Original Article

Accelerated Aging Effects on Surface Hardness and Roughness of Lingual Retainer Adhesives

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ABSTRACT

Objective: To test the null hypothesis that accelerated aging has no effect on the surface microhardness and roughness of two light-cured lingual retainer adhesives.

Materials and Methods: Ten samples of light-cured materials, Transbond Lingual Retainer (3M Unitek) and Light Cure Retainer (Reliance) were cured with a halogen light for 40 seconds. Vickers hardness and surface roughness were measured before and after accelerated aging of 300 hours in a weathering tester. Differences between mean values were analyzed for statistical significance using a *t*-test. The level of statistical significance was set at $P < .05$.

Results: The mean Vickers hardness of Transbond Lingual Retainer was 62.8 ± 3.5 and 79.6 ± 4.9 before and after aging, respectively. The mean Vickers hardness of Light Cure Retainer was 40.3 ± 2.6 and 58.3 ± 4.3 before and after aging, respectively. Differences in both groups were statistically significant ($P < .001$). Following aging, mean surface roughness was changed from 0.039 μm to 0.121 μm and from 0.021 μm to 0.031 μm for Transbond Lingual Retainer and Light Cure Retainer, respectively. The roughening of Transbond Lingual Retainer with aging was statistically significant ($P < .05$), while the change in the surface roughness of Light Cure Retainer was not ($P > .05$).

Conclusions: Accelerated aging significantly increased the surface microhardness of both light-cured retainer adhesives tested. It also significantly increased the surface roughness of the Transbond Lingual Retainer.

KEY WORDS: Orthodontic adhesives; Orthodontic retainer; Aging; Surface hardness; Surface roughness

INTRODUCTION

Some form of retention therapy is required to save the posttreatment tooth position following the active phase of orthodontic treatment. The first appliances were based on banded fixed appliances[1] followed by removable retainers.[2] Today, many clinicians prefer bonded fixed retainers that consist of a length of orthodontic wire bonded to the teeth with an acid-etch retained composite.[3]

Light-cured resin composites are the material of choice for bonding lingual retainers today, as they offer ease of application and extended time for wire placement. In contrast to bracket bonding, adhesives used with lingual retainers remain exposed to the oral cavity, so they need to have certain physical properties and need to be properly managed before the curing process.[4]

Several companies have developed adhesives for lingual retainer bonding and claim that these adhesives offer ease of application and optimal handling characteristics to allow the clinician to shape and finish the adhesive around the lingual retainer wire for maximum patient comfort. These highly filled, light-cured resins are also said to be a better choice when longevity and durability are required. The use of an adequate thickness of composite with adequate abrasion resistance placed over the wire has been suggested to minimize long-term failure of bonded retainers. Rap-

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Table 1. Adhesives and Light Curing Unit Used

Brand	Company	Lot
Adhesives		
Transbond LR	3M Unitek, Monrovia, Calif	CG/1AK
Light Cure R	Reliance, Itasca, Ill	106060
Light Curing Unit		
Ortholux XT	3M Dental Products, St Paul, Minn	120277

id wear of the composite in vivo quickly reduces the overlying thickness of composite, leading to early failure of the retainer.[5] Surface hardness is a determinant of resistance to wear, and thus materials with higher surface hardness values might be beneficial.

Surface roughness, on the other hand, is important in terms of avoiding plaque accumulation and providing patient comfort. The effect of aging on restorative dental composites has been extensively studied. These studies usually demonstrated significant changes in the surface characteristics, physical properties, and color of these resins with aging.[6–16] However, in vivo or in vitro information about the aged lingual retainer adhesives which are supposed to serve for a long time period in the mouth does not exist.

Therefore, the purpose of this study was to investigate the effect of accelerated aging on the surface microhardness and roughness of two light-cured lingual retainer adhesives. The null hypothesis assumed that accelerated aging has no effect on the surface microhardness and roughness of two light-cured lingual retainer adhesives tested.

MATERIALS AND METHODS

Two different composites available for bonding lingual retainers and a visible light source were used in this study (Table 1).

Sample Preparation

To evaluate surface roughness and hardness, disc-shaped samples 5 mm in diameter and 2 mm in height were cured between microscope slides in Teflon molds for each material tested. The samples were light-cured with a conventional halogen light for 40 seconds. This exposure time was previously shown to cure both adhesives adequately.[4] Twenty samples were prepared for each adhesive; 10 of these were tested right after preparation, and the other 10 were tested following aging.

Weathering Procedure

Specimens of each material were mounted on a panel that attached to the frame of an accelerated weathering tester (QUV, The Q-Panel Company, Cleveland, Ohio) and stored there for 300 hours. In the weathering tester, specimens were exposed to continuous ultraviolet (UV) and visible light, a temperature of 43.3°C, and a programmed cycle of 18 minutes of distilled water spray within each 2-hour period.[17–24]

Vickers Hardness Evaluation

Vickers hardness number (VHN) was measured 24 hours after polymerization for the nonaged specimens and right after delivery for the aged specimens. The MHT2 hardness tester (Matsuzawa Seiki, Tokyo, Japan) was used. A load of 300-gram force was applied for 15 seconds and three indentations of the cure sides of the samples were performed. The determined values were averaged to represent the VHN of that specimen.

