ORIGINAL RESEARCH

Evaluation of Penetration Depth and Caries Progression using Resin Infiltrant in Natural White Spot Lesions of Primary Molars

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Abstract

Background: Management of white spot lesions (WSLs) using resin infiltrants, like ICON®, is a novel technique that emphasizes the concept of minimally invasive dentistry.

Aim: Evaluate penetration depth and its effect on caries progression of ICON® in natural WSLs of primary molars.

Design: A total of 30 human primary molars with natural WSLs were selected. A total of 15 samples each were randomly selected to evaluate penetration depth and caries progression. To evaluate penetration depth, lesion surfaces were sectioned into two halves, wherein one half served as control, while the other half received ICON® infiltration treatment. To evaluate the effect on caries progression, samples were sectioned into two halves, wherein one half served as a control to its experimental counterpart, which received ICON® infiltration. The initial depth of the subsurface lesion (baseline data) was measured, and all the sample subsets underwent pH cycling. Confocal laser fluorescence microscope (CFLM) evaluation was performed, and penetration depth was assessed using a laser scanning microscopy (LSM) image reader, while caries progression was evaluated using PhotoScape® software.

Results: ICON® resin infiltrant penetrated to significant depths into the WSLs ($p < 0.001$) and demonstrated significant inhibition of caries progression ($p < 0.001$).

Conclusion: The novel technique using ICON® could be an invaluable tool in the management of WSLs in primary teeth.

Keywords: Confocal laser fluorescence microscopy, ICON®, Minimal invasive dentistry, pH cycling.

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Introduction

Increased knowledge of preventive methods, advanced techniques, and improved restorative materials allows clinicians to follow the concept of "minimal intervention" or "minimally invasive procedure." Minimally invasive techniques are based on a biological or therapeutic approach with the principles of remineralization of early lesions, reduction in cariogenic bacteria, control of disease, and repair of the defective tooth structure rather than replacement.[1]

There is much emphasis on the early diagnosis and detection of carious lesions.[2] In early caries lesions, the enamel surface remains relatively unaltered as whitish discolored areas or "white spots."[3]

The progression of the caries process in a white spot lesion (WSL) may be inhibited by consideration of methods that prevent demineralization and/or promote remineralization.

Consistent with the principles of minimally invasive procedures, nonoperative treatment options for restoring such lesions may be considered. Infiltration of caries with a low-viscosity resin (infiltrant) is a novel treatment option for initial proximal lesions wherein the hard tissue (subsurface enamel crystal lattice) that is lost due to demineralization is replaced to a substantial depth by infiltrating the subsurface lesion with the infiltrant.[4] This concept bridges the gap between nonoperative treatment options and operative options.

ICON® (DMG, Chemisch-Pharmazeutische, Fabrik GmbH, Hamburg) is a low-viscosity resin material (infiltrant) that can be used to fill the pore system of noncavitated WSLs in infiltration treatment.

The aim of caries infiltration is to soak up the body of the porous lesion with an infiltrant, thereby blocking the diffusion pathways for cariogenic acids and sealing lesions.[4] This may be demonstrated by the ability of the infiltrant to penetrate deep into the lesion and arrest the progressions of caries.

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Thus, the objective of the present study was to evaluate the depth of penetration and its effect on caries progression of a resin infiltrant (ICON®) in natural WSLs of extracted primary teeth.

Materials and Methods

The study was carried out after obtaining the necessary clearance from the Institutional Review Board.

Specimen Collection and Preparation

A total of 30 primary molars showing clear proximal WSLs of at least 5 mm width, which were close to exfoliation, were selected for the study. After obtaining the necessary consent from patients' parents, the selected teeth were extracted under local infiltration. The samples were cleaned using pumice slurry and stored in saline at room temperature till usage.

A rectangular piece of transparent adhesive tape measuring 5 × 2 mm was used to mark the WSLs on all the selected samples. The remaining areas of the teeth were painted with nail varnish, and after drying, the adhesive tape was removed.

