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Comparative Evaluation of Icon Resin Infiltration and Clinpro XT Varnish on the Remineralization of Enamel White Spot Lesions: An in Vitro Study

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Abstract

1.Background: The aim of this research is to investigate microscopically the behavior of two materials, Clinpro XT Varnish and Icon Vestibular, on the surfaces of teeth with chalky white lesions induced by 37% phosphoric acid. Microscopic evaluation is performed based on different degrees of penetration and infiltration. 2.*Methods*: The materials tested in this study were Icon – Vestibular DMG (LOT 281473) and 3M ESPE Clinpro XT – Varnish (LOT 9703392).*3.Results*: Phosphoric acid demineralizes the superficial enamel layer, exposing prisms and hydroxyapatite crystals, and generating a rough surface with uniform etching patterns visible at different magnifications, which favor the adhesion of restorative materials. The use of the infiltrant resin Icon fills microcracks and interprismatic spaces, integrating the enamel prisms into a compact, smooth mass that stabilizes the enamel structure and prevents the progression of demineralization. SEM images show that the varnish forms a thin, relatively uniform film on the enamel, but with small discontinuities and uncovered areas, indicating a less effective seal and protection compared with Icon. 4.Conclusion: The integration of materials such as Icon and fluoride varnishes makes it possible to postpone invasive restorative treatments and is particularly useful in the management of white spots, while maintaining the structural integrity of the teeth.

Keywords: Clinpro XT varnish, icon resin infiltration, scanning electron microscopy

INTRODUCTION

Incipient carious lesions manifest clinically as chalky white spots corresponding to a subsurface zone of enamel demineralization located beneath an apparently intact surface, which is initially reversible through remineralization. They represent a dynamic caries process driven by an imbalance between pathological factors (fermentable carbohydrates, hyposalivation, acidogenic bacteria) and protective factors (salivary flow, fluoride, antibacterial agents, diet), progressing from initial enamel demineralization to dentin involvement and cavity formation. Histopathologically, the initial enamel lesion shows two main demineralization zones (the translucent zone and the body of the lesion, located 15–30 µm below the surface) and two remineralization zones (the dark zone and the surface zone) [1].

Over the past decades, a change in the caries pattern has been noted, with a decrease in lesions on smooth surfaces and an increase on occlusal surfaces, which makes early detection and implementation of preventive measures essential. Traditional diagnostic methods – visual inspection and radiography – are limited: inspection depends on changes in color and texture, and radiography detects carious enamel only after a mineral loss of more than about 40%, and it also involves exposure to ionizing radiation. Lesions occur frequently on the maxillary anterior teeth, especially on plaque-retentive surfaces, and the risk is influenced by poor oral hygiene, age (adolescents), initial caries experience, and the extent of the etched surface. Chalky white spots may represent developmental defects (fluorosis, hypoplasia), areas of demineralization in patients without appliances, or consequences of fixed orthodontic treatment [2].

In orthodontics, chalky white spots are among the most frequent complications and have a long lasting negative esthetic impact, with carious lesions being rough and porous, in contrast to non carious spots, which are smooth and glossy. Reported prevalence is highly variable (about 2–96%), depending on the detection method, with studies using quantitative fluorescence showing higher rates than those based only on visual inspection; before orthodontic treatment, prevalence is roughly 15–40%, and during treatment the incidence of new clinical lesions often ranges between 30–70% of patients. Fixed orthodontic appliances increase plaque retention and reduce self cleansing by saliva, tongue, and cheeks, especially on vestibular surfaces; in contrast, lingual appliances appear to be associated with a lower incidence of white spot lesions, probably due to better cleaning by the tongue and salivary flow [3].

Individual caries risk during treatment is multifactorial: in addition to oral hygiene, salivary flow and composition, enamel solubility, immune response, genetic predisposition, diet, and the general medical context all play a role. Early lesions are easily missed in the presence of appliances, plaque, and gingival inflammation and often become evident only after appliance removal, which is why systematic assessment of at-risk teeth is recommended at every check-up, with inspection performed on clean and dry arches. Preventive responsibility is often perceived as resting with the patient, but the orthodontist and dentist have a central role in identifying high-risk patients, counselling them, and implementing a structured preventive protocol [4].

