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Original Article

Low-Viscosity Resin Infiltration Efficacy on Postorthodontic White Spot Lesions: A Quantitative Light-Induced Fluorescence Evaluation

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ABSTRACT

Objective: The aim of this *in vivo* study was to evaluate the efficacy of low-viscosity light-cured resin infiltration on postorthodontic white spot lesions (WSLs) on incipient and advanced lesions using quantitative light-induced fluorescence (QLF).

Methods: The study subjects were patients with clinically diagnosed postorthodontic WSLs (n=57). QLF images of the lesions were obtained using a QLF device (Inspektor-Pro, Amsterdam, The Netherlands) before any treatment. Images were processed using the built-in software (QLF patient v2.0.0.48), which produced fluorescence loss (ΔF^1), lesion area ($Area^1$), and impact (ΔF_1 x $Area_1$, ΔQ_1) values. Lesions were categorized as incipient ($-5<\Delta F_1<-12$, n=14) or advanced ($-12<\Delta F_1<-25$, n=43). They were then infiltrated with low-viscosity resin (Icon-DMG, Hamburg, Germany) according to the manufacturer's instructions. QLF imaging was repeated (ΔF_2, $Area_2$, and ΔQ_2) from the same aspects assured by the relative software. Kolmogorov-Smirnov, Wilcoxon, and Mann-Whitney tests were used for data evaluation.

Results: ΔF_1 (−8.40±0.73) and $Area_1$ (3.44±5.19) decreased to −6.58±0.88 and 0.18±0.33 for incipient lesions (p<0.001 and p=0.002, respectively). ΔF_1 (−13.20±5.32) and $Area_1$ (4.71±5.56) decreased to −7.51±2.7 and 0.29±1.86 for advanced lesions (p<0.001). When ΔF, lesion area, and ΔQ changes between the groups were compared, the decrease in ΔF was greater for advanced lesions (p<0.001), whereas the decrease in the lesion area and ΔQ was similar (p=0.690, p=0.291).

Conclusions: Infiltration treatment provides improvement of WSLs in terms of fluorescence loss, lesion area, and impact for both incipient and advanced lesions, with the latter group presenting higher fluorescence loss reduction.

Keywords: Dental white spots, icon infiltrant, quantitative light-induced fluorescence

INTRODUCTION

White spot lesions (WSLs) are one of the initial clinical findings of enamel demineralization, resulting from cariogenic bacterial metabolism acting on the tooth surface (1). The risk of WSL formation increases during orthodontic treatment as a consequence of plaque retention sites (2). The individual factors that determine the prognosis of such lesions are the efficacy of personal oral hygiene, saliva buffering capacity, salivary flow rate (3), and the presence of local fluoride (4).

WSLs appear mostly opaque-white due to the changes in the refractive index of the enamel, which are caused by mineral loss from the surface and deeper layers (5). In early stages, WSLs require air drying to become visible. At this stage, demineralization at the outer layer of enamel begins. Progression of this process results in a visible WSL even without air drying. The clinical appearance of a WSL is also related to its activity. Active lesions appear chalky and feel rough during light probing whereas inactive lesions are bright on the outside and feel smooth during probing (6).

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The progression of WSLs can be detained or even arrested by preventive measures such as oral hygiene education, dietary control, and local fluoridation (7). These are the primary choices of treatment, because they promote natural repair and prevention. Even though it has been claimed that these lesions could regress following preventive measures, varying clinical results have been reported that have questioned the predictability of the remineralization process (6, 8, 9). Many early incipient lesions were still visible after remineralization because most of the loss was at the center body of the lesion, where improvement in its light refraction was unlikely due to the limited remineralization potential (10). This type of remineralization results in a shiny and less obvious lesion, but the interior opacity remains. With noncompliant patients, this approach is often ineffective and the lesions tend to progress (6).

In 2009, the low-viscosity resin infiltration technique, which aims to fill the microporosities in the lesion body with a minimally invasive approach, was introduced (11). This resin connects and strengthens the affected tissue micromechanically and stabilizes the demineralized enamel against new acid attacks. Thus, the affected tissue is preserved and the gap between restorative treatment and preventive measures is principally closed (12). This technique is claimed to be suitable for noncavitated lesions that are unlikely to remineralize (13). Moreover, the refractive index of the infiltrant is defined as being similar to the sound enamel, which also provides the visual masking of the lesion (12).

