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Estimating the masking effect of post-orthodontic white spot lesions before resin infiltration

Introduction: Orthodontic treatment with fixed elements increases the risk of developing white spot lesions due to additional retention opportunities for biofilm. One approach for the esthetic treatment of these lesions is caries infiltration. In order to estimate the final masking effect of the resin infiltration, re-wetting with water or ethanol is often performed just after the etching procedure.

Patient cases: Four patients who were diagnosed with white spot lesions in the esthetically visible area during treatment with fixed orthodontic appliances were informed about the possibility of optically masking these lesions using resin infiltration. The infiltration (Icon, DMG) was performed according to the manufacturer's instructions, but the etching procedure was performed up to three times. The decision regarding whether to repeat the etching procedure was made subjectively by the practitioner during the re-wetting test with ethanol. The masking effect generated by ethanol and resin infiltration was analyzed using digital photographs before treatment, before and during the first 9 sec of re-wetting as well as one week after treatment.

Result: In all 4 patient cases, the observed minimum color difference during re-wetting appears to be a good indicator for assessing whether a satisfactory masking effect can be achieved. Furthermore, in the total of 55 treated white spot lesions, lesions with higher color value differences were etched more frequently than lesions with less pronounced color value differences. Overall, the masking effect one week after resin infiltration was satisfactory in all cases.

Discussion: During the re-wetting test, the minimum color difference between the initial lesion and the intact enamel which surrounds the lesion seems to be a good predictor of the final outcome of resin infiltration of post-orthodontic white spot lesions. Furthermore, white spot lesions with a higher initial color difference appear to require multiple etching procedures.

Conclusion: Resin infiltration is a useful microinvasive method for masking white spot lesions which develop during orthodontic treatment with fixed appliances. Moreover, the temporary masking effect achieved by the re-wetting test with ethanol can be used as an indicator for estimating the number of etching procedures required.

Keywords: caries infiltration; post-orthodontic treatment; enamel lesion; white spot lesion; esthetics

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Introduction

Orthodontic treatment with fixed appliances increases the risk of developing initial non-cavitated carious lesions – also called white spot lesions [3]. The more difficult oral hygiene around the brackets represents an additional retention opportunity for biofilm and therefore increases the caries risk [2]. A rapid and progressive development of white spot lesions could then potentially become an esthetic concern for patients [15]. The characteristic white, opaque appearance of the lesions can be physically explained by the stronger scattering of light within the lesion's body as a result of air and saliva inclusions in comparison to the surrounding healthy enamel [13]. In literature, the prevalence of white spot lesions after treatment with fixed elements varies between 23 %, 50 % and even 97 % [10].

White spot lesions remineralize once the brackets, which represent a retention site for plaque, have been removed. Although fluoride-containing agents can be used to enhance remineralization, the esthetic appearance is usually not sufficiently improved [19]. For this reason, different prevention strategies have been employed during treatment with fixed elements, e.g. fluoride-releasing sealants or bonding materials as well as the daily use of fluoride-containing or chlorhexidine-containing mouthwashes. However, these strategies cannot prevent the development of white spot lesions [21]. After removal of the fixed elements, microabrasion represents another treatment option which is most suitable for very superficial lesions because concave tooth surfaces can develop in the case of deeper lesions [22]. Direct and indirect restorations also lead to satisfactory and predictable results, but they should only be used in cavitated lesions due to their invasive nature [18].

Another therapeutic approach for the treatment of initial, non-cavitated carious lesions is caries infiltration. This involves the obturation of the microporous enamel areas of a caries by means of flowable resins („infiltrants“) so as to arrest further caries progression [17]. Furthermore,