After completion of orthodontic treatment, management depends on the severity and esthetic impact of the spots: in mild cases one may opt for monitoring and natural remineralization, possibly combined with tooth whitening; for more pronounced lesions, resin infiltration, micro /macro abrasion techniques, and, in severe situations, direct composite restorations or indirect veneers are described. Ideally, the risk of white spot lesion development should be discussed in detail as part of the informed consent process, and preventive measures, hygiene monitoring, and lesion status should be thoroughly documented in the patient's record [5].

Current minimally invasive concepts in dentistry focus on controlling etiological factors using non invasive and micro invasive methods and strategies. Whereas non invasive strategies aim to arrest or reverse non cavitated carious lesions, micro invasive strategies include barriers that prevent the enamel from being further exposed to the acidic attack of cariogenic bacteria. Among the micro invasive approaches, two procedures are currently used: pit and fissure sealants applied to enamel etched with phosphoric acid, and low viscosity resins that either penetrate or infiltrate, by capillary action, non cavitated lesions etched with hydrochloric acid [5].

It has been shown that resin infiltration with ICON provides immediate restoration of the esthetics of mild white spot lesions that appear after orthodontic treatment, matching the healthy enamel of the area adjacent to the spot [6]. This effect has been demonstrated to remain stable for 6 months, with no significant changes at 12 and 24 months. In the case of moderate lesions, an improvement has been observed over time following sequential treatment. Loss of fluorescence in the lesions recovered significantly immediately after resin infiltration and remained unchanged at the end of 6 weeks in artificially created lesions. These findings demonstrate that ICON resin infiltration is a benchmark intervention method for the esthetic restoration of white spot lesions [7].

The concept of resin infiltration with Icon is relatively new, being a product developed in Germany and used in the treatment of incipient lesions. It improves retention and prevents caries on smooth surfaces, but not on cavitated surfaces. The resin fills the pores of the lesion and blocks the further diffusion of bacteria by creating barriers and halting lesion progression, restoring the tooth without anesthesia and drilling in order to preserve its natural morphology [6].

Icon infiltrates the lesion, renders the bacteria inactive, and prevents caries progression, in contrast to sealant material, which only acts as a mechanical barrier between the dental structure and the oral environment [6]. It works on the principle of light scattering. Sound enamel has a refractive index of 1.62. The porosities of a carious white spot lesion are usually filled either with an aqueous medium or with air, which have refractive indices of 1.33 and 1, respectively. The whitish appearance of the lesion is due to the difference in refractive index between the enamel crystals and the surrounding medium, which causes light scattering. The microporosities in the body of the lesion are infiltrated with a resin material that has a refractive index of 1.46, thereby making the differences between enamel and porosities negligible so that the lesion appears similar to the surrounding enamel [7].

Fluoride, in its many forms, is used in dentistry as an effective measure for the prevention of carious lesions. In lower concentrations it is usually used by patients, whereas higher concentrations are applied by professionals. A wide range of fluoride products is available, but fluoride varnish has been the preferred option for the past 20 years because of its effectiveness, patient acceptance, and ease of application. It is also one of the most frequently reimbursed procedures by dental insurance companies and is widely recommended for use in children, even in infants. An increasing number of healthcare providers, such as pediatricians, family physicians, and nurses, now apply fluoride varnishes to children's teeth, advocating good oral health as an integral part of overall health [8].

Clinpro XT varnish is a resin modified glass ionomer cement product from 3M ESPE that has been widely used in the past for the treatment of dentin hypersensitivity. In orthodontics, it has been shown to be effective in preventing the occurrence of white spot lesions during orthodontic treatment and in managing artificially induced demineralized areas [9].

Aim and objectives

The objectives of the research are to investigate the microscopic behavior of two materials, Clinpro XT Varnish and Icon Vestibular, on the surfaces of teeth with chalky white lesions induced by 37% orthophosphoric acid. Microscopic evaluation is carried out based on the different degrees of penetration and infiltration.

MATERIAL AND METHODS

The materials tested in this study were Icon – Vestibular DMG (LOT 281473) and 3M ESPE Clinpro XT – Varnish (LOT 9703392). The composition and instructions for use of these materials are presented in Table 1.