Detection and diagnosis of WSLs can be performed using different methods. Quantitative light-induced fluorescence (QLF) is 1 of the diagnostic methods that can quantify the fluorescence difference between sound and demineralized enamel utilizing light refraction from affected dental surfaces (14-16). Previous studies have demonstrated that this method is reliable to monitor the mineral changes in incipient lesions *in vitro* and *in vivo* (17-20). When enamel demineralization occurs, minerals are replaced by water from saliva, which reduces light absorption. Thus, the intensity of the fluorescence decreases in such areas of the enamel, which appear as dark zones differing from sound structures (20).

Assessment of WSLs and deciding whether infiltration treatment would be efficient prior to the application is important. Varying clinical outcomes have been reported regarding the masking ability of this treatment, resulting in partial or unsuccessful camouflage of the lesions (21, 22). Data are lacking regarding the assessment of infiltration treatment efficacy in terms of lesion severity. Therefore, the aim of this study was to classify the WSLs identified after completion of orthodontic treatment by the lesion severity and to test the infiltration efficacy of these lesions by means of QLF. The null hypothesis tested was that efficacy of infiltration treatment would not differ between incipient or advanced WSLs.

METHODS

Study Design

The study protocol was approved by the ethics committee of Clinical Research of Medical School of Ege University (commission decision numbered 17-10/65). An informed consent form signed by the participant, and for those under age 18 years also signed by their parents, was obtained.

The participants were recruited consecutively for 6 months from patients being treated with fixed appliances at the department of orthodontics. The inclusion criteria were: patients of age 13 years or older, in good general health, with a treatment period with fixed appliances of at least 1 year at the debonding appointment, at least 1 WSL with no cavities present on the facial surface of the dentition before starting orthodontic treatment, and no prior WSL treatment utilized except tooth brushing with fluoridated toothpaste. The exclusion criteria were: patients with cavitated lesions, deciduous teeth, or WSLs that had been filled, restored, or had received therapy. If 1 exclusion criterion applied to 1 tooth, the subject was excluded from the trial.

No special attention was given to oral hygiene measures for subjects participating in this study immediately after debonding. At the start of fixed appliance treatment, the patients were advised to brush their teeth 3 times a day, were shown how to clean their mouth with the appliance in situ, and were given a leaflet with brushing instructions.

For every subject, the whole dentition was isolated with cotton rolls and air dried for 5 seconds. Subjects were diagnosed by a visual examination to determine the extent of demineralization, and the texture of the surface was gently evaluated with a periodontal probe. Carious white spot lesions appeared rough, opaque, and porous. Also, the presence and extent of lesions on the buccal surfaces of all teeth, except second and third molars, were assessed by means of QLF at the debonding visit.

Twenty eligible patients (12 boys, 8 girls; mean age, 15.6 years; n=57 teeth) who had recently finished orthodontic treatment were recruited by the second author (H.Ç).

At appliance removal, adhesive was removed with a carbide finishing bur, and complete removal was verified by air drying the teeth. All teeth were then polished with fluoride-free polishing paste using a rubber cup. No special measures were taken to remove plaque from the surfaces, apart from normal cleaning as part of the debonding procedure. After debonding, initial QLF imaging, infiltration treatment, and post-treatment QLF imaging were performed on the same day.

QLF Imaging

All QLF images were captured by the same operator using an intraoral fluorescence camera (Inspektor Research Systems BV, Amsterdam, The Netherlands) in a dark room with no ambient light and processed on a personal computer using the image capturing software (QLF Patient version 2.0.0.48) that came with the system. Prior to each QLF imaging, the enamel surfaces were air dried for 5 seconds. To ensure that the images of the teeth surfaces were always captured from the same aspects, the video-repositioning utility of the QLF software was used with a minimum correlation rate of 0.90 (23). The WSL images were processed using the software, in which the lesions appeared as dark areas surrounded by bright green fluorescing sound tooth tissue (24). The fluorescence loss and lesion area were measured using the WSL tool of the software to determine the lesion severity. The total fluorescence loss (ΔF in percent), corresponding lesion area (area in mm^2), and the impact (ΔQ in mm^2 x %) were measured for each subject (Figure 1, 2).

