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The evaluation of resin infiltration for masking labial enamel white spot lesions

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Objective. The aim of this study was to clinically assess the effectiveness of masking white spot enamel lesions using a resin infiltration technique that was recently developed to arrest incipient caries in a micro-invasive concept.

Methods. Twenty teeth with a Developmental Defect of Enamel (DDE) and 18 teeth with Post-orthodontic Decalcification (POD) were selected and treated with resin infiltration. Standardized photographs were taken before, immediately after, and 1 week after treatment and were analysed using image analysing software to calculate the ΔE values. The results were classified into three groups: completely masked, partially masked, and unchanged.

Results. Among the 20 teeth with DDE, five teeth (25%) were classified as completely masked, whereas seven (35%) and eight teeth (40%) were partially masked and unchanged, respectively. Among the 18 teeth with POD, 11 teeth (61%) were completely masked, six teeth (33%) were partially masked, and one tooth (6%) was unchanged. In some teeth, the result was more improved after 1 week than immediately after infiltration.

Conclusion. The masking effect was dramatic in some cases but not in others. The long-term colour stability of the result should be followed up through continuous clinical and scientific studies.

Introduction

It is not difficult to observe white spot lesions because of dental caries, Developmental Defect of Enamel (DDE), or post-orthodontic decalcification (POD) in the dental clinics of children and adolescents. The prevalence of molar incisor hypomineralization (MIH) to describe a more specific pattern of DDE ranges from 3.6 to 25%[1] and that of POD varies from 2 to 96% depending on the methods used to assess and score the extent of decalcification, the presence of decalcification before treatment, and the use of fluoride supplements during treatment[2].

These lesions may present aesthetic problems as well as the progression of demineralization[3]. Although white spot lesions after orthodontic treatment with fixed appliances might be remineralized partially after debonding, white enamel lesions are often irreversible[4–6]. These lesions may present aesthetic problems even more than 5 years after treatment[7].

Up to now, there are four methods available for treating white spot lesions. First, several studies have shown that white spot lesions may regress as a result of the remineralization by fluorides or casein phosphopeptide–amorphous calcium phosphate (CPP–ACP)[5,8]. Remineralization techniques are to some degree effective, but their aesthetic effect is limited because remineralization often is limited to the lesion surface[9,10]. Moreover, it takes considerable time and needs to be implemented at the very early stages of the lesion development. Furthermore, it strongly relies on the patient's compliance[10]. Second, the bleaching therapy with hydrogen peroxide for masking white fluorosis blemishes has been reported[11,12], but its aesthetic effect is also limited, and side effects such as post-treatment sensitivity are commonly encountered. The microhardness of

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sound enamel surfaces as well as demineralized enamel surfaces after bleaching might be reduced[13–15]. Third, microabrasion is a commonly used approach for improving the aesthetics of white spot lesions[16–19]. This technique, however, may cause the aggressive reduction of enamel as a function of the duration, intensity, and number of applications[20]. In addition, microabrasion is an effective treatment only in shallow defects[21]. Finally, restorations with tooth reduction, which is quite invasive, have been used considerably[22,23]. The problem with an invasive treatment is that most patients demanding treatment for white spots are children, adolescents, or young adults. The invasive procedures usually result in excessive sacrifice of tooth material, which accelerate the destruction of the tooth at an earlier age.

The resin infiltration concept, which was developed recently, aims at arresting the incipient enamel caries lesions by penetrating the low-viscosity resin into the enamel and obstructing the diffusion pathways for acids and dissolved minerals in the enamel[24]. In addition, the resin matrix can strengthen the enamel structure mechanically, thereby preventing breakdown of the enamel surface[25]. In several laboratory studies, resin penetration into artificial caries has been shown with commercially available adhesives and fissure sealants[26,27], but these materials only result in a diffusion barrier on the lesion surface owing to only superficial penetration[28]. Recently, a low-viscosity resin with a high penetration coefficient was developed specially for this purpose. As an additional effect of this method, the resin-infiltrated enamel lesions have been reported to lose their whitish opaque colour and recover the healthy enamel colour and translucency[29]. This study was performed for the purpose of assessing the masking effects of resin infiltration technique in white spot enamel lesions.