The samples were then randomly divided into two equal groups of 15 each—group I was selected for evaluation of the penetration depth of ICON®, while the samples in group II were evaluated for the inhibition of caries progression.

Preparation for Evaluation of Penetration Depth

The samples in group I were coded (P1–P15). Each individual sample was then cut longitudinally into two equal halves through the center of the natural WSL with a diamond disk to form two halves, wherein one half corresponds to the control and the other half to the experimental group.

The natural WSLs in the samples from the experimental halves were treated with ICON-proximal kit®, according to the manufacturer's instructions. The natural WSLs were first etched with 15% hydrochloric acid (HCl) gel (ICON Etch®) by turning the shaft of the delivery syringe 1.5–2 turns for 120 seconds, using a foil applicator. The gel was then washed off with air-water spray for 30 seconds and dried with compressed air for 10 seconds. The lesions were then dried with ethanol (ICON dry®) and, thereafter, redried with compressed air. The ICON® infiltrant was applied by turning the shaft of the delivery syringe 1.5–2 turns and left for 3 minutes, using a foil applicator. Before light curing, any excess resin was removed using dental floss. A second application of infiltrant was carried out, as described, but this time allowed penetrating for only 1 minute before curing. The samples were subjected to confocal laser scanning microscope (CFLM) evaluation, and the depth of penetration observed was recorded using a laser scanning microscopy (LSM) image reader.

The samples from the control halves were subjected to CFLM evaluation without any treatment to assess the lesion depth and compare the penetration of infiltration concept (ICON) into the lesion using an LSM image reader.

Preparation of Samples for Evaluation of Caries Progression

The 15 samples in group II were coded (A1–A15), and each sample tooth was then cut longitudinally through the center of the natural WSL using a diamond disk to obtain corresponding control and experimental halves.

From the control halves, a thin section of 700 µm through the WSL was obtained using a hard tissue microtome and subjected to CFLM evaluation to measure the initial depth of the subsurface lesion. This served as the baseline data.

The samples in the experimental halves were subjected to resin infiltration using ICON® treatment, according to the manufacturer's instructions, whereas the samples in the control halves did not receive any treatment.

The samples, both in the experimental and control halves, were then subjected to pH cycling in individual coded closed containers 10 mL of demineralizing solution (consisting of 1.4 mMCa, 0.9 mM P, and 0.05 M acetate buffer at a pH of 5.0) for 6 hours, followed by 5 mL of remineralizing solution (consisting of 1.5 mMCa, 0.9 mM P, and 0.1 M Tris buffer at pH 7.0) for 18 hours, and so on for over a period of 16 days with constant circulation.[5]

After pH cycling, a thin section of 700 µm cut through the lesion was obtained from both the experimental and control halves by using a hard tissue microtome and subjected to CFLM evaluation. The evaluation of progression or inhibition of the carious lesion was performed by comparing the images of sections obtained from the control and experimental subgroups against the initial baseline data, using PhotoScape® software.

Statistical Analysis

The data obtained were computed, and statistical analysis was carried out using Statistical Package for the Social Sciences software version 10. Student's *t*-test was used to compare the mean depth of penetration in the control and experimental subgroups in group I. One-way analysis of the variance was used to compare the lesion progression between the data from the baseline, control, and experimental subgroups, respectively, in group II. *Post hoc* Duncan's multiple range (DMR) test was used to elucidate the significance of multiple comparisons. For all statistical evaluations, a two-tailed probability of a value of <0.05 was considered significant.

Results

Images were analyzed based on the optical characteristics of the dye penetrating into the porous structure of the specimens. The porous structure displayed a red color due to the imbibition of the rhodamine dye. In contrast, the sound enamel and the surface layer showed a reduced intensity of red color. In the control subgroups (without ICON® treatment), the intensity and brightness of the red dye color were greater when compared to the experimental subgroups (with ICON® treatment) in the samples of both groups I and group II.