Table 1. Composition and manufacturing instructions of the tested materials

Material	Icon – Vestibular DMG	Clinpro XT - Varnish
Manufacturer	DMG – Hamburg, Germany	3M Germany GmbH
Composition	1. Icon-Etch (HCl 15%) 2. Icon-Dry (99% etanol) 3. Icon-Infiltrant (Methacrylate-based resin matrix, initiators, additives)	2-Hydroxyethyl methacrylate Water 2-Propenoic acid, 2-methyl-, 3-(trimethoxysilyl) propyl ester, hydrolysis products with silica.
Instructions for use	1. Clean the tooth. 2. Apply Icon-Etch. Allow it to act for 2 min. 3. Rinse with water for 30 s. Dry with air. 4. Apply Icon-Dry. Allow it to act for 30 s. Dry with air. 5. Apply Icon-Infiltrant. Allow it to act for 3 min. 6. Light-cure for 40 s. 7. Apply Icon-Infiltrant again. Allow it to act for 1 min. 8. Light-cure for 40 s	1. Clean the tooth. 2. Ultra etch: 35% phosphoric acid for 30 s. 3. Rinse with water for 30 s. Dry with air. 4. A thin layer of Clinpro XT varnish was applied and light-cured for 20 s.
Batch number	281473	9703392

Sample preparation:

A total of 11 extracted molar teeth without carious lesions were cleaned using pumice powder in suspension and a rotary toothbrush mounted on a contra-angle handpiece. The teeth used in this study were collected and stored in saline until the day of measurement, with inclusion criteria being molars without cracks, restorations, or developing lesions. The roots were removed and the crowns were sectioned longitudinally in a mesio-distal direction using a disc mounted on a straight handpiece, yielding 22 samples that were embedded in ZetaPlus impression material so that the crowns were exposed and the convex tooth surfaces could be examined; after measurements, all samples were stored in distilled water.

Chalky white lesions were created on all 22 samples using 37% orthophosphoric acid for 30 minutes, after which the samples were rinsed with water and dried. According to the protocols, Icon – Vestibular DMG was applied to 10 samples and Clinpro XT – Varnish to the other 10 samples, and both materials were light-cured with a Woodpecker cordless LED curing lamp. The remaining 2 samples, on which only 37% orthophosphoric acid had been applied, were used as control specimens for comparison of the subsequent results.

Figure 1. Samples treated with 37% orthophosphoric acid solution

Following treatment of the teeth, the samples were sent to the laboratory for analysis of the results using scanning electron microscopy (SEM).

RESULTS

Effect of orthophosphoric acid on the dental enamel prism

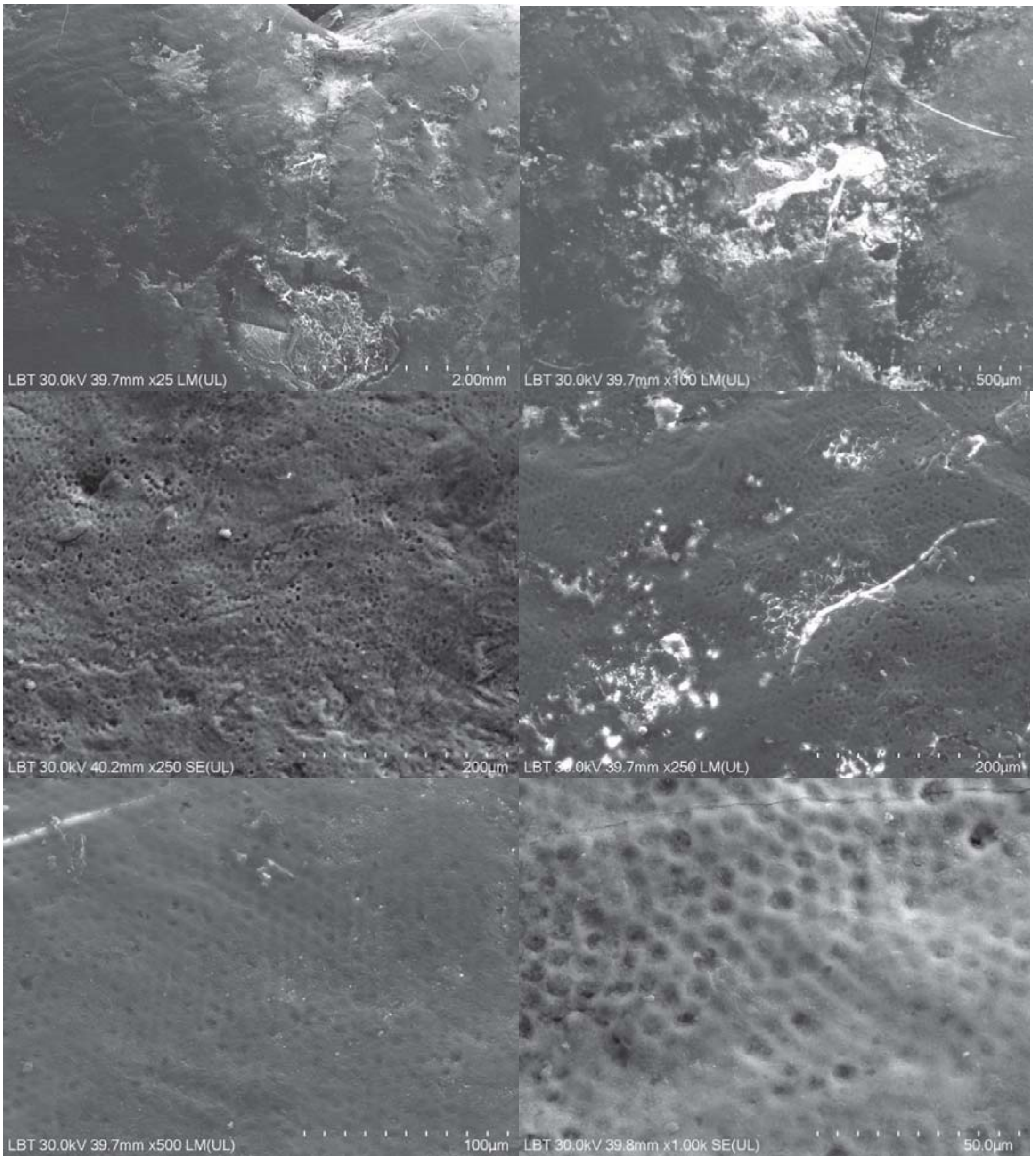
It acts by removing the superficial enamel layer and exposing the enamel prisms, thereby compromising their crystalline structure. This process is analyzed starting at high magnification and then gradually moving to lower magnifications to observe the changes in their overall context.