Materials and methods

Subjects

Twenty-one healthy patients with white spot enamel lesions on their maxillary anterior teeth were selected at the time of their regular dental visits in the Pediatric Dental Clinic at Pusan National University Dental Hospital from July 2009 to September 2009. Twenty teeth with DDE from 12 children (mean age = 12.5 year) and eighteen teeth with POD from nine children (mean age = 15.1 year) were decided as subjects. For the teeth with DDE in our experiment, only the incisors with MIH of hypomineralization type were selected[1]. Hypomineralization was indentified visually as an abnormality in the translucency of the enamel and also denominated as opacity of the enamel. For the teeth with POD, only the teeth longer than 3 months elapsed after debonding were selected to exclude those in active lesion state, and average time elapsed was 21 months (9 ~ 38 months). These teeth met the following criteria: inactive lesions with smooth, hard, and shiny surface, white spots, and ICDAS code 2.

Resin infiltration

For the maximum protection of patients during the infiltration procedure, the patients were made to wear the eye glasses, and rubber dam and separating rings were applied. The tooth surface was cleaned with a rubber cup and prophylaxis paste. The surface layer was eroded by the application of 15% hydrochloric acid gel (ICON®-Etch; DMG, Hamburg, Germany) for 120 s to expose the layer of lesion body. Subsequently, the etching gel was washed away thoroughly for 30 s using a water spray and dried. The lesions were desiccated using ethanol (ICON®-Dry; DMG) for 30 s followed by air drying. An infiltrant resin (ICON®-Infiltrant; DMG) was applied to the surface and allowed to penetrate inside for 3 min. Excessive material was wiped away using a cotton roll from the surface before light curing. Excessive resin in the proximal spaces was cleaned using dental floss. After light curing for 40 s, the application of infiltrant resin was repeated once for 1 min and light cured for 40 s. Finally, the roughened enamel surface was polished using a composite resin polishing discs (Sof-lex disk; 3M ESPE, Saint Paul, MN, USA).

Standardized clinical photography

Standardized clinical photographs were taken before (T1), immediately after (T2), and 1 week after (T3) infiltration. A standardized cephalometric head frame was used, and a camera was fixed at the same distance from the subject to standardize the photographic conditions. To exclude the influence of moisture on tooth colour, the tooth surfaces were dried with compressed air for 30 s. Clinical photographs were taken using a digital camera (EOS 450d camera; Canon, Tokyo, Japan), macrolens (SP AF90 mm F/2.8 Di 1:1 Macrolens; Tamron, Saitama, Japan), and flash (MT 24-EX twinlight; Canon). The camera settings were as follows: shutter speed 1/200, F29, ISO 400, and Auto white balance. The photographs were taken in a darkroom to cut off the external light sources, and a photometer was used to maintain the intensity of light. The twinlight and polarizing filters were equipped to minimize the light reflection. The part with reflected light was excluded from the analysis.

Evaluation of colour changes

The measurement was performed by an examiner after photographs were randomly labelled to avoid unwanted measuring bias. The sound enamel and white spot lesions were outlined on the screen, and the colours of the sound enamel and white spot lesions were measured using an image analysing software (I-solution; IMT technology, Seoul, Korea). The colour of the teeth in the same site was analysed by transferring the outlined layer of the T1 photograph to the T2 and T3 photographs. The RGB values of the sound enamel and lesions were obtained from each tooth, which were transformed into CIELAB space.

The CIELAB space applied in this study is an international system used in many standards for colour measurements. The difference (ΔE) in colour between the sound enamel and lesions at each time was calculated with the measured CIE $L^*a^*b^*$ values[30]. ΔE is a value for quantifying the discrepancy between two colours. A ΔE difference of 3.7 units is considered a clinical indicator for mismatching colours or colour change[31]. That is, white spot lesions are clinically invisible when the ΔE unit between the sound enamel and white spot lesions is lower than 3.7, and the lesion is clinically visible when ΔE unit between sound enamel and white spot lesions is higher than 3.7.

