E2 lesions in primary molars compared to sodium fluoride alone. Radiographic assessment over 12, 18 and 24 months showed only 40% showed progression in the test group whereas 72% showed progression in control group [5].

Efficiency of ICON compared to fissure sealant and Varnishes

Although ICON was developed for arresting secondary decay, studies were carried out to see the efficacy of ICON in sealing the fissures and pits which are the starting points in decay progression. The lesions selected were following ICDAS codes 0,1,2.

Researchers	Number of lesions	Test and control groups	Mode of Analysis.	Results
Paris S., *et al.* 2014	70	Helioseal Ivoclar Vivadent, ICON DMG, Soft etch n RI	Confocal laser scanning microscope in dual fluorescence mode using 5 × objective.	Percentage penetration PPmax of ICON is much deeper than fissure sealant.41% as compared to fissure sealant 5(0-9%) and lesions treated with soft etch infiltration 11%.
Peters., *et al.* 2018	32 most lesions E2 to D1.	Fluoride varnish, ICON	Logistic regression and McNemar's test	Less caries progression in ICON as compared with control lesions

Table 3: Comparing ICON with fissure sealants and fluoride Varnishes.

32 proximal lesion pairs were evaluated after 2 years. The lesions were interproximal and varying between E2 and D1. Received professional HCR evaluation including F varnish applications. The data was evaluated by logistic regression and McNemar's test. Digital standardized radiographs were taken (Paris., *et al*. 2018).

Comparative analysis shows less caries progression in Resin infiltrated lesions compared with control lesions. 74% progression in control lesions versus 97% in RI lesions when checked with cumulative fraction (Peters., *et al*. 2018).

Efficiency of ICON in conjunction with other preventive methods

Few studies were conducted to evaluate ICON in conjunction with other preventive methods.

One such study was conducted by O. Urquhart and associates (2019) comparing various non-restorative or noninvasive/ micro invasive methods to treat and/or reverse the non cavitated lesions on primary and permanent teeth. Used NMA s to evaluate treatments regarding their ability to arrest or reverse non cavitated carious lesions on various tooth surfaces against no treatment. The evidence suggests that on the occlusal surfaces of primary and permanent teeth combination of sealant and 5% NaF vanish works best. On approximal surfaces of primary and Permanent teeth, the combination of RI and 5% NaF varnish is most effective against non cavitated lesions. On root surfaces such lesions are best treated with 5000 ppm F (1.1%F) toothpaste or gel [6].

Idea was to have antimicrobial effect along with RI. Study was conducted by Luciana Teimi and associates for evaluating microbial inhibition zone by addition of chlorhexidine in different combinations with resin base. ICON consisting of methacrylate based resin matrix, initiators, and additives. The blended monomer

based infiltrate show enhanced performance than ICON alone. The antimicrobial property is desirable especially aiming in preventing secondary decay [7].

Group	Blended components	Inhibition zone	Changes in hardness of enamel
G1	TEGDMA		
G2	TEGDMA +0.1% chlorhexidine		
G3	TEGDMA +0.2% chlorhexidine	Inhibition zone against LA	
G4	TEGDMA/UDMA		High
G5	TEGDMA/UDMA/0.1% chlorhexidine	Highest inhibition zone against SM	Values of Knoop
G6	TEGDMA/UDMA/0.2% chlorhexidine	Inhibition zone against LA	Hardness Number.
G7	TEGDMA/BISEMA		
G8	TEGDMA/BISEMA/0.1% chlorhexidine		
G9	TEGDMA/BISEMA/0.2% chlorhexidine		

Table 4: Showing different blended groups with methacrylate and their performance compared with ICON alone.

TEGDMA = Tetra ethylene glycol dimethacrylate.

UDMA = Urethane dimethacrylate.

BISEMA = Bisphenol ethylene dimethacrylate.

LA= Lactobacillus acidophilus

SM= Streptococcus Mutans.

The methacrylate based resins like TEGDMA, UDMA AND BISEMA are blended with different percentages of chlorhexidine and the antimicrobial effect around them is measured. Group 4,5 and 6 show significant antimicrobial effect against Strep. mutans and Lacto. Acidophilus. Also G4,5 and 6 showed improved Knoop Hardness Number.

Efficiency of ICON in treating white spot lesions

White spot lesions (WSL) can occur as a consequence of pre or post eruptive changes in the structure of enamel due to fluorosis, molar incisor hypomyelination or traumatic hypocalcification. Histologically the enamel develops surface and subsurface porosities due to demineralization. White spot lesions can be visible one month after placing orthodontic brackets and typically persists 5 years after removal of appliances.

