Clinical evaluation of the immediate masking effect of enamel white spot lesions treated with an infiltrant resin

Rosa Maria Pereira Moises Barbosa Andrade, DDS, MSc
Clinical Dentistry, Uberaba University, Brazil

Tayllan Oliveira Lima, DDS
Clinical Dentistry, Uberaba University, Brazil

Maria Angelica Menezes-Oliveira, DDS, MSc, PhD
Professor, Clinical Dentistry, Uberaba University, Brazil

Ruchele Nogueira, DDS, MSc, PhD
Professor, Biopathology, Uberaba University, Brazil

Cesar Penazzo Lepri, DDS, MSc, PhD
Professor, Clinical Dentistry, Uberaba University, Brazil

Vinicius Geraldo-Martins, DDS, MSc, PhD
Professor, Clinical Dentistry, Uberaba University, Brazil

Correspondence to: Prof Vinicius Geraldo-Martins
Clinical Dentistry, Universidade de Uberaba, Av. Nene Sabino 1801 Room No. 2D04, Uberaba, 38055500, Brazil; Tel: +55(34)33198913; Email: vinigmartins@yahoo.com.br
Abstract

The aim of this study was to evaluate, in vivo, the immediate masking effect of white spot lesions (WSLs) treated with an infiltrant resin (IR). The investigation was conducted on 40 young adolescent and adult patients (11 to 23 years old) who presented with at least one permanent maxillary or mandibular anterior tooth with active WSLs on the enamel (ICDAS score 2). Before resin infiltration, the color of both the WSLs and the sound adjacent enamel (SAE) was evaluated by a digital spectrophotometer (CIELab). Subsequently, a resin infiltration technique (Icon) was performed on the WSLs according to the manufacturer’s instruction. At the end of the clinical session, the color of the IR was evaluated. The color difference (ΔE) was calculated between WSL × SAE, WSL × IR, and IR × SAE, and then analyzed using one-way analysis of variance (ANOVA), followed by the Tukey’s test. The L*, a*, and b* values of WSL, SAE, and IR were compared using the Student’s t test for related samples (α = 5%). The ΔE observed was 5.93 ± 0.41 on the WSL × IR comparison, and 5.77 ± 0.41 on the IR × SAE one, indicating that the color of the WSL changed after treatment, but that the infiltration did not fully camouflage the WSLs when compared with the SAE. The lightness was higher for the SAE than for the IR. It was concluded that the IR treatment was not able to camouflage the color of the WSLs when compared with the SAE. However, the treatment was able to attenuate the discoloration of the demineralized dental enamel.

Introduction

Dental caries is a slow-progressing infectious disease that involves local factors such as the microbial biofilm formed on the tooth surface and a diet based on fermentable carbohydrates. The disease also involves genetic and salivary influences as well as modifying factors such as the frequency of oral hygiene and the individual’s social situation. Caries formation occurs due to the demineralization of enamel caused by acids produced by cariogenic bacteria such as *Streptococcus mutans* and *Scardovia wiggsiae*. The initial demineralization starts at and below the enamel surface. Of the many organic acids generated by cariogenic bacteria, lactic acid is the most frequently produced and the one mainly involved in caries formation. These acids decrease the pH level of the biofilm to below critical levels (5.5); if this biofilm is not removed, the tooth loses minerals such as hydroxyapatite. The demineralization increases the porosity and the spaces between the enamel crystals. It also softens the surface, which allows the diffusion of acids into the tooth and results in demineralization of the enamel subsurface. The excess demineralization causes the appearance of a white spot on the enamel.

White spot lesions (WSLs) therefore represent the initial demineralization of the surface of anterior and posterior teeth. They are active when the enamel shows a rough and white-opaque appearance beneath the dental plaque, and inactive when the enamel presents a shiny and smooth surface. It is possible for WSLs to present brown coloration due to the absorption of extrinsic pigments by decalcified enamel. According to the International Caries Detection and Assessment System (ICDAS), the initial lesions with no evidence of surface breakdown or underlying dentin shadowing can be scored at 1 (initial caries) or 2 (distinct visual change in the enamel).