Infiltration Treatment

Following initial QLF recordings (ΔF_1, $Area_1$, ΔQ_1), lesions were treated by a single trained orthodontist with low-viscosity resin infiltrant (Icon, DMG, Hamburg, Germany) according to the manufacturer's instructions. The gingival soft tissues were protected with gingival barrier made of flowable composite resin. Fifteen percent HCl (Icon) was applied for 120 seconds on the lesion surface. Teeth were rinsed with water for 30 seconds and air dried. Then, they were treated with 99% ethanol (Icon Dry) for 30 seconds and air dried. In compliance with the manufacturer's instructions, the etching was repeated at this step if necessary.

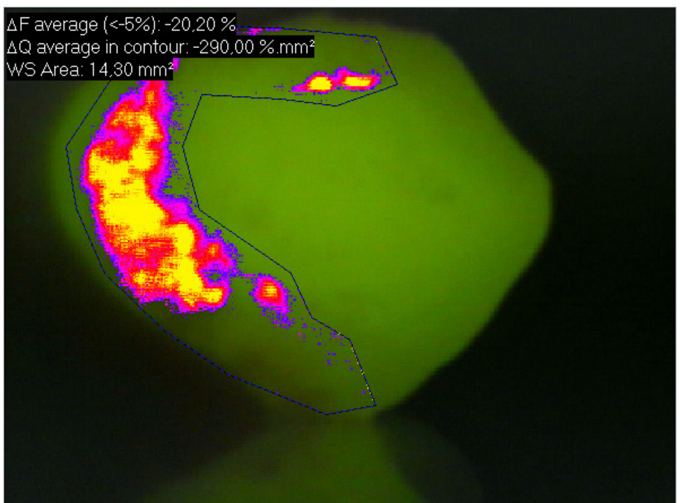

Figure 1. QLF image of the tooth 23 prior to resin infiltration. The black frame is the area of interest, where the software compares the fluorescence of sound and demineralized enamel

QLF: quantitative light-induced fluorescence

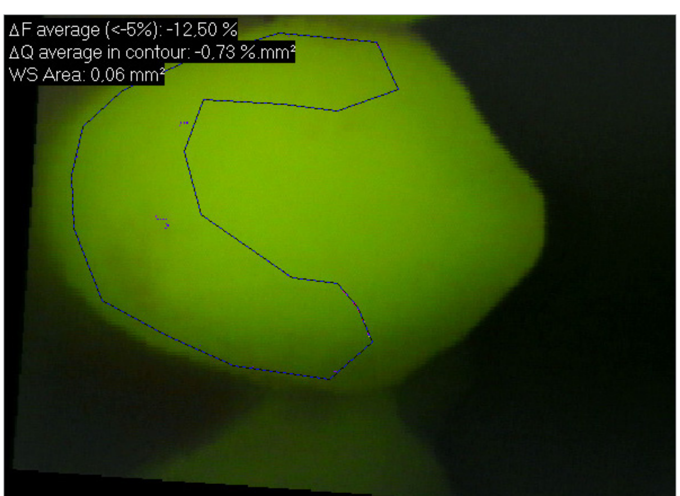

Figure 2. QLF image of the same tooth following resin infiltration

QLF: quantitative light-induced fluorescence

The need for additional etching was determined visually after the dry solution was used. One coat of infiltrant was applied with a microbrush, allowed to set for 180 seconds, and light-cured for 60 seconds. Then, a second layer was applied, allowed to set for 60 seconds, and light-cured for 40 seconds. The surfaces were polished with #4000 aluminum oxide abrasive paper. A second QLF imaging was performed immediately following the treatment (ΔF_2, $Area_2$, ΔQ_2).

Statistical Analysis

All analyses were performed with the Statistical Package for Social Sciences version 21.0 (IBM Corp.; Armonk, NY, USA). Descriptive statistics, including the mean and standard deviation, were calculated for all groups. Kolmogorov–Smirnov and Shapiro–Wilk tests were used to test the normal distribution of the data. As the data were not normally distributed, the Wilcoxon test was applied to analyze possible differences between the groups for the same time points and the differences between the time points within each group. After this, the Mann-Whitney test was used separately for group and time combinations. The significance level was determined at a probability value of $p<0.05$.

Lesions were grouped according to the ranges of ΔF_1, as either incipient ($-5<\Delta F_1<-12$, n=14) or advanced ($-12<\Delta F_1<-25$, n=43) (25). This provided over 90% power assuming that in 1 group (incipient) the standard deviation was 0.73, and in the other group (advanced) the standard deviation was 5.32. This was determined using a 2-group Satterthwaite t-test with a 0.05 2-sided significance level.