Surface Roughness Measurement

Microscope slides were used to provide smooth surface preparation to facilitate the surface roughness testing. The surface roughness was determined by the surface analyzer (Surftest Analyzer, Mitutoyo, Tokyo, Japan). The mean arithmetic roughness (Ra) was used to assess surface changes. Five measurements were performed for each specimen. The mean value of five measurements on one specimen was used as the Ra of that specimen.

Statistical Tests

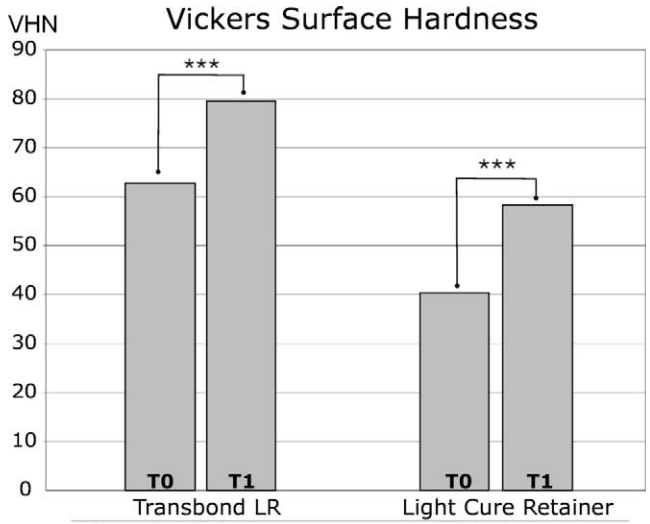
The results of surface hardness testing were entered into an Excel (Microsoft, Seattle, Wash) spreadsheet for calculation of descriptive statistics. Paired *t*-tests were used to analyze the data and compare groups.

Mean values and standard deviations for surface roughness were calculated for groups. Differences between mean values were analyzed for statistical significance using a *t*-test. The level of statistical significance was set at $P < .05$.

RESULTS

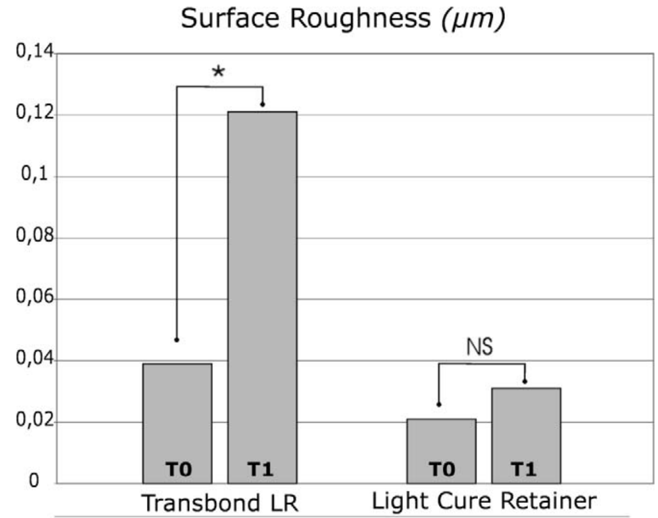
Vickers Hardness

Mean values of VHN of adhesives tested are presented in Figure 1. The mean VHN of Transbond Lingual Retainer (TLR) was changed from 62.8 $\pm$ 3.5 to 79.6 $\pm$ 4.9, and the mean VHN of Light Cure Retainer (LCR) was changed from 40.3 $\pm$ 2.6 to 58.3 $\pm$ 4.3 following aging. Both of these differences were statistically significant ($P < .001$). The amount of change in the VHN was also significantly different between the groups ($P < .001$). The null hypothesis was thus rejected.



	Transbond LR	Light Cure Retainer
T0	62.8 ± 3.5	40.3 ± 2.6
T1	79.6 ± 4.9	58.3 ± 4.3

Figure 1. Vickers surface hardness values of Transbond Lingual Retainer (TLR) and Light Cure Retainer (LCR) before and after accelerated aging. The test results are given above the brackets that combine the bars. VHN: Vickers hardness number. ****P* < .001.



	Transbond LR	Light Cure Retainer
T0	0.039 ± 0.008	0.021 ± 0.012
T1	0.121 ± 0.066	0.031 ± 0.005

Figure 2. Surface roughness values of Transbond Lingual Retainer (TLR) and Light Cure Retainer (LCR) before and after accelerated aging. The test results are given above the brackets that combine the bars. NS: not significant. **P* < .05.

