Original Article

External Bleaching Effect on the Color and Luminosity of Inactive White-Spot Lesions after Fixed Orthodontic Appliances

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ABSTRACT

Objective: To evaluate the effect of external bleaching on the color and luminosity of inactive white-spot lesions (WSLs) present after fixed orthodontic appliance treatment as means for achieving color matching of the WSLs with adjacent tooth surfaces.

Materials and Methods: Ten patients with inactive WSLs after therapy with fixed orthodontic appliances were selected. At baseline, the lightness of maxillary incisors and canines was assessed with a colorimeter. Color determinations were performed in the area of the initial lesions (F1) and at adjacent, sound enamel areas (F2). Then, anterior teeth were bleached once with a bleaching gel for 60 minutes. After a break of 14 days, in-office bleaching was followed by a 2-week home bleaching period with daily home bleaching for 1 hour. After this, color determinations were repeated. Additionally, patients were asked to fill out a questionnaire to provide information about their degree of contentment with the treatment.

Results: The lightness values of both the F1 and F2 regions were significantly higher after bleaching as compared with baseline. F2 L-values increased significantly more as compared with F1, indicating a better color matching of these two areas in comparison with baseline. All patients were satisfied with the outcome of the bleaching therapy.

Conclusion: External bleaching is able to satisfactorily camouflage WSLs visible after therapy with fixed orthodontic appliances.

KEY WORDS: Bleaching; White-spot lesion; CIE(*L,*a,*b) colorimetry

INTRODUCTION

The use of fixed orthodontic appliances is an essential part of today's orthodontic therapy. However, the period of fixed therapy endures for months or even years. Øgaard et al[1] stressed the fact that enamel demineralization associated with fixed orthodontic therapy is an extremely rapid process. The rapidity of formation of decalcified areas beneath orthodontic bands was also observed by Melrose et al,[2] who provoked the in situ development of white-spot lesions (WSLs) within 4 weeks under clinical conditions. In an in situ model, Benson et al[3] showed a reduction of remineralization in the presence of a simulated orthodontic bracket compared with a nonbracketed sample.

In patients with a high caries risk, demineralized white spots can often be observed after completion of orthodontic treatment, which might impair the esthetic outcome of the treatment. In some cases, WSLs seem to decrease within the first year after debonding.[4–6] It might be assumed that they diminish as they are brushed away over the years.[7] Owing to the results of the classical study by Backer Dirks,[8] it might be assumed that remineralization processes are responsible for the disappearance of the WSLs. However, their disappearance might also be ascribed to attrition by functional wear and toothbrushing.[9] In this sense, Årtun and Thylstrup[10] stated that "primarily the result of surface abrasion with some redeposition of minerals" is to be held responsible for the loss of porous tissue and the gradual regression of the WSLs after debonding.

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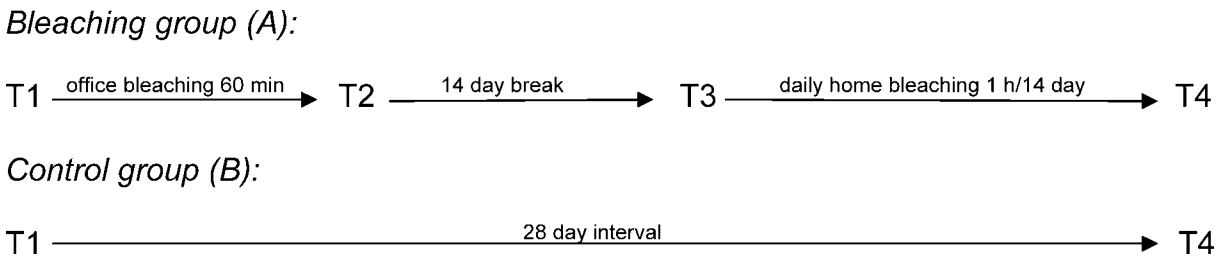

Figure 1. Setup of the study. Color assessments were conducted on T1–T4.

Many authors have described the effect of fluorides on preventing formation of WSLs[11–13] on remineralization of WSLs. Thus, Donly et al[14] showed in vitro that fluoride-releasing glass ionomer cement for cementing bands supports remineralization of the body of WSLs. Geiger et al[15] claimed that occurrence of WSLs might be distinctly reduced by daily rinsing with a neutral sodium fluoride solution. With respect to concentration of the fluoride solution, Linton[16] showed in an in vitro study that low-concentrated solutions with 50 ppm fluoride are more suitable for remineralization of WSLs than are solutions containing 225 ppm. However, in the clinical situation Willmot[6] did not detect any advantage in using a low-fluoride formulation (50 ppm) vs a nonfluoride mouth rinse and toothpaste regimen.