Method Error Assessment

The accuracy of the QLF in recording the fluorescence loss and lesion area values was determined by repeating computer assessments of randomly selected lesions that were performed by the same operator (n=20). The intraclass correlation coefficient (ICC) was used to evaluate the intraexaminer agreement. The ICC of all measurements was 0.997, showing no significant difference between the measurements at 2 different time points.

RESULTS

Fifty-seven clinically diagnosed WSLs (14 incipient, 43 advanced) were evaluated. The median fluorescence loss at debonding was –8.40% and –13.20% in the incipient and advanced groups, respectively. Median, interquartile range, minimum, and maximum values of incipient and advanced lesions before and after the infiltration procedure and groups presenting significant fluorescence changes are presented in Table 1.

Fluorescence of WSLs improved significantly following infiltration treatment in both groups (p=0.001, p<0.001). The median value for total lesion area per lesion was 3.44 mm^2 initially, which decreased to 0.18 mm^2 in the incipient group. In the advanced group, lesion area was 4.71 mm^2, which then decreased to 0.29 mm^2 following treatment. The median values for ΔQ_1 at debonding were 30.75 and 57.50 in the incipient and advanced groups, respectively. In the incipient group, ΔQ_2 was 1.24 following infiltration treatment whereas it was 1.86 for the advanced

Table 1. Median, interquartile range (IQR), minimum (Min), and maximum (Max) values of incipient and advanced lesions before and after infiltration procedure

	Incipient (n=14)					Advanced (n=43)				
	Min.	Max.	Median	IQR	p	Min.	Max.	Median	IQR	p
ΔF1 (%)	−7.12	−9.69	−8.40	−2.57	0.001	−10.00	−33.20	−13.2	−23.20	<0.001
ΔF2 (%)	−5.88	−9.18	−6.58	−3.30		−5.56	−15.60	−7.51	−10.04	
Area1 (mm^2)	0.19	14.06	3.44	13.87	0.001	0.10	22.70	4.71	22.61	<0.001
Area2 (mm^2)	0.00	1.18	0.18	1.18		0.00	6.70	0.29	6.70	
ΔQ1 (mm^2 x %)	−1.60	−133.00	−30.75	−131.40	0.001	−1.86	−336.00	−57.50	−334.14	<0.001
ΔQ2 (mm^2 x %)	−0.02	−10.80	−1.24	−10.78		−0.01	−88.20	−1.86	−88.19	

* Statistically significant at p≤0.05
p values indicate significant differences between two time points within the same lesion group

Table 2. Median, interquartile range (IQR), minimum (Min), and maximum (Max) value differences of incipient and advanced lesions before and after the infiltration procedure

	Incipient				Advanced				
	Min.	Max.	Median	IQR	Min.	Max.	Median	IQR	p *
ΔF1-ΔF2	−0.13	−2.89	−1.68	−2.76	−0.30	−27.00	−5.60	−26.69	<0.001
Area1-Area2	0.17	13.37	3.34	13.20	−0.01	19.34	2.67	19.36	0.690
ΔQ1-ΔQ2	−1.45	−122.20	−30.10	−120.75	−1.67	−318.11	−49.24	−316.44	0.291

* Statistically significant at p≤0.05
p values indicate significant differences of the infiltration effect between the 2 lesion groups

group. When ΔF, lesion area, and ΔQ changes between the groups were compared, the decrease in ΔF was greater for advanced lesions (p<0.001) whereas the decrease in the lesion area (p=0.690) and ΔQ (p=0.291) was similar (Table 2).

DISCUSSION

Assessment of low-viscosity resin infiltration efficacy in incipient and advanced WSLs was the main aim of this study. The results showed that fluorescence loss, lesion area, and impact decreased significantly in both incipient and advanced lesions. The amount of improvement in fluorescence loss was greater in advanced lesions but for the other 2 parameters the amount of improvement was similar in both incipient and advanced lesions. Therefore, the null hypothesis can be partially rejected.

The state of the cariogenic activity as the WSL is diagnosed determines the topographic characteristics of the lesion (13). The exterior surfaces of active WSLs are more porous and permeable whereas the surfaces of the passive WSLs are more intact and less permeable (11). This considerably affects the penetration of both the remineralization agents and the infiltration adhesive into the lesion body. Factors identifying the state of cariogenic activity are the presence of an uneven surface during probing, appearance of opacity after being air dried, dental plaque presence over the lesion surface, and gingival bleeding in the area adjacent to the lesion (26). Elapsed time between the detection of the lesion and the infiltration procedure should be minimized to prevent the surface from become more intact (14, 27). Paris et al. (13) suggested that in postorthodontic WSLs, the infiltration treatment should be done as soon as possible following bracket removal, fearing that the lesion at that time is active and would eventually lose its surface integrity. In this study, the infiltration procedure was applied during the appointment for bracket removal of the tooth with WSL, in order to standardize the effect as well as to improve it.