In group I, the depth of penetration of ICON® in the experimental subgroup was measured in µm from the surface layer to the deepest portion at the advancing front of the lesion, with reduced intensity of red dye (where the gray values clearly changed to a dark gray), by using an LSM image reader (Figs 1 and 2). The mean depth of carious lesion in the control subgroup was 184.09 ± 39.51 µm, while the depth of penetration of ICON® in the experimental subgroup was found to be 265.55 ± 33.02 µm (Table 1).

In group II, caries progression was evaluated by considering the saturation of the color (red) in the image of the samples from the baseline (before pH cycling), control subgroup (pH cycling without ICON® treatment), and experimental subgroup (pH cycling after ICON® treatment), by using PhotoScape® software. An increase in the saturation of red from baseline was interpreted as further

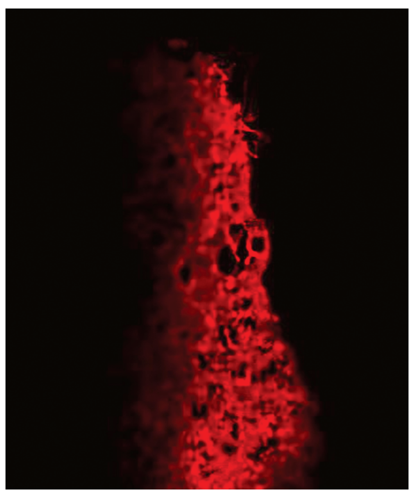

Fig. 1: Confocal laser fluorescence microscope (CFLM) image showing the depth of lesion in group I, control subgroup

progression of the caries lesion, while a decrease in the saturation of red from baseline was interpreted as the inhibition of the caries lesion (Figs 3 to 5). The mean color saturation obtained in the baseline, control, and experimental subgroups were 24.33 ± 10.20, 59.73 ± 21.83, and 04.53 ± 5.55%, respectively (Table 2).

Discussion

Remineralization techniques, such as fluoride therapy, casein phosphopeptide–amorphous calcium phosphate, novamin, and bioactive glasses that need to be implemented at the very early stages of caries development, are limited to the lesion surfaces alone and take considerable time.[6]

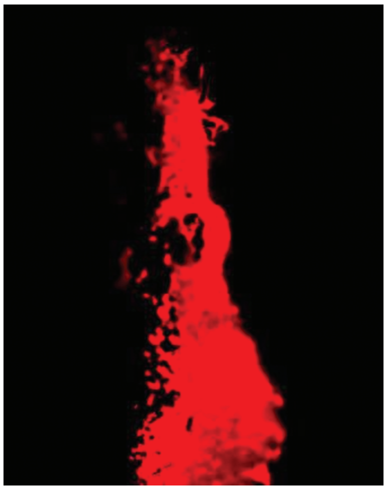

Fig. 2: Confocal laser fluorescence microscope (CFLM) image showing the depth of penetration of ICON® in group I, experimental subgroup

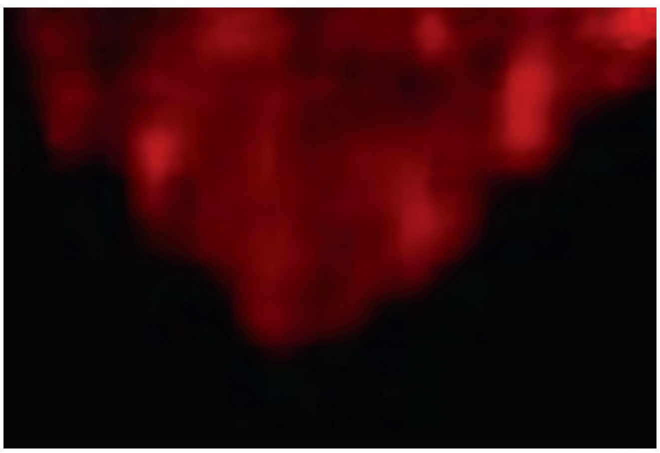

Fig. 3: Confocal laser fluorescence microscope (CFLM) image showing baseline caries lesion in group II