Recently, Tezel et al[11] found that titanium tetrafluoride is more effective in preventing WSLs than are other fluoride agents. Dubroc et al[17] showed in an experimental rat model that fluoride-releasing resin reduces demineralization around orthodontic brackets. According to Demito et al,[18] the mean depth of enamel demineralization is up to 38% less after application of fluoride varnish in comparison with a control group lacking fluoridation.

Kalha[19] and Benson et al[20] recommended that patients with fixed braces should rinse daily with a 0.05% sodium fluoride mouth rinse. They noted that daily use of a sodium fluoride mouth rinse helps reduce the severity of enamel decay adjacent to a fixed brace.

Øgaard et al[21] and Øgaard[22] concluded that daily rinsing with neutral 0.2% sodium fluoride inhibits lesion development by about 60%, whereas rinsing with 0.6% fluoride prevents formation of WSLs completely.

Also, chlorhexidine applications, such as the chlorhexidine-thymol varnish Cervitec (Vivadent, Schaan, Liechtenstein) used in conjunction with a fluoride varnish (Fluor protector, Vivadent), might help lower the level of mutans streptococci, thus preventing formation of WSLs.[23]

However, although it could be shown that the application of fluorides reduces the development of WSLs and helps remineralize them, WSLs still remain a problem to a certain percentage of patients. The milky color of WSLs may impair the esthetic appearance, thus reducing satisfaction with the outcome of the orthodontic therapy.[24] Hence, a comprehensive orthodontic therapy concept should at least also consider the color and appearance of the anterior teeth.

Bussadori et al[25] reported using a 35% hydrogen peroxide (H_2O_2) bleaching therapy for masking white fluorosis blemishes on the upper incisors. This approach resulted in a more uniform appearance of the teeth affected by fluorosis, for the color of the fluorotic areas matched better with the remaining tooth surface after the bleaching process.

Until now, no reports have been given in the literature that prove whether WSLs that are visible after removal of orthodontic brackets might also be less visible after an external bleaching therapy. Thus, the aim of the present study was to evaluate the efficacy of external bleaching on inactive WSLs present after fixed orthodontic therapy in comparison with surrounding enamel areas.

MATERIALS AND METHODS

Nineteen patients with inactive WSLs after therapy with fixed orthodontic appliances were selected and randomly placed into two groups. Group A (n = 10) underwent bleaching therapy, whereas group B (n = 9) was used as a control. The participants and their guardians gave informed consent for taking part in the study. Exclusion criteria for participating in the study were the following:

a. Active initial lesions. WSLs were categorized as active when they showed a chalky and dull surface after cleaning and drying.[26]
b. Hypersensitivities.
c. Proximal caries.
d. Insufficient restorations.
e. Patients younger than 14 years.
f. Gingival diseases.
g. Time elapsed after debonding was less than 3 months.

The setup of the study is given in Figure 1. For baseline examination (T1), color determination of carefully wetted maxillary incisors and canines was carried out chairside in well-lit standardized ambient condi-

Figure 2. Color determinations were performed in the area of initial white-spot lesions (F1) and the adjacent enamel area that had been guarded by the bracket's base (F2).

tions in both groups with a colorimeter (ShadeEye, Shofu, Ratingen, Germany) recording CIE (Commission internationale de l' éclairage) Lab values. The L-value corresponds to the degree of lightness in the Munsell system, whereas the a-values and the b-values give the position on red or green (+a = red, −a = green) and yellow or blue (+b = yellow, −b = blue) axes. All determinations were performed by the same operator.

With group A, color determinations were performed directly before starting the in-office bleaching session in the area of the initial lesions (F1) and at adjacent, sound enamel areas (F2) by placing the nozzle of the colorimeter on these areas. Typically, the former area of the bracket base was chosen as F2 because this area did not show any signs of WSLs in any patient and was easy to retrieve (Figure 2).

Next, bleaching gel, Illuminé office (30% H_2O_2, Dentsply DeTrey, Konstanz, Germany) was applied once onto the anterior maxillary teeth with a tray for 60 minutes. Neither heat nor light activation of the bleaching gel was carried out. Afterwards, the color determination was repeated (T2).