According to degrees of colour changes evaluated 1 week after treatment, the teeth were divided into the following three types: Type 1 : the whitish opaque colours are completely masked (tooth with $\Delta E \leq 3.7$ units in the area of the white spot vs. the area of sound enamel after 1 week); Type 2 : whitish opaque colours are partially masked but not completely (tooth with $\Delta E > 3.7$ units in the area of the white spot *versus* the areas of sound enamel after 1 week, and with $\Delta E > 3.7$ between before and 1 week after treatment); Type 3 : the whitish opaque colours show little change (tooth with $\Delta E > 3.7$ units in the area of the white spots *versus* areas of sound enamel after 1 week, with $\Delta E \leq 3.7$ between before and 1 week after treatment). To evaluate intrarater reproducibility, ten randomly selected images were re-examined by the same examiner after 2-week interval.

Statistical analysis

Intrarater reliability was evaluated with scale reliability analysis. A Wilcoxon's signed rank test was performed to determine the statistical significances (using $P < 0.05$) of the colour difference between those taken before, immediately after, and 1 week after treatment.

Results

There was no loss of subject from the beginning to the follow-up or exclusion. All participants (12 children with DDE and nine children with POD) attended the check-up examination after 1 week. Intrarater reliability coefficient was 0.91 ($P < 0.05$), showing no significant difference between the two measurements. Among the 20 subject teeth with DDE, five teeth (25%) were classified as completely masked whereas seven (35%) and

eight (40%) were partially masked and unchanged, respectively (Table 1, Figs 1 and 2). Among the 18 subject teeth with POD, 11 teeth (61%) were completely masked, six teeth (33%) were partially masked, and one tooth (6%) was unchanged (Table 1, Figs 3 and 4).

Overall, the colour differences between the sound and white spot enamel decreased significantly after infiltration in both DDE and POD

Table 1. Colour changes of white spot lesions.

	Type 1 (completely masked %)	Type 2 (partially masked %)	Type 3 (unchanged %)	Sum
DDE	5 (25)	7 (35)	8 (40)	20
POD	11 (61)	6 (33)	1 (6)	18

DDE, developmental defects of enamel; POD, post-orthodontic decalcification.

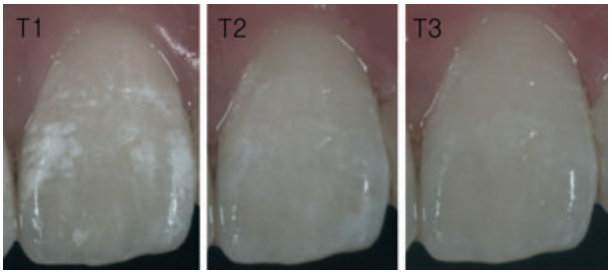

Fig. 1. Type 1 colour changes in a maxillary left central incisor with developmental defect of enamel. Compared to the T1 images (before treatment), enamel colour had recovered considerably in T2 (immediately after treatment) and further in T3 (1 week after treatment) appearing almost normal.

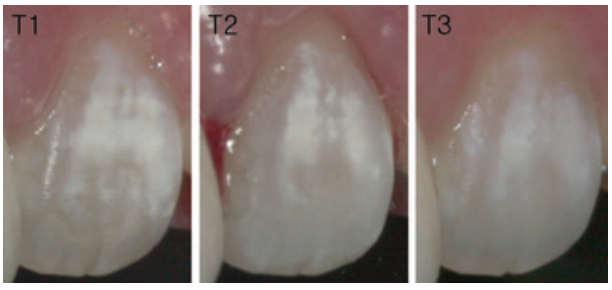

Fig. 2. Type 2 colour changes in a maxillary left lateral incisor with developmental defect of enamel. Although the enamel colour had recovered slightly in T2 (immediately after treatment) and further in T3 (1 week after treatment) compared to T1 (before treatment), the white spot remained.

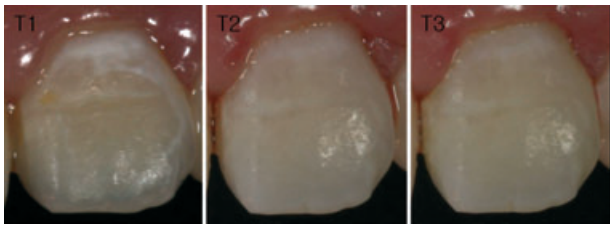

Fig. 3. Type 1 colour changes in a maxillary left lateral incisor with an orthodontic decalcified lesion. Compared to T1 (before treatment), the enamel colour had recovered considerably in T2 (immediately after treatment) and further in T3 (1 week after treatment), appearing almost normal.