Traditional methods to remineralization includes the use of fluoride gels, varnishes, Caesin Phosphopeptide amorphous calcium phosphate. (CPP ACP), but all these means only work superficially and can not penetrate deeper (He Yuan., *et al*. 2014).

Comparative study on the efficiency of ICON in treating WSL was carried out by He Yuan and his co workers using spectrometry and fluorescence. They carried out study on 114 human permanent pre molars and molars, creating artificial WSL. First group was treated with 500 ppm of NaF (sodium fluoride). Second group was put under CPP-ACP crème (GC tooth mousse, GC Corp, Tokyo) with micro brush and left it undisturbed for 5 min. Third was RI group, treated with ICON, DMG, HAMBURG, GERMANY according to the manufacturer's instructions. Fourth DDW (distilled deionized water) group was (control group). After statistical analysis mean Δ E and Δ Q values were calculated for all groups. Before WSL, the mean Δ E was 12.41 ± 3.47 for the control group and 12.91 ± 3.36 for the test groups. The color improvement of WSL in the ICON treatment group improved significantly and had the lowest mean Δ E (2.9 ± 1.2) when compared with other groups. The fluorescence loss Δ Q in the ICON group was significantly ameliorated ($P<0.05$) after the treatment. No difference in values were found with time. Whereas in other groups the recovery was seen only in 4 weeks (Yuan., *et al*. 2014).

ICON as restorative treatment for WSL produced during post orthodontic phase was studied in Gottingen University by Michael Knosel and associates. They studied 20 subjects and 39 quadrants. 108 teeth are in control group and 111 teeth are in treatment group. The color change is observed over a period of 6 months, Δ E -color change baseline Vs. 6 monthly 2.55 (95% confidence interval) Untreated control teeth show no significant changes over 6 months compared with baseline. Mean Δ E 0.29. Pictographic records were taken to assess the effect of ICON on WSL. 6 month follow up in treated teeth is visible, WSL are clearly not returned. (Knősel., *et al*. 2013).

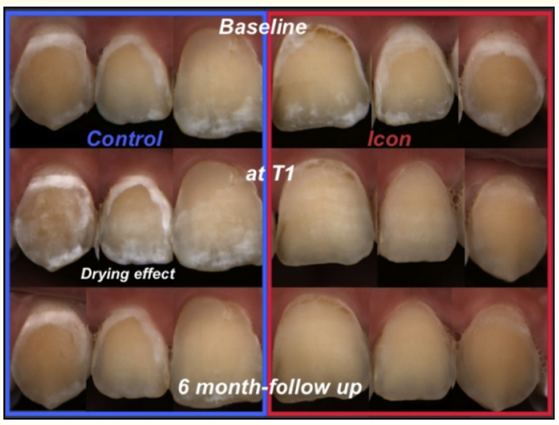

Figure 2: The picture has been taken by spectrophotometry over 6 months. The temporary desiccation in control teeth is visible on the 1st day (Knősel., *et al* 2013).

Improvement in aesthetic aspect after using ICON

The specific aspect of the WSL is due to demineralization process happening due to post orthodontically, an increase in pore volume and refractive indices of the enamel changes due to air and water present in the tubules.

To demineralize the WSL, traditional restorative regimes like topical fluoride gels, fluoride rinses, CPP-ACP with fluoride (Tooth mousse – Mi paste plus, GC Tokyo) and pastes like Remin-pro from Voco Germany containing hydroxyapatite, fluorine and xylitol are used. Micro abrasion is also used with 18% HCl acid and pumice. But unfortunately all these methods are successful only after prolonged use, plus requires patient's compliance. Most of the incidences show inadequate penetration and the lesion body remains porous [1].

Angela Pia Cazzolla and her associates selected a patient with multiple post orthodontic lesions, treated with ICON DMG and followed up at 6 months,1 and 4 years. The standardized digital radiographs were taken at each visit.

The photographic evidence shows aesthetic stability over a period of 4 years. Also no progression of early carious lesions [1].

Figure 3: Preoperative picture showing numerous WSL of upper and lower dental arch [1].