At high magnification (×25), the structure of dental enamel becomes clear and detailed. At this stage, grooves between cusps and other fine details of the enamel surface are evident, and orthophosphoric acid begins to exert its effects, especially in the fissure areas where enamel is more exposed to erosion. Enamel prisms, hexagonal or prismatic structures arranged perpendicular to the tooth surface, are the basic components of enamel. At this magnification, 37% orthophosphoric acid causes prism demineralization, removing the organic matrix and exposing hydroxyapatite crystals, a process that is essential for creating a rough surface that will facilitate adhesion of dental restorative materials.

By reducing the magnification (×250), a more integrated image of the dental enamel appears. At this level, enamel prisms are still visible, but their fine details merge into a broader view, and it becomes clear how orthophosphoric acid has affected the superficial layer as the initially smooth surfaces become rough and porous, highlighting the effectiveness of the acid treatment. Acid etching creates characteristic patterns in the enamel, which at this magnification are seen to be uniformly distributed, preparing the surface for application of dental composites; typical etching patterns include honeycomb- and cobweb-like forms resulting from selective dissolution of the enamel prisms.

At lower magnifications (×5000), the image becomes even more integrated, revealing large-scale changes in enamel structure. The increased roughness and uniform distribution of the etching pattern indicate effective surface preparation for subsequent procedures, and the interaction between etched enamel and underlying dentin becomes evident. It is crucial to understand that excessive demineralization can weaken the tooth structure and compromise the integrity of the tooth.

In the study of enamel prism behavior after acid exposure, two enamel specimens were used, both being uniformly and equally affected by orthophosphoric acid, as shown in Figure 2.