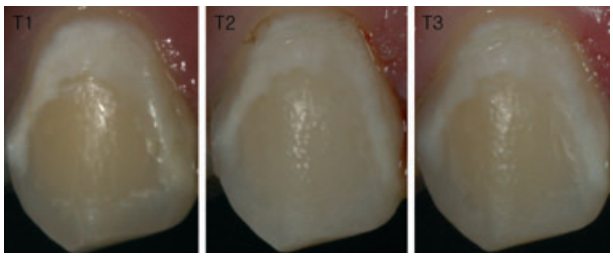

Fig. 4. Type 3 colour changes in a maxillary right canine with an orthodontic decalcified lesion. Compared to T1 (before treatment), no change in enamel colour was observed either in T2 (immediately after treatment) or T3 (1 week after treatment).

Table 2. Statistical analysis of the colour changes.

	T1–T2*	T1–T3**	T2–T3***
DDE	$P < 0.05$	$P < 0.05$	$P < 0.05$
POD	$P < 0.05$	$P < 0.05$	$P = 0.09$

DDE, developmental defects of enamel; POD, post-orthodontic decalcification.
*T1–T2: colour change between T1 (before the treatment) and T2 (after the treatment).
**T1–T3: colour change between T1 and T3 (1 week after the treatment).
***T2–T3: colour change between T2 and T3.

($P < 0.05$) group. In DDE, the colour difference decreased significantly 1 week after infiltration compared to that immediately after infiltration (Table 2). There was no harm or adverse effect to participants.

Discussion

The white spot appearance of initial caries and DDE is caused by subsurface porosity in the enamel below a well-mineralized surface

layer[32,33]. White spot lesions are more obvious when the teeth are dry because of the different refractive indices of enamel, water, and air. Sound enamel has a refractive index of 1.62. Enamel becomes porous when demineralized. If the pores within the lesion are filled with water (refractive index: 1.33), the lesions will appear opaque compared to the sound tissue. If dried, the water in the pores is replaced with air (refractive index 1.0), and the lesion becomes more apparent[34]. On the other hand, when the microporosities are filled with infiltrant resin, the refractive indices increase to 1.52, the difference in refractive index between the infiltrated lesion and enamel is negligible, and the lesions appear similar to the surrounding sound enamel.

In contrast to remineralization using fluoride or CPP–ACP, infiltrant resin can improve the colour, even in deeper lesions, because it penetrates deeper lesions and the effect appears immediately after treatment[9,10,35]. In addition, resin infiltration is much less invasive than microabrasion or restoration[22,23,36,37].

The resin infiltration concept aims to arrest the incipient enamel caries lesions instead of removing the lesion and obstruct the diffusion pathways for acids and dissolved minerals in the enamel[24]. The resin matrix can also strengthen the enamel structure mechanically[26]. An infiltrant resin shows very low viscosity, high surface tension, and low contact angle with the enamel[38]. These properties are important for penetrating the resin into the layer of lesion body of enamel caries. The hypermineralized surface layer impedes penetration of the resin into the lesion body, however. Therefore, complete erosion of the surface layer and exposure of the lesion body is the aim of a conditioning procedure[28]. Removal of the surface layer might also weaken the lesion structure, but Meyer-Lueckel *et al.*[37] reported that 15% HCl is most suitable for removing approximately 40 μm of the hypermineralized surface layer. Moreover, in this study, no cavitation occurred after etching, even when the surface layer had been eroded completely. In practice, subsequent resin infiltration should ensure restrengthening of the lesion structure. In contrast, microabrasion, which has been commonly used in white spots, removes up to 360 μm of enamel[36]. The purpose of using 99% ethanol is to remove the water that is stored inside the microporosity of the lesion body and allow the resin to penetrate into the lesion body driven by capillary forces[39]. Because the infiltration technique aims to construct a diffusion barrier inside the lesion and rather than on lesion surface, the overlaying resin is wiped away prior to light curing. A resin layer on lesion surface is not required if the lesion body is infiltrated homogeneously with the resin. Rather, cleaning of the overlaying material from the surface is advantageous because the ideal form of the surface can be retained[27]. The reason for applying the resin twice is because of the shrinkage of materials after the first application resulting in the generation of space that can then be occluded by a second application[26].