In the time period after bleaching therapy, the patients of both groups were instructed to use the fluoride gel Elmex Gelée (Gaba, Basel, Switzerland) once per week. After a break of 2 weeks and reassessment (T3), a 14-day period of daily home bleaching for 1 hour with Illuminé home (15% H_2O_2, Dentsply DeTrey) was performed in group A. Finally, color determinations were repeated (T4). Also, in group B initial color assessment (T1) was repeated after a 4-week interval (T4).

Evaluation of Patients' Satisfaction

A questionnaire was used to evaluate the patients' subjective satisfaction concerning the outcome of the bleaching therapy (scale 1–10) as well as the occurrence of side effects during bleaching (Figure 3).

Statistical Analysis of Color Change

Color determinations for F1 and F2 were performed four times (T1–T4) in both groups A and B. Statistical analysis was performed by using the Statistica programme (StatSoft Inc, Tulsa, Okla). In this study, Mann-Whitney *U*-test ($P = .05$) was applied for calculating the significance of the differences in groups A and B at any time point (T1–T4). Paired *t*-tests ($P = .05$) were used to compare the changes between F1 and F2 at time points T1–T4.

RESULTS

Determination of Clinical Visibility: Analysis of CIE Lab Values

Although some authors name a ΔE difference (discrepancy between two hues) of 3.0 units as an indicator for mismatching colors, according to the most of the studies concerning color stability a color change is said to be clinically visible in any site with ΔE data higher than 3.7 units.[27] Ideally, CIE Lab ΔE should be lower than 3.7 units after bleaching, indicating that a color difference between the two sites could not be seen by the naked eye.[27]

The ΔE data of areas F1 and F2 before bleaching (T1), after completion of office session (T2), and after completion of bleaching therapy (T4) were evaluated on the basis of the following equation[28]:

$$\Delta E_{(FxTx\text{-}Fy,Ty)} = [(L_{Fx,Tx} - L_{Fy,Ty})^2 + (a_{Fx,Tx} - a_{Fy,Ty})^2 + (b_{Fx,Tx} - b_{Fy,Ty})^2]^{1/2}.$$

Afterward, the F1 and F2 data were individually examined at T2 and T4 (Tables 1 through 3).

Color Change: Descriptive Statistics

Apart from contemplating ΔE data, (L*, a*, b*), singular values were examined to judge the color development during bleaching therapy.

L-data. Regarding the L-value (L ($F1_{T1\text{-}T4}$) vs L ($F2_{T1\text{-}T4}$)), there was a significant change ($P = .03$) in group A but not in group B (the control). All L-values (F1 and F2) of group A were significantly higher after office bleaching (T2), indicating that lightness of both areas increased significantly as compared with baseline (T1). F2 L-data increased significantly ($P = .03$) more during bleaching therapy than did F1 L-data. Between T3 and T4, a significant increase was noted in F2 but not F1.

a-data. At T3, a significant decrease of a-value in comparison with T2 was recorded in both areas of group A. Comparing T1 and T4 (a ($F1_{T1\text{-}T4}$) vs a ($F2_{T1\text{-}T4}$)), no significant changes can be observed.

Questionnaire: Expectation, Outcome and Side Effects of Bleaching Therapy

1. Satisfaction with outcome of orthodontic treatment **before** bleaching therapy

1	2	3	4	5	6	7	8	9	10

1= discontented, expectations not fulfilled 10= complete satisfaction

2. Influence of tooth colour on satisfaction with orthodontic outcome

1	2	3	4	5	6	7	8	9	10

1=unimportant 10=very important

3. To what extent „white spots" are bothering you?

1	2	3	4	5	6	7	8	9	10

1=not at all 10= strongly

4. Satisfaction with outcome **after office bleach session**

1	2	3	4	5	6	7	8	9	10

1= discontented, expectations not fulfilled 10= complete satisfaction

5. Satisfaction with outcome **after home-bleaching**

1	2	3	4	5	6	7	8	9	10

1= discontented, expectations not fulfilled 10= complete satisfaction

6. **Side effects**: Hypersensitive teeth

1	2	3	4	5	6	7	8	9	10

Side effects: Enamel surface roughness

1	2	3	4	5	6	7	8	9	10

Side effects: Gingival (gums) problems

1	2	3	4	5	6	7	8	9	10

1 =not acceptable 10 =no side effects

7. Expenditure of time

1	2	3	4	5	6	7	8	9	10

1 = not appropriate 10 = appropriate

8. Would you recommend this kind of bleaching therapy to your best friend?

YES	NO

Thank you for your cooperation!