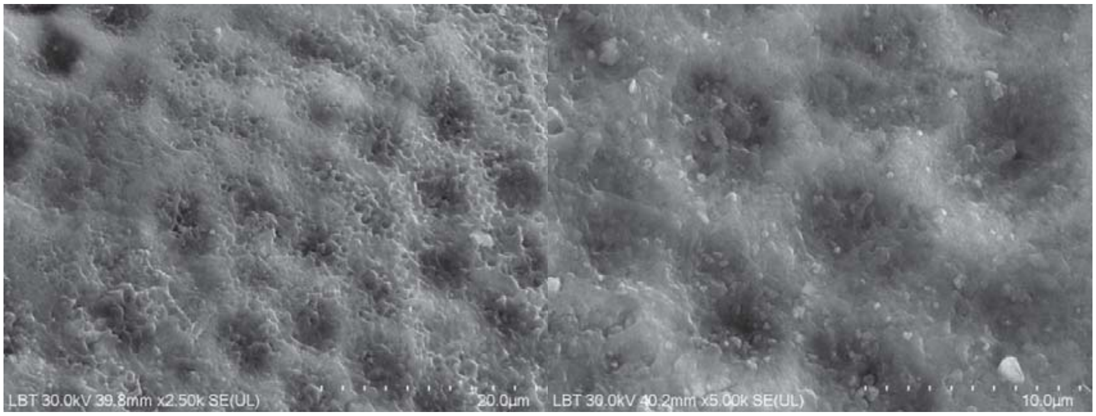
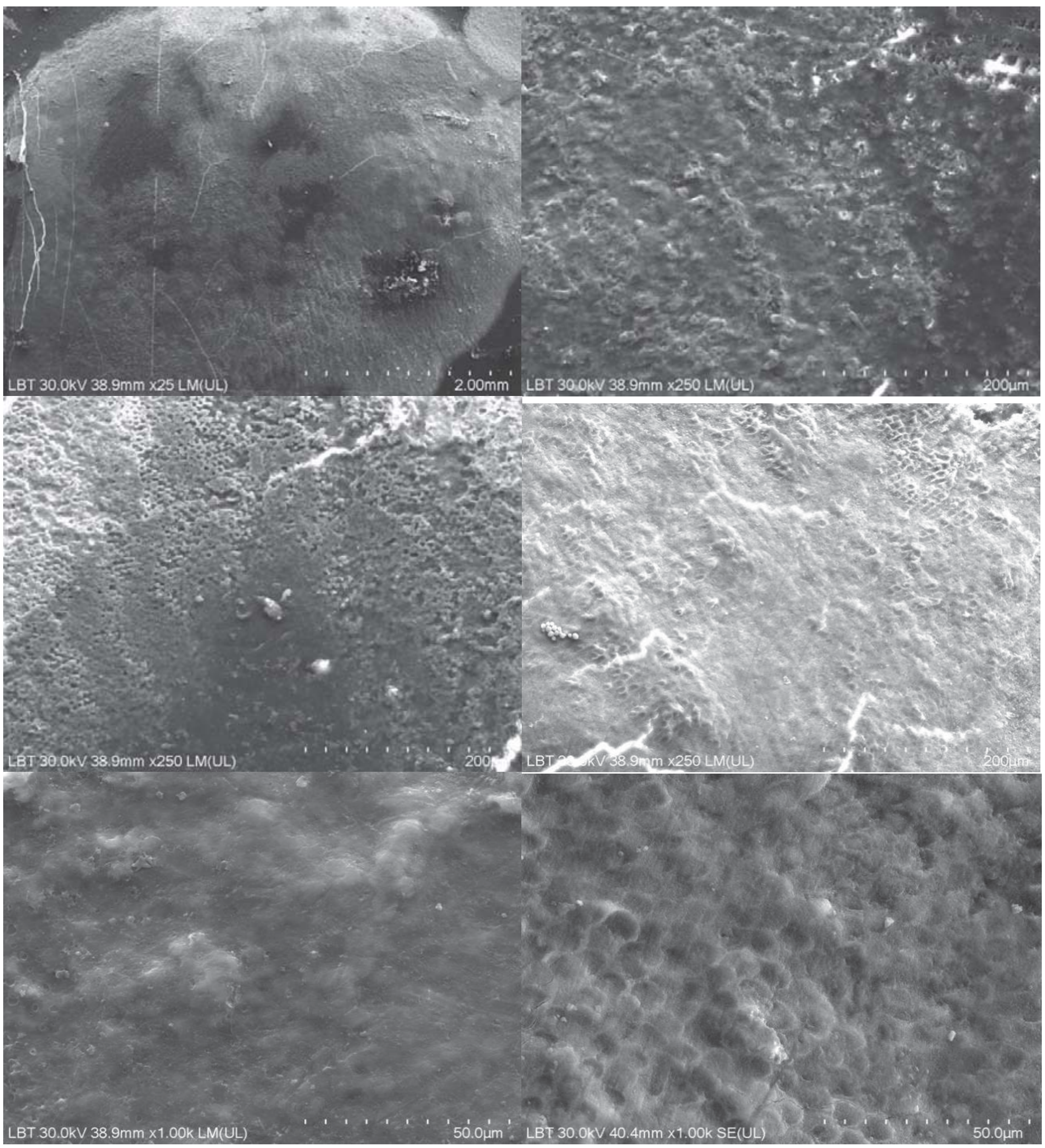


