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“Color Stability of Artificial White Spot Lesions treated with Resin Infiltration”

Thesis submitted to the Operative Dentistry Department,
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White spot lesions (WSLs) are whitish opaque discolorations present on the enamel surface. They are often present in children and young adults especially within the esthetic region affecting their appearance and self-esteem.[1] WSLs are subsurface enamel porosities caused by imbalance between processes of demineralization and remineralization that are inherent to the oral environment.[2]

These subsurface porosities develop a different refractive index than hydroxyapatite. This heterogeneity lead to light scattering and the appearance of dull whitish discoloration.[3] Therefore, several treatments were proposed for arresting these lesions and masking their whitish discoloration. Additionally, maintaining this esthetic appearance for a long period of time may be challenging.

Remineralization of white spot lesions rather than restoring such lesions is considered one of the most important elements of minimal intervention in modern dentistry.[4] Remineralization aims at arresting or reversing the WSLs through the application of remineralizing agents. These agents can promote remineralization of the sub-surface enamel lesions.[5]

On the other hand, micro-invasive techniques have also been introduced for treatment of WSLs. It involves filling the pores within the body of the lesion with a low-viscosity light-cured resin, therefore, preventing further dissolution of enamel by acidic challenges.[6] Resin infiltration has been advocated for its ability to mask the whitish, opaque color of WSLs and enhance the final tooth appearance.[3]

Owing to the dynamics of the oral environment with frequent intake of chromogenic foods and drinks, chromophores may become incorporated into the WSLs before and after treatment, jeopardizing overall color and stability.[8] Therefore, the impact of different colorants and materials for their staining susceptibility over time is still needed. Hence, color stability of different treatment modalities is a determinant of immediate and long-term clinical success of WSLs that is worthy of investigation.

White spot lesions (WSLs) are opaque chalky demineralization patches with indistinct outline.[9] They represent the first clinical signs of dental caries progression with the possibility of being reversed. WSLs are often present on the labial surface of the maxillary anterior teeth affecting the esthetic region.[10,11]

Clinically, WSLs appear opaque and white when dehydrated, but once rewet, they disappear. This optical phenomenon (appearance-disappearance) is due to the difference in the refractive index of light between different media (air=1), (enamel =1.62) leading to light scattering. [3] Moreover, if these patches are filled with an aqueous solution of similar refractive index to hydroxyapatite, the opacity seemingly disappears and enamel regains its translucency.[17]

WSLs show different zones with varying pore volumes. The superficial layer is a densely mineralized thin layer with low pore volume of only 1%. Then, the body of the lesion which is demineralized with a variable pore volume up to 25%. The advancing front of the lesion have the least demineralization with pore volume of about 1% (compared to sound enamel with a pore volume of 0.1%).[13] It is worth mentioning that increased opacity of WSL is correlated to extensive and increased porosity.[14] These porosities if left untreated, WSLs may persist and eventually result in cavitation.[15] Nevertheless, if these porosities are exposed to different colorants present in dietary sources, WSLs may get stained resulting in their color change.[8]

In view of that, treatment of WSLs should aim to fill the non-cavitated pores, prevent caries progression, reinforce tooth structure and mask the whitish discoloration.[16] Although color masking is considered a very important aspect during treatment of WSLs, maintaining this esthetic appearance for a long period of time may be also challenging. Several improvements in dental materials have been achieved during recent years, however, discoloration over time is still a problem.[17] Consequently, success or failure of any dental material depends first on its masking ability then on the color stability of this material.[18,19]

Color stability of different restorative materials is considered a fundamental property in the oral cavity.[17] Color stability is defined as the ability of any dental material to resist staining and retain its original color.[19] Staining has a multi-factorial etiology, one may be due to the frequent intake of chromogenic foods and drinks. Some socially consumed beverages, such as coffee, cola and tea or even mouth rinses such as chlorhexidine may result in discoloration of esthetic restorative materials.[8,20] **Lee et al., (2015)** related the staining capabilities of some beverages to its low pH and high sugar content. The combination of low pH, high sugar content, and presence of microorganisms may cause further demineralization, leading to increased staining potential of the treated WSLs.[8]

Color stability can be tested by immersing the specimens into a staining solution for a period of time and then color change is evaluated. Coffee has been reported in several studies as one of the most powerful staining drinks.[15,20,21] Moreover, coffee has been found to have strong chromogens due to presence of large amounts of gallic acid.[19] Red wine is also considered a potent staining solution due to its acidic nature and presence of large quantity of tannins.[8,23] **Ceci et al., (2017)** evaluated the color stability of different resin materials when immersed in coffee and red wine for 28 days and found no significant difference between the two staining solutions.[17] Meanwhile, Coca-Cola and black tea were also used in different studies as staining beverages. Coca-Cola is well known for its acidic nature affecting the surface integrity of the enamel causing discoloration.[24] While presence of chromogenic agents in black tea along with its acidity and high sugar content may cause further demineralization and discoloration of the enamel surface.[8,25] Therefore, when testing different materials for treatment of WSLs, it is necessary to investigate their capability to resist staining and stabilize their color over time.