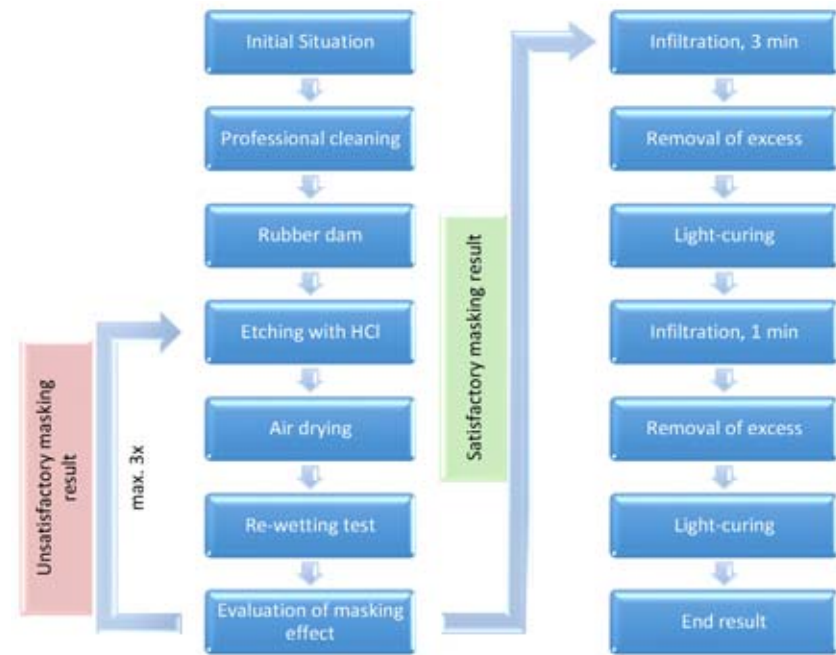


Figure 1 The treatment scheme for resin infiltration of white spots. The subjective examination of whether the masking effect was satisfactory was made during the re-wetting test. If the result was not satisfactory, the etching procedure was repeated. The etching procedure was performed up to a total of three times. Afterwards, the treatment scheme was continued.

the optical appearance is positively changed by caries infiltration [11]. Yet, it is difficult to predict the masking effect during the clinical application of the procedure. The varying masking results can be explained in relation to the variable thickness of the surface layer [8, 14]. In inactive lesions, the layer is usually thicker and less permeable than in newly formed active ones [1]. In contrast, the pores of active carious lesions appear larger and the surface layer less mineralized, thus allowing the resin to penetrate deeper into the lesion's body [13]. However, to date, there is no way of estimating the ability of the infiltrant to diffuse into the (remaining) surface layer after etching. This would be desirable because it is difficult to remove the infiltrant after its application if the final result is considered not satisfactory. At the same time, a high degree of demineralization of the carious lesion is also unfavorable for attaining the most complete masking result possible.

The refractive indices of liquids are closer to the refractive index of healthy enamel than to the refractive

index of air. Therefore, the application of a liquid after the etching process should permit a (temporary) assessment of whether the surface layer has been sufficiently removed in order to allow a sufficiently deep diffusion [6]. Consequently, a liquid could theoretically be used to assess the masking effect before the infiltrant is applied. In this context, based on the four cases presented in this study, it was investigated if the final infiltration result is predictable using the re-wetting test.

Case studies

Four patients who complained about „white spots“ on their teeth in the esthetically visible area after the removal of the fixed appliance were treated in a clinical study [10]. The white enamel areas were diagnosed as post-orthodontic white spot lesions. After the patient's consent, the infiltration procedure was performed according to the following treatment scheme (Fig. 1):

- a. Cleaning the teeth with fluoride-free polishing paste (Cleanic; Kerr, Bioggio, Schweiz)

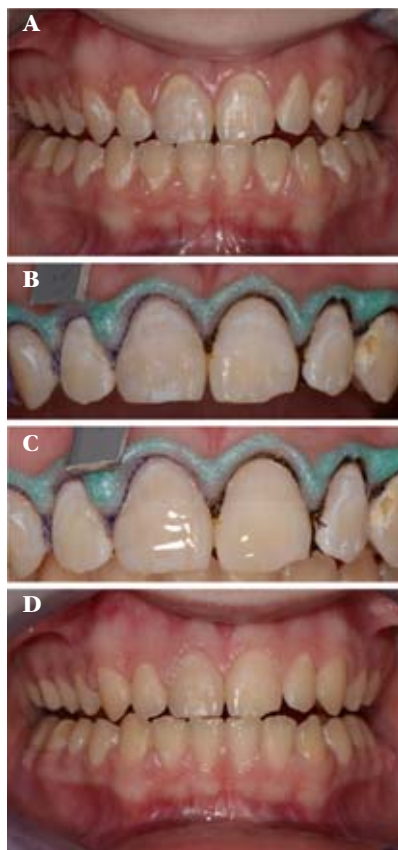


Figure 2A–D After orthodontic treatment with fixed elements, multiple white spot lesions dominated the appearance of the upper and lower jaw (**A**). Appearance after the etching procedure (**B**). Estimation of the masking effect during the re-wetting test (**C**). A satisfactory final result was obtained one week after infiltration (**D**). The color difference one week after infiltration at the cervical margins of teeth 11 and 21 (**D**) is even lower than the minimum color difference during re-wetting (**C**). It should be noted that the partial image (**C**) only shows the re-wetting test on teeth 11 and 21. Before recording the final result (**D**), the cavitated lesion on tooth 23 was treated with a restoration.