Figure 2. SEM specimen with acid



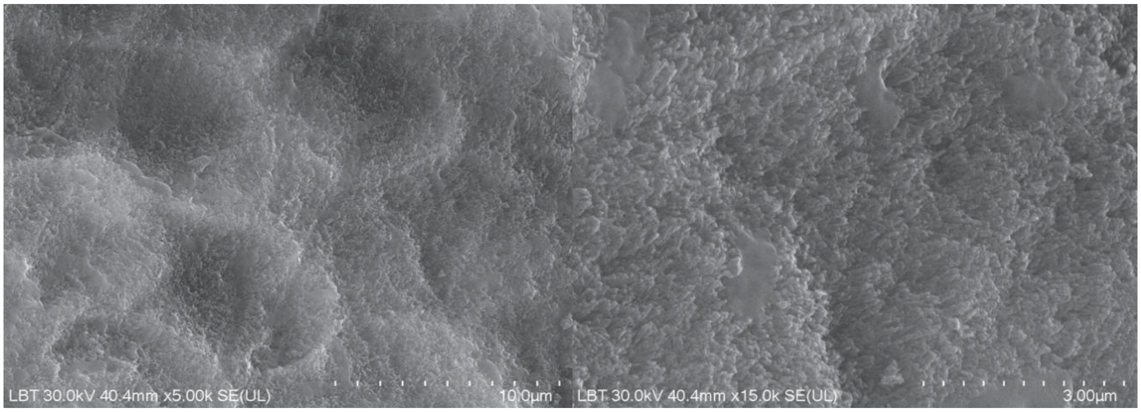


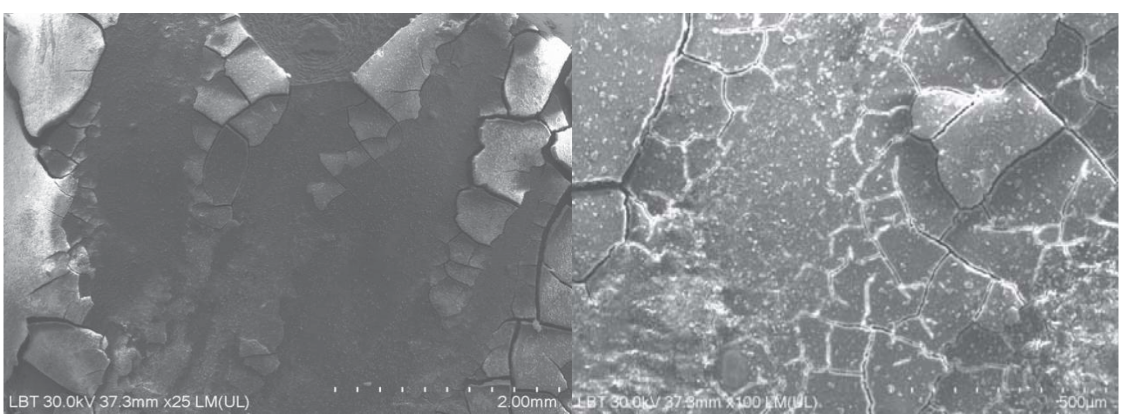
Figure 3. SEM specimens with ICON at different incidences

At ×25 magnification, the overall surface of enamel treated with Icon can be observed, showing visible uniformity and smoothness without clearly distinguishable prismatic structures, as Icon has filled the microcracks and visible pores to create a compact, homogeneous surface.

At ×250 magnification, Icon is seen to have penetrated deeply into the enamel, infiltrating interprismatic spaces and enamel prisms so that these structures appear less distinct and the interprismatic spaces almost completely sealed.

At ×5000 magnification, enamel prisms, which are usually well-defined hexagonal structures, now appear fused and homogenized due to Icon infiltration, with interprismatic spaces completely filled with resin, leading to consolidation of the enamel structure and prevention of caries progression. The treated enamel surface exhibits a markedly smoother and more compact texture, reflecting the efficiency of Icon in infiltrating and stabilizing the enamel.