Standardized clinical photography used in this study is simple and clinically relevant approach for quantifying the lesion size and colour. Many studies have reported this to be an objective, reproducible, and reliable method if the camera and light sources are positioned in the same orientation[40–43]. The present study evaluated the results from standardized clinical photography and image analysing software using the ΔE unit, which quantifies the discrepancy between the two colours. It was reported that human observers can be expected to detect colour differences of one ΔE unit under standardized laboratory conditions. In the oral cavity, where the light source cannot be standardized, $\Delta E \leq 3.7$ units was considered to be a match for compared teeth. Although some authors report $\Delta E = 3.0$ units as an indicator for mismatching colours, most studies consider $\Delta E > 3.7$ units to be clinically visible in any site[31,44,45].

The selected patients with POD had elapsed time after debonding more than 3 months because after 3 months with careful oral hygiene, the active lesion decreases spontaneously because of the remineralization by oral fluids. Some white spot lesions disappear within several weeks, and most lesions decrease with time until 3 months[46,47].

Therefore, lesions remaining after 3 months were selected. This period is enough for post-orthodontic white spot lesions to improve spontaneously.

Among the 38 subject teeth, the masking effect was observed in 12 of the 20 DDE (60%) teeth and 17 of the 18 POD (94%) teeth. Among the 20 teeth with DDE, five teeth (25%) were classified as completely masked, whereas 11 of the 18 teeth (61%) with POD were completely masked. Therefore, the masking effect was better in POD lesions than DDE lesions. Forty percentage of DDE teeth and 6% of POD teeth were classified as unchanged. The masking effect was dramatic in some cases but not in others. The effect was believed to be dependent on the lesion depth and activity. There might be little or no masking effect in lesions deeper than the infiltration range and/or the inactive, rather old lesions with thicker surface layers. Incomplete removal of surface layer by single erosion in inactive lesions with thicker surface layer might lead to incomplete penetration. Thus, the masking effect might be better for the lesions in more active and younger state when the lesion is not so deep and surface layer is relatively thin.

As the surface layer becomes quite thicker in inactive lesions, it was proposed to repeat eroding the surface layer several times to completely remove it and consequently to ensure the deep penetration of infiltrants[29]. But, as resin infiltration concept was developed from the basis of micro-invasive concept, repetition of HCl erosion was thought to have something to be studied further, and we strictly followed the manufacturer's recommendation in this study.

Nevertheless, the original purpose of resin infiltration is to obstruct the diffusion pathways to protect internal lesions with the masking effect being an additional effect. We thought it not meaningless to block the lesion progression, even if the colour is not changed. A method for clinically measuring the lesion depths was thought highly desirable to distinguish the indications of resin infiltration for masking purposes, however. The long-term colour stability of this technique should be followed up through continuous studies. In some cases, the result improved after 1 week compared to that observed immediately after treatment, and further study will be needed to explain these optical characteristics.

Conclusions

The masking effect of resin infiltration was dramatic in some cases but not in others. The long-term colour stability of this technique should be followed up through continuous clinical and scientific studies.

What this paper adds

- This study demonstrates that resin infiltration can be used not only to arrest the incipient caries lesions in smooth surfaces but also to improve the enamel colours in aesthetic purpose in lesions with developmental defects or post-orthodontic decalcification frequently found in upper anterior teeth in children and adolescents.
- The result, however, showed that aesthetic improvement cannot be expected in some lesions probably due to the lesion depth and activity, and any method to measure the lesion depths was highly desirable.

Why this paper is important for paediatric dentists

- This paper provides the better understanding about resin infiltration concept especially when it is used for aesthetic purpose in minimal invasive philosophy which is strongly required for children and adolescents.

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