- b. Application of a resin-based, light-curable barrier (OpalDam; Ultradent, South Jordan, USA) to keep the working area dry and protect the gingiva.
- c. Etching the teeth with 15 % HCl gel – 2 min per lesion (ICON etch; DMG, Hamburg, Deutschland)
- d. Removing the HCl gel and spraying with water – 30 sec per tooth
- e. Air drying the teeth with compressed air – 30 sec per tooth

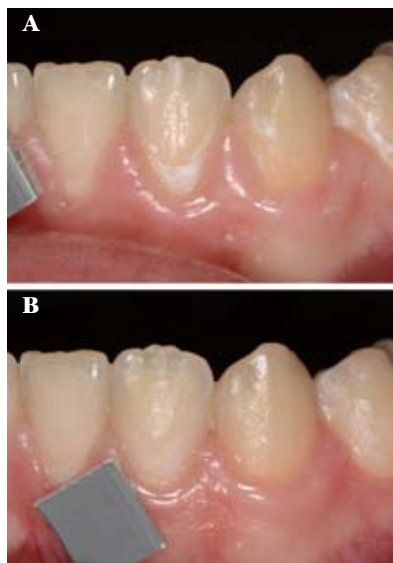


Figure 3A/B Cervical white spot lesion on tooth 33. The gray chart on the images was used to standardize colorimetric evaluation. **A**: initial situation; **B**: situation one week after resin infiltration.

- f. Re-wetting the teeth with ethanol – 30 sec per tooth (ICON dry; DMG, Hamburg, Deutschland)
- g. Air drying the teeth with compressed air – 10 sec per tooth

During the re-wetting process, the practitioner (C.K.) decided if the masking result was satisfactory. If the subjective assessment was not satisfactory, steps c–g were repeated. The etching process was performed a maximum of three times. Afterwards, the treatment scheme was continued:

- h. Application of the infiltrant – 3 min exposure time (ICON Infiltrant; DMG, Hamburg, Deutschland)
- i. Removing the excess with a foam pellet
- j. Light-curing – 40 sec per tooth
- k. Application of the infiltrant – 1 min exposure time
- l. Removing excess with a foam pellet
- m. Light-curing – 40 sec per tooth
- n. A final polishing of the infiltration area was performed (Sof-Lex; 3 M, Saint Paul, USA and Occlubrush; Kerr, Orange, USA).

In order to evaluate the masking effect, standardized digital photo-

graphs (shutter speed: 1/250, aperture: F29, ISO sensitivity: 100, white balance: 6250 K, tooth/lens distance: 20 cm) were taken at the following times: before treatment, 1 sec before ethanol application (treatment step f), in the following 9 sec (1 image per second) and one week after treatment (Fig. 2–4). Care was taken to avoid a color change due to the dehydration of the teeth.

Results

After removal of the brackets, 55 white spot lesions (ICDAS code 2, upper jaw: n = 29; lower jaw: n = 26) were diagnosed on the anterior teeth and first premolars in the 4 patients (14–16 years). The initial situation and the final treatment result are shown in Figure 2 and Figure 5. Satisfactory masking effects were achieved in all cases. This was independent of the number of etching procedures. The evaluation of the digital images after treatment showed that the number of etching procedures correlated with the initial color differences. The stronger the (remaining) color difference was estimated during the treatment, the more etching procedures were performed. Furthermore, it was shown that the subjectively perceived minimum color difference during the re-wetting test is well suited for estimating the color difference one week after infiltration. Teeth which did not show a satisfactory masking result during the first 3–5 sec of the re-wetting test were etched again (Fig. 4). Furthermore, the evaluation of the digital images confirmed that a difference in the practitioner's color perception existed; it was significantly lower one week after infiltration as compared to during re-wetting (Fig. 5).