At ×15000 magnification, the fine details of the enamel structure are extremely clear. The enamel prisms, which at lower magnifications may appear separate and distinct, now seem fully integrated into the homogeneous mass of Icon resin, with the previously porous interprismatic spaces almost completely sealed and no longer susceptible to acid attack. At this scale, Icon appears as a protective barrier that fills and stabilizes the microcrystalline structures of the enamel, preventing further demineralization.



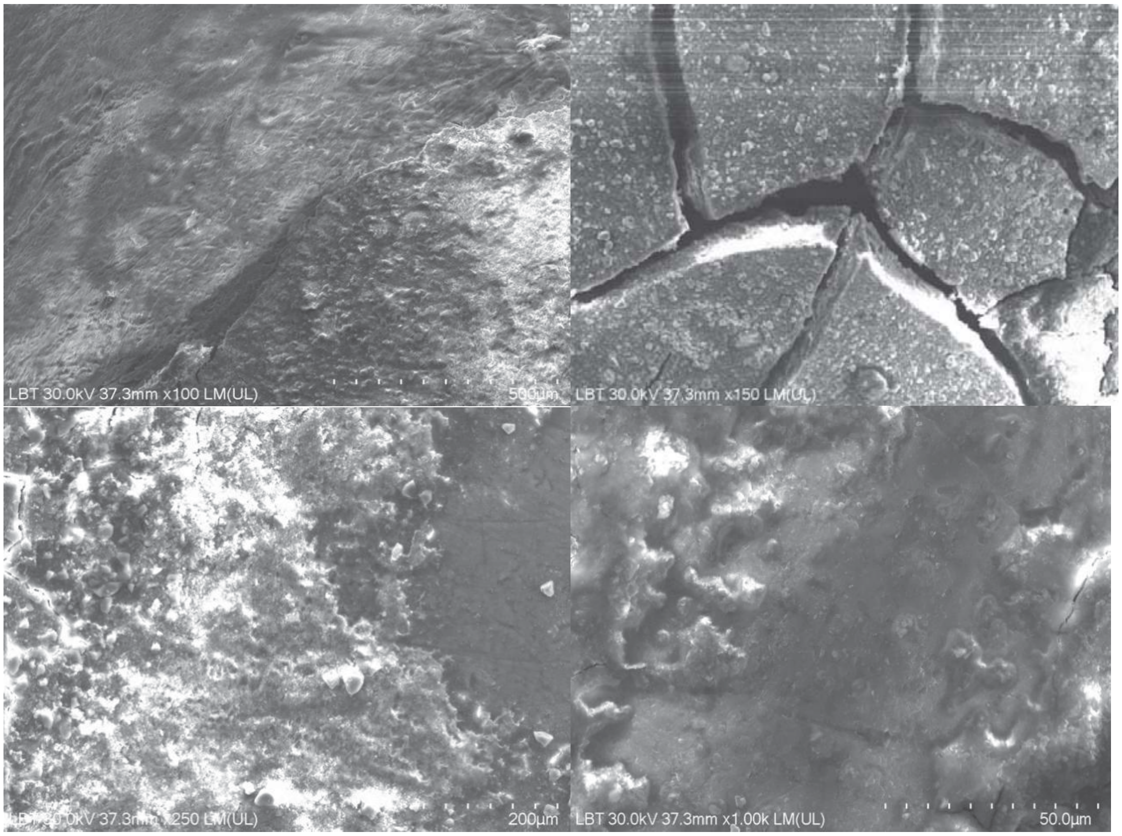


Figure 4. SEM specimens with VARNISH at different incidences

Seal provided by varnish in dental enamel

SEM images show the varnish layer forming a thin, relatively uniform film that covers the entire treated surface. However, it exhibits slight discontinuities or uncovered areas, indicating an application and protection that are not as effective as in the case of Icon application.

DISCUSSIONS

In our days, the amount and frequency of consumption of acidic foods and drinks have increased [10]. As a result, examining the etiology, prevalence, prevention, and treatment of dental erosion has become very important. Many factors can cause enamel erosion: diet, oral hygiene routine, medications, and the professional environment [11]. Maintaining poor oral hygiene also leads to the appearance of chalky white spot lesions. Studies show that low pH beverages cause dental erosion of varying degrees [12]. Case reports as well as other studies suggest that dietary acid erosion plays a significant role in tooth wear. The degree of demineralization of a solution depends on the type of acid it contains, its pH value, the acid concentration, and its temperature [13]. The results of other studies show that acids in liquid form are more harmful to dental tissues than gels; therefore, beverages and acid reflux are a greater concern.