Repetition of the etching procedure has been advocated when severe and more opaque lesions are to be treated, assuming that the outer layer is less permeable. This need can be determined during the ethanol application step in cases in which the opacity of the lesion does not disappear (22). In the present study, the etching procedure was repeated up to 3 times only when necessary at this stage.

WSLs have been shown to decrease in size within 8 weeks following bracket removal if the etiological factors had been eliminated (28). Combinations of surface remineralization via saliva and other remineralization agents as well as toothbrush abrasion result in the gradual reduction of the affected tissue, thereby providing the natural regression of the lesion (29). It has been demonstrated that remineralization occurs mostly on the surface and the peripheries of the lesion, which improves the visual appearance by decreasing the opacity (6). The remaining lesions have been shown to have limited improvement, which might impair the esthetic appearance (22, 30). For this reason, arresting of such lesions has been advocated, in which the infiltrant would penetrate into the capillary structures of the lesion body offered by its low contact angle formed between the liquid (in this case the infiltrant resin) and high wettability potential with a significantly deeper penetration in the lesion body (13). These infiltrant features are rather important to ensure effectiveness (6, 11, 22, 27).

The masking ability of the infiltration stems from the light refractive index of the low-viscosity resin (1.475), which is similar to the refractive index of sound enamel (1.65). Thus, the opacity appears masked following a successful infiltration procedure. Because QLF utilizes the refraction of light from the surface, the fluorescence difference of the WSL as compared to adjacent sound enamel decreases (30). Although some aesthetic improvement is observed (27, 31), the lesion may not be camouflaged totally in severely advanced lesions. This may be due to the incomplete infiltration of the lesion body and the polymerization shrinkage (13). In the present study, fluorescence loss, lesion area, and impact (which represents a combination of fluorescence loss and lesion area), improved significantly for both incipient and advanced lesions. The amount of improvement regarding fluorescence loss was significantly higher for advanced lesions, whereas the reduction in the lesion area and impact were similar for both advanced and incipient lesions. Although both lesion groups were infiltrated almost completely, revealing very low lesion area values, corresponding fluorescence loss improvements were higher for advanced lesions, as one would expect. Unlike previous reports of partially infiltrated lesions (21, 22, 32), almost all lesion areas were reduced to a level where only a very small area of fluorescence loss could be detected. This might be due to the fact that immediate infiltration of active lesions was performed in this study. It might be speculated that the leftover detected area might be the center of the lesion body where the infiltration is least efficient.

The decision to remineralize or immediately infiltrate clinically diagnosed WSLs is a critical one. The patient's oral hygiene history during the treatment, his/her manual dexterity in tooth brushing, personal perception, and awareness level are possible determinants of this decision. Immediate infiltration of WSLs in patients with poor oral hygiene and low remineralization expectancy is advocated (27).

The uneven and limited number of lesions in study groups was one of the shortcomings of this study. Consecutive patients with WSLs in a 6-month timeframe were included, and it was not possible to equalize the number of lesions for each group. A larger scale study with long-term follow-up of the infiltrated lesions would add more depth to the present data.

CONCLUSION

Within the limitations of this study, the following could be concluded:

- Low-viscosity resin infiltration improves fluorescence loss, lesion area, and impact in both incipient and advanced lesions.
- Immediate infiltration of clinically diagnosed WSLs can be the primary choice of treatment in orthodontic patients with poor oral hygiene and low remineralization expectancy.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Clinical Research of Medical School of Ege University (commission decision numbered 17-10/65).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - E.Y.; Design - E.Y., R.A.; Supervision - E.Y.; Materials - H.Ç., E.Y., R.A.; Data Collection and/or Processing - H.Ç., E.Y., Y.L.S.; Analysis and/or Interpretation - Y.L.S.; Literature Search - Y.L.S.; Writing Manuscript - Y.L.S, E.Y.; Critical Review - Y.L.S., E.Y.

Conflict of Interest: The authors have no conflict of interest to declare.

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