Discussion

Based on the presented cases, the color change during the re-wetting tests, their influence on the number of etching procedures and their correlation with the masking results one week after infiltration were described. It was observed that the minimum color difference during re-wetting seems to be suitable for estimating the color difference one week after infiltration. Especially during the first

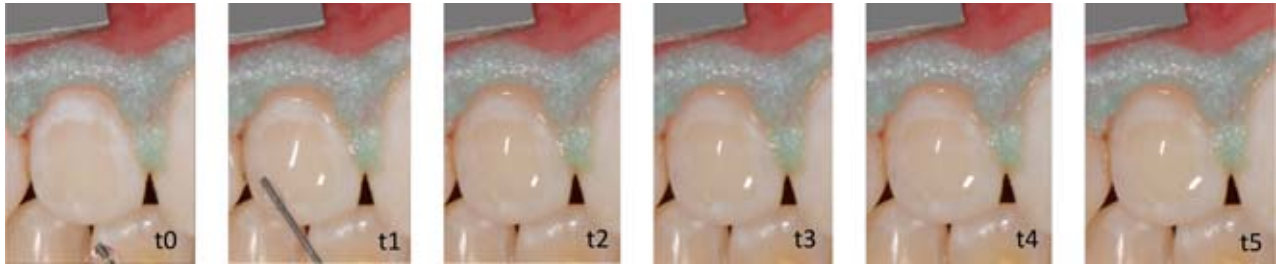


Figure 4t0–t5 Using the re-wetting test with ethanol before subsequent infiltration, it can be assessed whether the success of masking will be satisfactory for previously etched lesions (**t0**). If masking is not satisfactory within the first 3–5 sec (**t1–t5**), as in this case, etching with hydrochloric acid for 2 min should be repeated.

3 sec of re-wetting, there is a strong reduction in the color difference. If no considerable reduction in the color difference is subjectively detected, etching should be repeated. In any case, after resin infiltration the color difference is (even) further reduced when compared to the color difference during re-wetting. This might be explained by the higher refractive index of the infiltrant ($RI = 1.51$), which is closer to the refractive index of healthy enamel ($RI = 1.63$) than to the refractive index of ethanol ($RI = 1.36$). Furthermore, it could be observed that the number of etching procedures correlated with the initial color difference. The data showed a positive albeit weak correlation between the number of etching procedures and the subjective evaluation of the severity of the white spot lesion [10].

In order to achieve an esthetically satisfactory masking result for white spot lesions, it is necessary to infiltrate the body of the lesion as

completely as possible [13]. For this purpose, the surface layer of the lesion has to be modified during the etching procedure so that the resin or ethanol can diffuse into the lesion. However, the thickness of this surface layer varies greatly [14]. This may help explain why the number of etching procedures, and thereby the length of the etching procedure varied, not only in these patient cases, but also in other studies [7, 8]. Depending on the esthetic appearance, the number of etching procedures and the duration of etching varied both in the previous studies and in the present patient cases. However, the maximum number of etching procedures was limited to three in order to not remove too much enamel. This was also done if the esthetic result of the re-wetting test was not satisfactory after the third etching procedure. Since each etching procedure removes between $35\ \mu\text{m}$ and $45\ \mu\text{m}$ of the enamel surface [14], 3 etching

procedures lead to a maximum removal of $105\text{--}135\ \mu\text{m}$. This probably results in the complete removal of the surface layer in most active and also inactive lesions. A further etching procedure would therefore remove an unnecessary amount of enamel because, after the removal of the surface layer, the success of masking is likely to depend on the depth, or degree of mineralization of the lesion, instead of the remaining less porous surface layer.

The cases presented here were treated within the framework of a study which had been approved by the Ethics Committee of the RWTH Aachen University (EK 110/13) and which had already been published [10]. In this study, a total of 221 lesions in 29 patients were infiltrated and resin infiltration noticeably reduced the color difference of white spot lesions after treatment both subjectively and objectively. The final color differences were only slightly above the perceivable thresh-