Table 1: Comparison between the mean lesion depth in the control and the mean depth of penetration of ICON® in the experimental subgroups in group I

Group I	*Mean depth*	*± Standard deviation (SD)*	*t*	*p-value*
Control	184.09	39.51	–6.128	<0.001
Experimental	265.55	33.02		

Noncavitated occlusal lesions have been found to be effectively controlled by superficial sealing.[7] Proximal caries lesions; however, are difficult to detect and treat. Often, the destruction of large amounts of sound enamel and dentin is necessary to access these lesions and initiate a restoration cycle.[8]

An alternative approach for the treatment of natural WSLs that are not expected to remineralize or arrest by noninvasive measures is to treat them by a microinvasive technique,[3,8,9] where low viscosity resins called infiltrants are used to permeate the pores of the

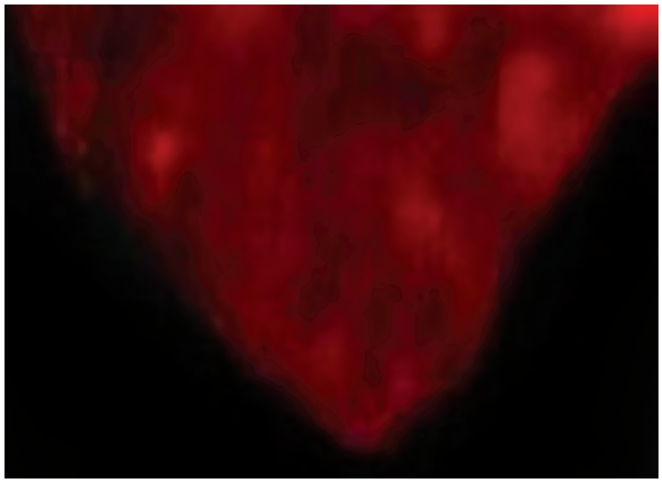

Fig. 4: Confocal laser fluorescence microscope (CFLM) image showing the progression of caries lesion in group II, control subgroup, receiving only pH cycling without ICON® treatment

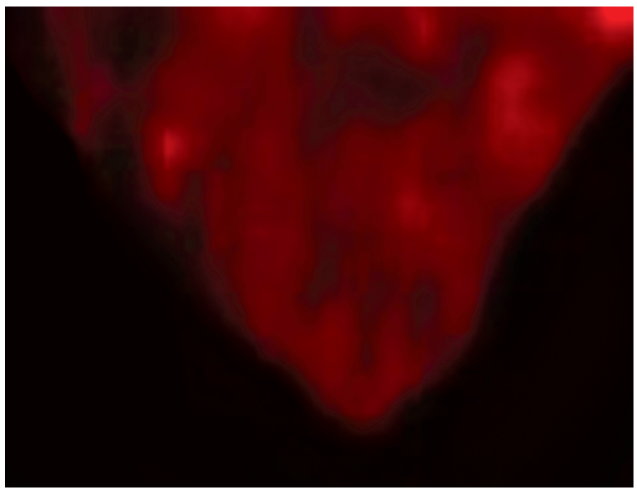

Fig. 5: Confocal laser fluorescence microscope (CFLM) image showing inhibition of caries lesion in group II, experimental subgroup, receiving pH cycling after ICON® treatment

Table 2: Comparison between the saturation of red dye color in the baseline, control and experimental subgroups in group II

Group II	*Mean saturation*	*± SD*	*F*	*p-value*
Baseline	24.33^{b}	10.20	57.557	<0.001
Control	59.73^{c}	21.83		
Experimental	04.53^{a}	5.55		