Figure 3. The questionnaire as used for evaluation of side effects and patients' satisfaction.

Table 1. Number and Percentages of Sites with $\Delta E > 3.0$ or > 3.7 Units in the Areas of Initial White-spot Lesions (WSLs) (F1) vs Areas of Sound Enamel (F2)

	Bleaching Group (Group A)[a]			
F1–F2	T1	T2	T3	T4
$\Delta E > 3.0$ units, n	26	24	27	22
$\Delta E > 3.0$ units, %	63.4	58.5	65.9	53.6
$\Delta E > 3.7$ units, n	20	22	22	17
$\Delta E > 3.7$ units, %	48.8	53.7	53.7	41.5

	Control Group (Group B)[b]	
F1–F2	T1	T4
$\Delta E > 3.0$ units, n	20	18
$\Delta E > 3.0$ units, %	69.0	62.1
$\Delta E > 3.7$ units, n	20	18
$\Delta E > 3.7$ units, %	69.0	62.1

[a] $\Delta E_{(F1T1-F2T1)} = ((L_{F1T1} - L_{F2T1})^2 + (a_{F1T1} - a_{F2T1})^2 + (b_{F1T1} - b_{F2T1})^2)^{1/2}$ gives the color difference between reference area (F2) and WSL area (F1) at baseline (T1), $\Delta E_{(F1T2-F2T1)} = ((L_{F1T2} - L_{F2T2})^2 + (a_{F1T2} - a_{F2T2})^2 + (b_{F1T2} - b_{F2T2})^2)^{1/2}$ gives the color difference between reference area (F2) and WSL area (F1) after completion of office session (T2), $\Delta E_{(F1T3-F2T3)} = ((L_{F1T3} - L_{F2T3})^2 + (a_{F1T3} - a_{F2T3})^2 + (b_{F1T3} - b_{F2T3})^2)^{1/2}$ gives the color difference between reference area (F2) and WSL area (F1) after the 14-day break (T3), $\Delta E_{(F1T4-F2T4)} = ((L_{F1T4} - L_{F2T4})^2 + (a_{F1T4} - a_{F2T4})^2 + (b_{F1T4} - b_{F2T4})^2)^{1/2}$ gives the color difference between reference area (F2) and WSL area (F1) after completion of office and home sessions (T4).

[b] $\Delta E_{(F1T1-F2T1)} = ((L_{F1T1} - L_{F2T1})^2 + (a_{F1T1} - a_{F2T1})^2 + (b_{F1T1} - b_{F2T1})^2)^{1/2}$ gives the color difference between reference area (F2) and WSL area (F1) at baseline (T1), $\Delta E_{(F1T4-F2T4)} = ((L_{F1T4} - L_{F2T4})^2 + (a_{F1T4} - a_{F2T4})^2 + (b_{F1T4} - b_{F2T4})^2)^{1/2}$ gives the color difference between reference area (F2) and WSL area (F1) after the 28-day control interval (T4).

Table 2. Number and Percentages of Sites with $\Delta E > 3.0$ or > 3.7 Units in Area of Initial White-spot Lesions (F1)

	Bleaching Group (Group A)[a]		
F1	T2	T3	T4
$\Delta E > 3.0$ units, n	33	26	33
$\Delta E > 3.0$ units, %	80.5	63.4	80.5
$\Delta E > 3.7$ units, n	25	25	33
$\Delta E > 3.7$ units, %	61.0	61.0	80.5

	Control Group (Group B)[b]
F1	T4
$\Delta E > 3.0$ units, n	14
$\Delta E > 3.0$ units, %	48.3
$\Delta E > 3.7$ units, n	10
$\Delta E > 3.7$ units, %	34.5

[a] $\Delta E_{(F1T1-F1T2)} = ((L_{F1T1} - L_{F1T2})^2 + (a_{F1T1} - a_{F1T2})^2 + (b_{F1T1} - b_{F1T2})^2)^{1/2}$ gives the color changes of F1 after completion of office session (T2), $\Delta E_{(F1T1-F1T3)} = ((L_{F1T1} - L_{F1T3})^2 + (a_{F1T1} - a_{F1T3})^2 + (b_{F1T1} - b_{F1T3})^2)^{1/2}$ gives the color changes of F1 after the 14-day break (T3), $\Delta E_{(F1T1-F1T4)} = ((L_{F1T1} - L_{F1T4})^2 + (a_{F1T1} - a_{F1T4})^2 + (b_{F1T1} - b_{F1T4})^2)^{1/2}$ gives the color changes of F1 after completion of office and home sessions (T4).