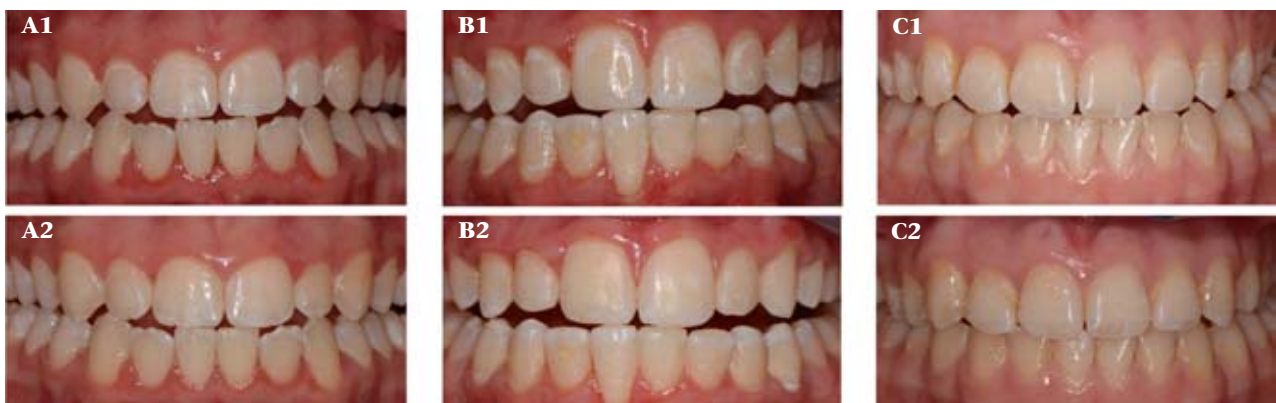


Figure 5A1–C1 and A2–C2 Overview images of 3 patients with post-orthodontic white spot lesions. **A1, B1, C1**: initial situation. **A2, B2, C2**: respective clinical situation one week after infiltration. A satisfactory masking result was achieved in all 3 cases.

Authors	Year of publication	Time interval until follow-up examination	Number of patients treated/number of infiltrated lesions	Treated teeth	Results
Kim et al. [7]	2011	1 week	9 patients, 18 teeth	Anterior teeth	61 % complete, 33 % partial, 6 % no masking effect
Hammad et al. [4]	2012	Immediately	18 patients, 108 teeth	Maxillary anterior teeth (ICDAS 2+3)	Significant increase of gray scale value (= masking)
Knösel et al. [8]	2013	6 months	20 patients, 111 infiltrated and 108 control teeth	Anterior teeth and canines	$\Delta\Delta E$: Infiltration -2,3 Controls +0,2 Significant improvement
Knösel et al.# [9]	2019	2 years	8 patients, 45 teeth	Anterior teeth and canines	$\Delta\Delta E$: Infiltration -3,2
Senestraro et al. [20]	2013	8 weeks	20 patients, 46 infiltrated and 20 control teeth	Maxillary anterior teeth	Reduction of lesion's surface 61 % Infiltration 1 % Controls

#Post evaluation of Knösel et al. 2013

(Fig. 1–5, Tab. 1: R. J. Wierichs and C. Kobbe)

Table 1 Clinical studies investigating the masking success of white spot lesions, mostly after orthodontic treatment.

old [5]. These color differences are not perceived by the human eye from a normal social distance. Furthermore, a subgroup analysis showed that the color difference was below this threshold for 73 % of lesions that were etched just once, whereas lesions that were etched two or three times were below the threshold in only 62 % and 32 % of the cases, respectively. The final result, for lesions etched two or three times, was therefore less satisfactory than for lesions etched once. Furthermore, a strong correlation between the minimum color difference during re-wetting and the final color value one week after infiltration could be observed. It was also demonstrated that the minimum color difference during re-wetting is also well suited to assess if another etching step is necessary. The results are also consistent with previous studies [7, 8], which also showed a good masking effect using this treatment procedure for post-orthodontic white spot lesions. Further clinical studies which investigated the masking effect after resin infiltration and their results are also shown in Table 1.

Interestingly, the studies also suggest that the time interval between bracket removal and resin infiltration appears to play an important role for the successful masking of white spot lesions [8]. The shorter this time interval, the more successful the masking effect seems to be. Consequently, patients who had undergone orthodontic treatment more than 12 months ago were excluded in the present study. Furthermore, the question as to how the masking effect could be further optimized by infiltrating the white spot lesions during orthodontic treatment was raised. Thus far, however, this question has only been investigated in a non-controlled study [16] and a case report [12]. In both publications white spot lesions were infiltrated immediately after detection without interrupting orthodontic treatment. Although the results in both publications were promising, this approach has not yet been widely explored.

Conclusion

The patient cases illustrate that the temporary masking effect during the

re-wetting test with ethanol, before subsequent resin infiltration, seems to be a good predictor of the final masking result and can be used to determine the necessary number of etching procedures. Furthermore, white spot lesions with a higher initial color difference seem to require more etching procedures. Overall, resin infiltration has been shown to be a useful method for masking white spot lesions occurring during orthodontic treatment.

Note from the authors

The cases presented in this article have been treated in a clinical study published in the Journal of Dentistry titled „Evaluation of the value of re-wetting prior to resin infiltration of post-orthodontic caries lesions“ [10].

Conflicts of interest

R. Wierichs and C. Kobbe declare that there is no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

The Charité – Universitätsmedizin Berlin (Germany) holds US and European patent for an infiltration technique for dental caries lesion in which one of the authors (Hendrik Meyer-Lückel, HML) is appointed as inventor. HML receives royalties as well as research funding from DMG (Hamburg, Germany), the manufacturer of Icon.

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