$^{a, b, c}$, the same superscript within each parameter does not differ from each other (Duncan's multiple range test) enamel lesion. This is known as caries infiltration, resin infiltration, or infiltration technique.[9,10] Infiltrants are light-cure resins that are optimized for rapid penetration into the capillary structures of the lesion body. These materials exhibit very low viscosity, low contact angles to enamel, and high surface tensions, which are important properties for complete penetration of the resin infiltrant into the body of enamel caries lesions.[11] The aim here is to occlude these pores and prevent acid penetration into lesions, thereby creating a diffusion barrier within the enamel lesion in contrast to fissure sealing techniques wherein the diffusion barrier is established on the enamel surface.[10,12]

Resin infiltration offers select advantages in comparison with the remineralization approach. First, the appearance of deep lesions can be improved because the infiltrant penetrates deep into the lesions. Second, the technique is much less invasive, and only negligible tooth substances need to be sacrificed by etching and polishing.[11] Third, esthetic improvement is achieved instantly. Fourth, resins have a refractive index of 1.475, which is close to the refractive index of enamel (1.65). Thus, the difference in refractive indices between the porosities and enamel is reduced and the lesion regains a translucency like the surrounding enamel.[12]

ICON®, a resin infiltrant, was commercially introduced by DMG America LLC, Englewood, New Jersey, United States of America, in 2009 as the first infiltration product for clinical use.[13] Its microinvasive infiltration technology was recommended for use in initial, noncavitated enamel proximal caries lesions (ICDAS D1).[13,14] However, scientific evidence pertaining to the depth of penetration of ICON® and its effect on caries progression in natural WSLs of primary molars is sparse.

In this study, ICON® resin infiltrant demonstrated increased penetration into the microporosities of WSLs of primary molars, following erosion of the surface layer. The increase in the mean depth of ICON® penetration compared to the initial lesion depth (Table 1) could be attributed to the complete erosion of the surface layer by 15% HCl acid gel and its positive influence on the penetration of the infiltrant.[13] These results are comparable to those of increased depth of penetration obtained using experimental infiltrants in artificial and natural WSLs of permanent teeth[8,12,15] and in natural WSLs of primary teeth.[7,16]

The results of this study also showed that infiltration treatment using ICON® in the initial natural WSLs of primary molars yielded a significant decrease in dye color saturation from baseline till the end of pH cycling (Table 2). This was interpreted as the inhibition of caries progression and regarded as an additional benefit to using resin infiltration technique in the treatment of interproximal caries lesions of primary teeth. These results are similar to the inhibition of lesion progression demonstrated by the penetration of various adhesives and experimental infiltrants in artificial caries lesions.[8,17,18]

Thus, it can be concluded, based on the results of our study, that the ICON® infiltration technique exhibited the ability to adequately penetrate the natural WSLs of primary molars and efficaciously arrest the progression of caries. Moreover, we estimate that the ICON, as a novel microinvasive technique, can be an important treatment alternative for the management of frequent clinical problems with initial enamel caries lesions or WSLs in primary teeth. ICON®, as a resin infiltrant, can be a promising material for the infiltration management of these lesions.

In this *in vitro* study model, it was not possible to replicate the oral environment and the dynamics of the caries process. Thus, to extrapolate the results of this study *in vivo*, randomized clinical trials with larger samples are required. We further recommend an investigation of the penetration depth of ICON®, *in vitro*, with larger samples using investigation techniques, such as transversal wavelength independent microradiography, transverse microradiography, and CFLM evaluation.

Conclusion

Based on the results of this study, it can be concluded that:

- ICON® can penetrate up to significant depths into the WSLs of primary molars.
- ICON® penetration into WSLs of primary molars seems to inhibit caries progression during pH cycling.

ICON® can be considered a promising material for resin infiltration technique. The novel method could prove to be an invaluable technique for the management of initial WSLs in primary teeth.

Why This Paper is Important to Pediatric Dentists

- White spot lesions often arise as precursors to frank enamel caries. Their management of primary teeth poses a special challenge to pediatric dentists.
- ICON® resin infiltration of WSLs is a microinvasive technique that demonstrates the potential to prevent the development of frank enamel caries lesions by bridging the gap between noninvasive (remineralization) techniques and invasive (restorative) techniques.

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