[b] $\Delta E_{(F1T1-F1T4)} = ((L_{F1T1} - L_{F1T4})^2 + (a_{F1T1} - a_{F1T4})^2 + (b_{F1T1} - b_{F1T4})^2)^{1/2}$ gives the color changes of F1 after the 28-day control interval (T4).

Table 3. Number and Percentages of Sites with $\Delta E > 3.0$ or > 3.7 Units in Areas of Sound Enamel (F2)

	Bleaching Group (Group A)[a]		
F1	T2	T3	T4
$\Delta E > 3.0$ units, n	30	18	39
$\Delta E > 3.0$ units, %	73.2	43.9	95.1
$\Delta E > 3.7$ units, n	24	16	38
$\Delta E > 3.7$ units, %	58.5	39.0	92.7

	Control Group (Group B)[b]
F2	T4
$\Delta E > 3.0$ units, n	9
$\Delta E > 3.0$ units, %	31.0
$\Delta E > 3.7$ units, n	8
$\Delta E > 3.7$ units, %	27.6

[a] $\Delta E_{(F2T1-F2T2)} = ((L_{F2T1} - L_{F2T2})^2 + (a_{F2T1} - a_{F2T2})^2 + (b_{F2T1} - b_{F2T2})^2)^{1/2}$ gives the color changes of F2 after completion of office session (T2), $\Delta E_{(F2T1-F2T3)} = ((L_{F2T1} - L_{F2T3})^2 + (a_{F2T1} - a_{F2T3})^2 + (b_{F2T1} - b_{F2T3})^2)^{1/2}$ gives the color changes of F2 after the 14-day break (T3), $\Delta E_{(F2T1-F2T4)} = ((L_{F2T1} - L_{F2T4})^2 + (a_{F2T1} - a_{F2T4})^2 + (b_{F2T1} - b_{F2T4})^2)^{1/2}$ gives the color changes of F2 after completion of office and home sessions (T4).

[b] $\Delta E_{(F2T1-F2T4)} = ((L_{F2T1} - L_{F2T4})^2 + (a_{F2T1} - a_{F2T4})^2 + (b_{F2T1} - b_{F2T4})^2)^{1/2}$ gives the color changes of reference area (F2) after the 28-day control interval (T4).

b-data. At T2, there was a significant increase of b-value in both areas of group A. Between T3 and T4, a significant change was noted in F2 but not F1. Comparing T1 and T4 ($F1_{T1\text{-}T4}$ vs $F2_{T1\text{-}T4}$), there was a significant change ($P = .04$) in group B, which means a change of color coordinates from yellow to blue domain, but not in group A.

Table 4 gathers the mean L*, a*, b* data for all measurements.

Analysis of the Questionnaire

All patients in group A were satisfied with the outcome of the bleaching therapy and thought the WSLs were less visible than before bleaching and fluoride application. In the control group, patients did not judge their WSLs as less visible than before treatment with the fluoride gel. They acquainted an increase of the contentment with the orthodontic result in general after masking white spots by bleaching therapy. All patients would recommend this kind of bleaching therapy to a friend. With exception of slight hypersensitivities, the patients did not report side effects or discomfort.

DISCUSSION

According to Johnston,[27] a color change in ΔE exceeding 3.7 units is clinically visible. For area F1, this was true in 80.5% of the patients in group A and 34.5% of the patients in group B. For F2, 92.7% showed a change in $\Delta E_{(F2T1\text{-}F2T4)}$ higher than 3.7 units in group A, as did eight sites (27.6%) in group B.

Table 4. Mean Values and Standard Deviations (SD) of L*, a*, b* in Groups A and B at the Respective Time Points (T1, T2, T3, and T4) with the Number of Sites in Which the Measurements in Areas of Initial White-spot Lesions (F1) and Sound Enamel (F2) Were Performed