Past studies have shown that WSLs can be reversed by modifying the causative factors or applying preventive measures. Several approaches have been proposed for the noninvasive management of non-cavitated enamel, with fluoride compounds being the most frequently used agents for the prevention or remineralization of caries. Besides being inexpensive and easily accessible, the daily use of fluoride toothpaste provides fluoride ions for caries-protective processes on the tooth’s surface. One method regularly used in dental offices is the topical application of fluoride. Professionally applied fluoride compounds such as varnishes or gels are recommended four times a year for high-risk patients. In addition to tooth remineralization, the advantages of the professional application of fluoride include its relatively low cost, short treatment time, low risk of fluoride intake, and reduction of risk of dental fluorosis in children. However, although fluoride compounds remineralize the WSLs, the stain remains on the affected enamel, contrasting with the healthy tooth color and compromising smile esthetics. The white spots on the enamel result from the optical effect of light scattering, which occurs due to different refractive indexes (RIs). When the porosities on the enamel are filled with air, a greater light dispersion occurs because the RI of the air (1.00) is lower than that of the hydroxyapatite (1.62 to 1.65), leading to an opaque and whitish appearance.

To inhibit the progression of caries and to restore the healthy appearance of demineralized enamel, an infiltrant resin (IR) was developed, which is described as a low-viscosity resin that penetrates the demineralized enamel, creating a diffusion barrier and allowing the replacement of the lost mineral by the applied resin. This minimally invasive technique is applied in a single session, without anesthesia, cavity preparation,
Materials and methods

The present research was fully approved by the Uberaba University Ethics Committee (reference CAAE 659278174.0000.5145), and written informed consent was obtained from all the patients involved. Patients who did not meet the inclusion criteria or did not agree to participate in the study were excluded from this research.

Experimental procedures

The present investigation was conducted on 40 adolescent and young adult patients (11 to 23 years old) who presented with good general health and with at least one permanent maxillary or mandibular anterior tooth with an active WSL on the enamel. An active WSL was defined as an opaque, matte, chalky white area on the enamel. The selected tooth must have received an ICDAS score of 2, with no direct restorations present.

Initially, the selected tooth was cleaned with prophylactic toothpaste and a rubber cup at low speed. Before resin infiltration, the color of the WSL and of the sound adjacent enamel (SAE) were evaluated by a digital spectrophotometer (Vita Easyshade Compact Advance V; VITA Zahnfabrik) using the CIExab system. This system has three coordinates to define the color: L* specifies the lightness and darkness of the color, while a* and b* define its chromatic characteristics. This system allows for the examination of the color differences between two objects – in this case, teeth.

An individual transparent polyester template was designed and positioned on the tooth to mark the exact position of the WSL and the area adjacent to it. Thus, the initial and final color analyses could always be done in the same position. A hole of the same size as the tip of the spectrophotometer was made in the template to allow the
color to be read directly over the tooth. The spectrophotometer was positioned perpendicular to the labial surface of the clinical crown, and the measurements before and after treatment were performed against a black background that was positioned behind the tooth. Variance in assessments with the spectrophotometer error were determined on the basis of repeating the assessment three times. A researcher other than the one who did the treatment performed the initial and final color measurements.

Subsequently, rubber dam was placed and a trained dentist performed the resin infiltration (Icon; DMG) on the WSL according to the manufacturer’s instructions, as follows: the lesion was etched with 15% hydrochloric (Icon etch) acid, rinsed after 2 min, and air dried for 30 s. In the second step, ethanol (Icon Dry) was applied for 30 s, and air dried for 10 s. Finally, the IR (Icon Infiltrant) was applied, and the excess resin was then removed after 3 min with air spray, flossed, and light cured for 40 s. The resin infiltration step was repeated with a penetration time of 60 s to allow the resin to infiltrate the remaining porosities, then light cured for 40 s. The rubber dam was removed and the tooth was polished with polishing cups. The tooth was left to rehydrate for 60 min, then the color of the infiltrated lesion and the adjacent enamel were reevaluated using the same digital spectrophotometer via the previously mentioned procedures.26

Statistical analysis

The data were tabulated and subjected to statistical analysis (SigmaStat 3.01; Systat). Means and 95% confidence intervals of the lightness and color parameters L*, a*, and b* of the WSLs, SAE, and IR were calculated separately and summarized using ΔE values according to the following formula:

\[
\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}
\]

The color difference (ΔE) was calculated between WSL × SAE, WSL × IR, and IR × SAE, and then analyzed using the one-way analysis of variance (ANOVA) test, followed by the Tukey’s test. The L*, a*, and b* values of WSL, SAE, and IR were compared using the Student t test for related samples (α = 5%).