The management of chalky white spot lesions can be divided into prevention (before lesion formation), intervention (during orthodontic treatment), and treatment (after completion of orthodontic treatment). In the prevention and intervention categories, fluorides in the form of varnish, toothpaste, mouthwash, sealants, laser therapy, silver nanoparticles, and ozone have been widely used [14]. The effectiveness of preventive methods is inadequate, because their efficacy is limited to remineralization of the superficial part of the lesion and not of the lesion body [15].

Dental photography is of utmost importance in several respects. It is simple, quick, and extremely useful for documenting the techniques, stages, and outcomes of this study [16]. The 37% orthophosphoric acid solution was the most effective in dissolving enamel [17]. The appearance of the teeth after 30 minutes of demineralization, as shown in Figures 14–16, is that of pure white spots, as if the teeth were covered with a thin layer of chalk.

The use of an unfilled resin to seal lesions (chalky white spots) proves effective in preventing further demineralization. Various materials containing unfilled resins have shown promising results regarding lesion infiltration and arresting acid attack [18]. The infiltration technique has several advantages over other techniques. First, deeper lesions can be improved by infiltration techniques, which can induce both remineralization and aesthetic enhancement. Second, when compared with other techniques, infiltration is far less invasive [19].

The purpose of using ICON is to block the porosities within the body of white spot lesions with a light curing resin specially optimized to penetrate porous enamel. The infiltrants are light curable and have low viscosity, low contact angles with enamel, and high surface tension, which together enable complete penetration into the lesion's porosities [20]. Before application of the material, the enamel is conditioned with 15% hydrochloric acid gel. The resin then penetrates the lesion driven by capillary forces, and ICON infiltrant is a blend with a very high penetration coefficient [21], so that a diffusion barrier is created within the lesion rather than on its surface. After the material has infiltrated, the excess is removed from the lesion surface with a cotton pellet and then polymerized using ultraviolet light.

Alternatively, ClinproTM XT varnish is a specialty material available on the market that releases fluoride, calcium, and phosphate in a controlled manner [22]. It is a chemical agent with an occlusive action, sealing dentinal tubules through chemical adhesion to dentin mediated by polyalkenoic acid, which forms ionic bonds with calcium hydroxyapatite, the primary mineral of dentin. This is followed by a chelation mechanism in which the carboxylic groups of the polyacrylic acid in Clinpro XT react with calcium in the enamel and with apatite in the dentin [23]. It also contains calcium glycerophosphate, which increases the bioavailability of calcium and phosphate in saliva. The calcium released from covering or restorative materials can contribute to strengthening enamel surfaces, and studies report that Clinpro XT releases fluoride into saliva for up to six months [24]. Enamel has increased resistance to acid when fluoride is incorporated into the apatite, which reduces enamel degradation [25]. At present there are relatively few studies in the orthodontic field. For this reason, the present study aimed to evaluate the effectiveness of ClinproTM XT varnish, which could potentially be used during orthodontic treatment to prevent the occurrence of white spot lesions in orthodontic practice.

The purpose of using Clinpro XT is to occlude dentinal tubules, efficiently reduce permeability by increasing resistance to abrasive or acidic stimuli, and inhibit tubule reopening after erosive or abrasive challenges. In addition, a statistically significant reduction in surface roughness is achieved after a single application. Furthermore, the product has increased the bioavailability of calcium and phosphate in saliva, demonstrated its ability to release fluoride into saliva over six months, promoted enamel remineralization, and partially inhibited enamel demineralization under acidic challenge, resulting in greater immediate and long term protection of enamel against dentin hypersensitivity [26].

CONCLUSIONS

Due to a refractive index close to that of sound enamel and their low viscosity, these resins mask chalky white spots and provide a superior aesthetic outcome while blocking acid diffusion and slowing or arresting caries progression.

Infiltration provides the treated enamel with a degree of mechanical stabilization, improving surface resistance and durability without additional removal of dental tissue, which allows for a conservative approach.

The use of materials such as Icon, together with fluoride varnishes, enables postponement of invasive restorative treatments and is particularly useful in the management of white spot lesions, while preserving the structural integrity of the teeth.

However, infiltrative resins are indicated only for non cavitated lesions that are superficial or limited to the outer third of the dentin; advanced or cavitated lesions require other types of restorative treatment.

Conflicts of Interest

The authors declare no conflict of interest.

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