Several treatments have been proposed in order to arrest and mask the whitish opacity of the WSLs. Treatment of WSLs usually involves remineralization of the tooth structure either by salivary action or by the aid of remineralizing agents. Resin infiltration have also been introduced as a micro-invasive technique for treatment of WSLs.[10]

Remineralization of WSLs is considered one of the most essential elements in minimally invasive dentistry.[4] Remineralization is defined as the process whereby calcium and phosphate ions are supplied from an external source to the tooth, aided by saliva. Consequently, promoting deposition of ions into the pores of the demineralized enamel to produce net mineral gain.[26] The remineralization potential of saliva is well documented. At physiological pH, saliva is supersaturated with phosphoprotein-stabilized Ca^{2+} and PO_4^{3-} ions, ensuring that the ions remain bioavailable to diffuse into mineral deficient lesions. However, net salivary remineralization is a slow process, with tendency for mineral gain only on the surface due to the low ion concentration gradient from saliva into the lesion.[27]

According to **Torres et al., (2011)** the opacity of WSLs can be altered if it could be remineralized. Therefore, the translucency of the enamel occurs in function of its mineral content.(28) Several studies including **Bailey M., (2012)** has proved that saliva can effectively mask the color of the WSLs.(29,30) Nevertheless, **Borges et al., (2014)** studied the color change of different remineralizing agents including artificial saliva and compared them with resin infiltration. Specimens were immersed in a coffee solution ten minutes daily for eight days. Results of this study showed that treatment with artificial saliva for four weeks can result in higher color stability than resin infiltration.(3)

Meanwhile, different remineralizing agents such as milk-derived products have been shown to produce a beneficial effect in arresting WSLs and promoting remineralization.(26,29) They can be categorized into one of the three types: Crystalline, unstabilized amorphous, or stabilized amorphous formulations.

Unstabilized amorphous calcium phosphate (ACP) remineralizing system provides the benefit of having both calcium and phosphate ions close to each other in an amorphous phase.(26) However, the use of ACP alone has been challenging due to its tendency to form clusters and precipitate these ions in crystals.(31) Consequently, the ACP technology requires a two-phase delivery system to keep the calcium and phosphorus components from reacting with each other before use. Meanwhile, in stabilized amorphous formulations, the milk protein casein phosphopeptide (CPP) doesn't allow the combination of calcium and phosphate into crystals, and also prevents these clusters from reaching the critical size for precipitation.(26,31)

The beneficial effect obtained from casein phosphopeptide amorphous calcium phosphate (CPP-ACP) is its ability to localize calcium and phosphate ions in dental plaque making it available when needed.(29) In the presence of an acidic challenges, the CPP protein releases amorphous calcium and phosphate, creating a supersaturated state of calcium and phosphate around the tooth.(31) In conclusion, the CPP-calcium phosphate complexes are anticariogenic products capable of enhancing remineralization, decreasing demineralization or providing a combination of both during acidic challenges. However, these agents are subjected to dilution and washing out by saliva.(4) They also require time and patient compliance.(3)

CPP-ACP has been incorporated into several products including a commercially available sugar-free chewing gum such as Recaldent™ (GC Corp, Japan), mints such as Recaldent Mints™ (Cadbury Japan Ltd, Japan) topical gels such as Tooth Mousse® and Tooth Mousse Plus® (GC Corp, Japan), and many other experimental sports drinks and glass ionomer cements.(15)

Although many studies have proved the effectiveness of CPP-ACP in masking of the opacity of WSLs.(29,32,33) Color stability of WSLs treated with CPP-ACP is still being investigated. **Imamura et al., (2013)** evaluated the color change of CPP-ACP, CPP-ACPF and NaF on bleached enamel, after immersion in black tea for seven days. They declared that application of CPP-ACP can decrease the re-staining and discoloration of teeth after bleaching.(34) On the other hand, **Alaghemand et al., (2015)** studied the staining susceptibility of bleached enamel treated with CPP-ACP after immersion in black tea for 14 days (ten minutes/day). It was found that CPP-ACP had no influence on preventing of enamel staining.(35)

A modern micro-invasive approach to treat WSLs with resin infiltration has been advocated. This technique involves infiltrating WSLs using a low-viscosity resin with specific penetration coefficients. This resin is able to infiltrate into the body of the lesion beyond its highly mineralized surface layer.[13] The idea of resin infiltration technique was developed and registered as ICON (Infiltration Concept) by DMG, Hamburg, Germany in 2008. ICON's kit consists of Icon-Etch (15% hydrochloric acid gel), Icon-Dry (99% ethanol containing gel) and Icon-Infiltrant (TEGDMA-based resin matrix, initiators and additives).[25]

Resin infiltration aims to fill the non-cavitated pores of WSLs with a low-viscosity light-cured resin.[8] This prevents further diffusion of bacteria, impedes lesion development and reinforces the enamel structure. Besides, it requires no preparation or anesthesia and does not alter the anatomical shape of the tooth.[3,36] In addition to arresting caries by creating a diffusion barrier for cariogenic acids, resin infiltration has the added benefit of masking the opaque, whitish color of the WSLs. This is due to its low viscosity which enabled it to diffuse through the enamel porosities filling the intercrystalline spaces within the enamel rods.[29] Moreover, the refractive index of the resin infiltrant is 1.51 which is close to hydroxyapatite, enabling it to mask the opacity and consequently enhancing the final tooth appearance.[3,17]

Several studies including **Torres et al., (2011)** proved the effectiveness of resin infiltration in masking the opacity of the WSLs when compared to other treatment modalities.[28,37,38] Nevertheless, evaluating the staining susceptibility and color stability of WSLs treated with resin infiltration is still crucial to determine its long-term success. **Cohen-Carneiro et al., (2014)** evaluated the color change of resin infiltration