Results

The present study was conducted with 40 patients (53% female, 47% male) with a mean age of 16.3 years. Treatment was performed in only one tooth of each patient, according to previously established criteria. In the maxillary arch, 13 (32.5%) canines, 9 (22.5%) central incisors, and 7 (17.5%) lateral incisors were treated. In the mandibular arch, 6 (15%) canines, 2 (5.5%) central incisors, and 3 (7.5%) lateral incisors were treated.

Table 1 shows the mean (± standard error of the mean [SEM]) data of the ΔE found for the WSL, SAE, and IR comparisons. The color difference found for WSL × SAE comparison (8.05 ± 0.48) indicated that the lesions were easily visible on the enamel. The ΔE observed for the WSL × IR comparison (5.93 ± 0.41) showed that the IR treatment changed the color of the WSL, reducing the color difference between the adjacent enamel and the demineralized enamel (P < 0.05). The comparison between IR × SAE (5.77 ± 0.41) showed that the IR did not fully camouflage the WSL on the en-

### Table 1 Mean (± SEM) of the ΔE found for the different comparisons

<table>
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<tr>
<th>Comparisons</th>
<th>ΔE</th>
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<tr>
<td>WSL × SAE</td>
<td>8.05 (± 0.48)*</td>
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<tr>
<td>WSL × IR</td>
<td>5.93 (± 0.41)*</td>
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<tr>
<td>IR × SAE</td>
<td>5.77 (± 0.41)*</td>
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amel, but that the treated lesion approached the color of the sound enamel when compared with the ΔE found on WSL x SAE (P < 0.05).

Table 2 shows the mean (± SEM) data of the L*, a*, and b* values found in the WSL, SAE, and IR analyses. The WSL lightness (L*; 71.4 ± 2.03) showed no difference compared with SAE (73.62 ± 1.78) and IR (71.78 ± 1.79). However, lightness was higher in SAE compared with IR (P < 0.05). The a* is a measure of redness (a > 0) or greenness (a < 0) of the teeth, and the values were statistically different in all comparisons. While WSL (1.58 ± 0.48) and IR (0.99 ± 0.35) presented positive values, SAE showed slight greenness (-0.55 ± 0.27). The b* is a measure of yellowness (b* > 0) or blueness (b* < 0) of each analyzed area. All values pointed to yellowness; the only difference was found when the infiltrated lesion (24.41 ± 1.21) and SAE (23.08 ± 1.05) were compared.

Figure 1 shows a representative image of two cases, where the images (a) (ΔE = 8.38 [WSL x SAE]) and (b) (ΔE = 7.88 [IR x SAE]) show a situation where ΔE was lower than 3.3. Figure 2 also shows different situations: In the first case – (c) (ΔE = 5.98 [WSL x SAE]) and (b) (ΔE = 14.2 [IR x SAE]) – the IR was observed to mask the WSL. However, in the second case – (c) (ΔE = 5.01 [WSL x SAE]) and (d) (ΔE = 3.24 [IR x SAE]), the IR did not mask the WSL; however, it did attenuate the enamel discoloration.

**Discussion**

The objective of the present research was to evaluate, in vivo, the camouflage effect of IR in the treatment of WSLs. The results showed that although the color difference was reduced between the treated WSLs and the sound enamel, the treatment performed in vivo did not totally mimic the color of the WSLs with that of the dental enamel. However, as the treatment altered the color of the WSLs, the null hypothesis was rejected.

As previously described, WSLs occur due to demineralization of the enamel surface and represent the first sign of dental caries. Several methods have been proposed to remineralize the affected area, and although some (mainly fluoride compounds) show satisfactory results, they do...
not change the color of WSLs to be the same as sound enamel.\textsuperscript{12,27} From a functional point of view, the aim of the resin in filtration technique is to arrest caries lesion progression with low-viscous, light-curing resins, since it creates a diffusion barrier on the surface and within the enamel, thus occluding the pathways for acid entry into the hard tissue.\textsuperscript{12} Furthermore, due to its composition, in some situations the IR leads to an esthetic improvement of caries lesions.\textsuperscript{9}

The literature reports the use of IR in cases of enamel hypoplasia and amelogenesis imperfecta.\textsuperscript{18,24} The present study selected only patients who were diagnosed with alterations in the color of the vestibular enamel of the anterior teeth due to demineralization (ICDAS, score 2). The discussion is therefore focused on that specific problem.