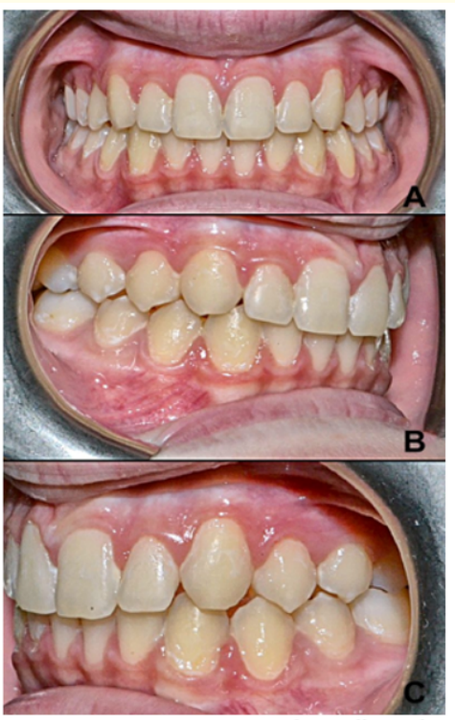

Figure 4: Post-operative picture[1].

Figure 5: One year follow up picture [1].

Figure 6: Four years follow up picture [1].

Discussion

ICON Resin infiltration was introduced in 2009 in Germany, as noninvasive or micro invasive way to deal with incipient carious

lesions, NCPL and WSL. Here, I am trying to evaluate the same by reviewing the literature and articles [1].

How deep is penetration of resin in one application? Is there increase in the micro hardness of the defective enamel after RI?

As ICON had good penetration depth in the primary carious lesions up to 15% area and more than 0.5 mm in most cases (Paris at al 2013), the best indications for the same are NCPL and WSL. It's also moderately effective in hypomineralisation cases. The good penetration also increases micro hardness of the structure (Paris., *et al*. 2013) [2,3].

Is RI effective in improving resistance to secondary decay?

Secondary decay formation is prevented in most cases. Evidence suggests that it's efficient than fissure sealants and Varnishes. To make it more resistant against secondary decay, some researchers also added chlorhexidine 0.1%-0.2% and that produced antimicrobial zone against *L. acidophilus* and Step. mutans [7-19].

Is RI more efficient than fissure sealant in preventing decay formation?

Fissure sealants are applied to teeth not affected by caries and to prevent formation of primary lesion. Studies conducted by Paris S. And her associates showed ICON has a better penetration than fissure sealants. If cleaned properly with probe before curing, it doesn't create areas for plaque accumulation, this preventing secondary decay formation.

Is ICON efficient enough to treat WSL adequately?

WSL is a big concern as post orthodontic opaque lesions also as enamel developmental defects. ICON if used more than 2-3 times does take care of WSL aesthetically as well as preventing secondary decay (Knősel., *et al*. 2013).

The e brochure and case studies published by the manufacturer states that ICON can be used in the cases of mild to moderate fluorosis to mask discoloration. They have published an article by PD Dr. Michael Wicht stating – mild to moderate fluorosis can be treated successfully by prior bleaching before resin infiltration. Severe fluorosis can be treated to a large extent according to Prof. Dr. Leandro Augusto Hillgart and Marilla Bizinoto Silva Duarte. But as we do not have satisfactory clinical data for the same, it's difficult to approve the use of ICON in such cases.

Based on reviewing the literature, ICON seem to be efficient material in treating NCPL and WSL s. Studies showing effectiveness of ICON against fissure sealants are not showing enough evidence of ICON s effectiveness but the structure and penetration ability suggests it's advantage over fissure sealants.

Due to presence of HEMA, glycol dimethacrylate and ethanol the penetration coefficient gets better and ICON can replace the lost minerals in carious enamel and Improves micro hardness of enamel. In enamel developmental defects like MIH, although it produces irregular pattern in enamel penetration, it still helps in producing better bonding to produce future restorations – which is difficult to produce otherwise.

Use of ICON in such cases can give predictable outcomes.

While treating WSL, the results are slightly variable. Recent study be Cazzolla and her associates state they had to apply ICON more than 2 times to get best aesthetic outcome. Most of the clinicians agree to this. So one disadvantage is multiple application times [1].

ICON gets troublesome treatment when the carious lesion extends to D2 and application of gel is painful and that needs to be restored in a conventional way.

Conclusion

After reviewing the literature and other resources, I believe ICON can be used effectively to prevent secondary decay in primary and permanent teeth if the lesions are non cavitated. If used 2 - 3 times following manufacturer's instructions, it can be treated to WSL effectively as well. In MIH cases ICON pretreatment can improve the success rate of restorations. So as a unique member in this segment, ICON definitely is bridging the gap between noninvasive and invasive treatment modalities.

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