	Group	Area	Sites, n	T1 Mean (SD)	T2 Mean (SD)	T3 Mean (SD)	T4 Mean (SD)
L	A	F1	41	71.01 (3.51)	72.97 (3.43)	72.77 (3.25)	73.87 (3.46)
a	A	F1	41	0.78 (1.18)	0.76 (1.2)	0.17 (0.81)	0.11 (1.07)
b	A	F1	41	14.09 (4.42)	11.24 (4.4)	11.47 (4.55)	10.02 (4.26)
L	A	F2	41	69.9 (3.5)	72.63 (3.45)	72.35 (3.30)	73.88 (3.68)
a	A	F2	41	0.44 (1.15)	0.28 (1.0)	0.30 (0.79)	−0.36 (0.8)
b	A	F2	41	13.6 (4.43)	10.72 (3.72)	9.97 (3.95)	8.00 (3.41)
L	B	F1	29	73.42 (3.41)			73.14 (3.62)
a	B	F1	29	0.68 (1.37)			0.37 (1.2)
b	B	F1	29	14.0 (4.09)			15.80 (4.37)
L	B	F2	29	70.53 (4.65)			70.66 (4.73)
a	B	F2	29	−0.3 (0.66)			−0.14 (1.05)
b	B	F2	29	14.2 (3.84)			15.7 (5.03)

In group A, 41.5% of the patients showed a difference higher than 3.7 units after bleaching, compared with 48.8% before bleaching. In group B, 62.1% of the sites showed a difference higher than 3.7 units at T4, compared with 69% at T (Table 1). Setting the threshold at 3.0 units, a decrease from 63.4% to 53.6% can be noted in group A.

These results correlate with the authors' impressions and patients' perceptions that bleaching therapy contributed to a more uniform look of the enamel's surface, though some opacities were still noticeable.

The whitening result on area F2, which is representative for the enamel surrounding the WSLs, proved to be moderate after the initial office session and tended to relapse after 2 weeks (T3). Therefore, the office bleaching was followed by the home bleaching session to enhance the camouflage effect. As a result, a more uniform enamel appearance was generated by increasing $\Delta E_{(F2T1\text{-}F2T2)}$ values of F2: At T2, 58.5% were higher than 3.7 units, compared with 92.7% at T4 (group A in Table 3). In the same time, area F1 showed a similar development until T2 but failed to show in later time points. After office bleaching, 61% of the sites had $\Delta E_{(F1T1\text{-}F1T2)}$ values higher than 3.7 units, compared with 80.5% after completion (T4) (group A in Table 2). These results associate the fact that F2 L-values have increased significantly ($P = .03$) more during bleaching therapy than the WSL area as compared with the controls (group B).

Despite clinically visible opacities of the WSL region in any case, the colorimeter recorded a difference of more than $\Delta E_{(F1T1\text{-}F2T1)}$ 3.7 units in only 48.8% of patients (63.4% beyond 3.0 units) before bleaching in group A and 69% in group B. This lack of difference may be attributed to the performance of the measurements at different areas of the tooth's surface, which even without any visible lesions or mottling show different physical properties, such as histological structure and different luminance or brilliance. Moreover, most of the WSLs were typically located gingivally to the reference area.[29] This fact may have contributed to a lower luminosity in the WSL region, as the crown's thickness and dentin diameter increases in cervical direction. Finally, WSLs themselves show a different histological structure with different physical properties, such as a higher opacity in comparison with sound enamel structures.[7] Thus, it is difficult to directly compare CIE Lab data of sound enamel and WSLs in vivo.

In the sense of a more blue appearance, a significant change regarding parameter b in group B has been recorded, which may be attributed to ambient conditions. Although it has been attempted to provide identical ambient illumination with extraordinary diligence, completely reproducible conditions hardly can be achieved in vivo.

This study is the first attempt to prove whether a bleaching therapy is able to camouflage WSLs visible after removal of orthodontic brackets. The results of the color determination indicated that the bleaching therapy as applied was successful in achieving this goal, as the F2 L-values increased significantly ($P = .03$) more during bleaching therapy than in F1 areas. This result is noteworthy because the esthetic result of bleaching spot- or stripe-shaped local opacities is rather limited, according to Glockner et al.[30] Also, a distinct increase of the patients' contentment could be registered. About 30% of patients experienced side effects, which was as expected.[31,32]

If bleaching therapy is used to mask decalcified areas, it has to be taken into account that the microhardness of sound enamel surfaces as well as demineralized enamel surfaces after bleaching might be reduced.[33] Moreover, the susceptibility to formation of carieslike lesions after bleaching increases.[34] Therefore, this kind of therapy should be restricted only to well-selected cases in which perfect oral health and hygiene can be warranted. Moreover, fluoridation

should be performed after the bleaching therapy to enhance remineralization of bleached teeth.[35]

CONCLUSION

a. External bleaching is able to satisfactorily camouflage WSLs visible after therapy with fixed orthodontic appliances.

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