In the present study, a portable spectrophotometer was used for the color measurement. A dentist other than the one who applied the IR carried out the initial and final analyses. The measurements were performed three times in each area. Instrumental color analysis is advantageous compared with visual color determination because instrumental readings are objective, can be
A spectrophotometer works by measuring the spectral reflectance or transmittance curve of a specimen. The color change (ΔE) of the teeth was evaluated using the CIELab system, one of the most common color measurement systems used in dentistry today. In this system, three different intervals are used for distinguishing color differences: ΔE values of 1 are regarded as not appreciable by the human eye; ΔE values between 1.0 and 3.3 mean that this change is noticeable only by a qualified person (i.e., the color difference is clinically acceptable); and ΔE values over 3.3 indicate that the color difference of the objects can be easily observed.

The initial situation of the teeth evaluated here showed a remarkable difference between the color of the WSLs and the SAE (ΔE = 8.05 ± 0.48), which represented one of the main complaints of the subjects. WSLs present a porous surface, and those microholes are filled with water or air that present a RI of 1.33 and 1.0, respectively, while the RI of sound enamel is 1.62. The difference in RIs between the enamel crystals and the medium inside the porosities affects the light scattering and gives these
lesions a whitish appearance, especially when desiccated.\textsuperscript{10,31}

Also observed in the present study was that the IR technique changed the color of the WSL, since the color difference between the initial lesion and that after treatment was 5.93 ($\pm$ 0.41), which is above the reference threshold for visual changes of color between two objects, as previously described.\textsuperscript{30} The color change occurs because the micropores of the WSL are infiltrated by the low-viscosity resin ($RI = 1.46$), which has a similar RI to sound enamel.\textsuperscript{21}

The comparison between the color of the infiltrated lesion and the adjacent enamel showed that the treatment was not able to mask the WSL ($\Delta E = 5.77 \pm 0.41$) but was able to decrease the color difference (when compared with the $\Delta E$) between the initial lesion and the SAE. Previous in vivo studies have achieved the same results as those observed here.\textsuperscript{52,35}

It must be pointed out that different factors may influence masking outcomes, such as extension, depth, and activity of lesions. Unlike in vitro studies, where there is complete control of the initial situation of the enamel demineralization, in vivo clinical studies have no mechanism to standardize the degree of demineralization of the WSLs for all subjects. It is known that the effectiveness of the treatment is directly related to the demineralization of the WSL by the 15% hydrochloric acid used in the IR technique.\textsuperscript{34} The function of the acid etch is to increase the enamel porosity and wettability to allow for the penetration of the low-viscosity resin.\textsuperscript{34} Therefore, if the pores of the lesion body can be completely occluded with the infiltrant, the progression of the lesion can be prevented and the esthetic issues resolved. Thus, considering the same action time, the effect of acid conditioning may be lower on a more mineralized tissue than on a less mineralized one. This could explain the better performance outcomes of the infiltration technique when carried out in vitro compared with in vivo.

As previously described, according to the manufacturer’s specifications, two applications of the IR were performed in the same session. Likewise, the evaluation was performed only immediately after treatment. Previous longitudinal clinical studies have shown that although the camouflage effect is reported to be immediate, concern exists about the durability of the esthetic results due to staining and aging of the low-viscosity resin used for infiltration.\textsuperscript{23,33,35} Although studies show that the IR exhibits satisfactory long-term color stability, it is possible that tooth brushing and food/ beverage intake could interfere with the esthetic result of the treatment over time.\textsuperscript{22,33,35}

After treatment, it was possible to observe without the spectrophotometer that the color of the WSL was attenuated by the IR, and in some cases the color difference was imperceptible. This was also observed in a previous study comparing the subjective and objective methods of color analysis of teeth treated with IR.\textsuperscript{23}

Table 2 shows there was little difference in the $L^*$ and $b^*$ values, and that the main color changes due to the treatment occurred in the $a^*$ value, which represents the degree of redness ($a > 0$) or greenness ($a < 0$) of an object. This was probably due to the color of the infiltrating resinous monomers in an attempt to leave the white stain in a shade closer to yellow.

**Conclusions**

The results of the present study show that IR treatment was not able to leave the WSL on the dental enamel with the same coloration as that of the sound tissue. However, the treatment was able to attenuate the discoloration of the demineralized dental enamel.

As previously described, the research was performed in a university clinic on ado-
lescent and young adult patients. As there was no longitudinal analysis, it was not necessary to standardize the oral hygiene protocol of the patients. Thus, further studies are necessary to verify whether this color change obtained immediately after treatment will present satisfactory results over time, under standardized conditions.

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