Surface Roughness

The mean surface roughness of TLR was changed from 0.039 μm to 0.121 μm, and the mean surface roughness of LCR was changed from 0.021 μm to 0.031 μm following aging (Figure 2). These results represent a statistically significant roughening of TLR with aging ($P < .05$), while the change in the surface roughness of LCR was not statistically significant. The null hypothesis was thus rejected in part. The surface roughness was also different between the groups at both time points ($P < .05$ at before aging and $P < .01$ at after aging).

DISCUSSION

The accelerated aging process has been used to assess changes in physical characteristics of a range of materials and to examine color change over time.[11,12,18,20,24–26] In our study the effect of accelerated aging on the physical surface characteristics, ie, hardness and roughness of light-cured lingual retainer adhesives were examined. Although chemically cured materials are occasionally used for lingual retainer bonding, the hardness values of the chemically cured composites are considerably less than those of the light-cured ones.[4,6] This is possibly due to factors such as a lower degree of conversion than the light-cured materials, incorporation of more air bubbles and nonhomogenous mix due to hand mixing, and a thick layer of oxygen inhibition on the surface.[8,27] In this study formation of an oxygen inhibited layer was not allowed as the samples were cured between microscope slides. This provided a better reference point to evaluate the surface roughness, and a relatively smooth surface was achieved this way. The effect of aging alone on surface roughness was also possible to be distinguished because no thick oxygen-inhibited layer was present.

While the oral environment is more complex, the simulated aging treatment is useful for comparing different materials.[12,18,21,23,28] In our study, instead of the thermocycling process, an accelerated aging process was performed with an aging device to subject samples to both visible and UV light and distilled water spray to simulate aging. Water spray and visible UV light have a direct effect on the properties of resins and may change their physical properties. The manufacturer of the weathering instrument estimates that 300 hours of aging is equivalent to 1 year of clinical service.[11,18]

The effect of aging on restorative dental composites has been extensively studied. These studies usually demonstrated an increase in hardness[5] and surface roughness,[6–10] discoloration,[6,11–13] and decreased mechanical properties such as strength and modulus.[14–16] Initially, when a filled polymer like resin cement is exposed to aqueous aging, the uptake of water occurs as a diffusion-controlled process.[14] Water that is absorbed tends to act as a plasticizer and causes polymer swelling by stretching resin matrix entanglements. Absorbed water may also break hydrogen bonds within the resin matrix and bound to polymer hydroxyl groups.[29] Such interactions with the resin matrix can result in a decreased modulus which is a measure of the stiffness of a given material.[30] Water, which has entered the polymer through sorption, can also cause hydrolytic degradation of the resin matrix, the filler/matrix interface, or the filler.[15,31] The effects of hydrolysis are loss of molecular weight and mass, filler debonding, and decreased mechanical properties, such as strength and modulus.[14–16]

A study by Xu[32] suggested the use of strong and stable fillers as a key microstructural parameter in the development of strong dental composites that are resistant to long-term water attack. However, no reductions in the surface hardness were recorded in this study, and these values were even increased significantly. This may be due to the fact that the duration of water spray period in a 2-hour cycle was about 20 minutes, and the samples were allowed to dry back during the non–water-spray phase. This in turn may imply that the surface hardness values could have been higher, if the experiments had been conducted in a totally dry condition.

The results of the present study confirmed the results of previous studies with significant increases in surface hardness for both materials tested. On the other hand, the effect of aging on the surface hardness of the two different materials was not identical, and the LCR from Reliance demonstrated a higher degree of hardness change. Moreover, only TLR demonstrated a significant increase of surface roughness after accelerated aging. Increased surface roughness after accelerated aging has been attributed to wear of the resin[6,7,9] or exposure of interior porosities.[6,8,10] No mechanical wearing effect was present in the aging chamber of the device used. Therefore, the increased surface roughness of the TLR is most likely caused by the chemical degradation of the samples or by microscopic crack formations on the surface which appeared during the dry phase of the aging cycle. It is also likely that the varying results can be attributed to differences in resin and filler composition, extent of cure, and testing methods.

A previous study by Usumez et al[33] demonstrated that degree of conversion with Ortholux XT for 40 seconds was 40.3% and 62.7% for TLR and LCR, respectively. This means that the conversion degrees of resins may have been already different when they were placed into the weathering chamber, and this may account for the different responses of two resins to accelerated aging in part. Because of the relatively high temperature in the aging chamber, a postcuring polymerization effect can be expected, with more carbon double bonds converting to single bonds.[34] Others have also suggested that heat treatment improves mechanical properties, such as hardness, wear, and water solubility, because of increased conversion.[35–37] Again, hardening of the resins after aging can be explained in part with the further possible curing of the resin samples in the weathering chamber with the effect of light sources. However, it was previously shown that when these two resins were cured up to their possible maximum (66.9% for TLR and 75.3% for LCR), their surface hardness values did not reach those recorded after accelerated aging. Therefore, the accelerated aging process must have affected the matrix structure with mechanisms mentioned above other than further monomer conversion.

From a clinical point of view, the use of an adequate thickness of composite with adequate abrasion resistance placed over the wire is essential to minimize long-term failure of bonded retainers. Rapid wear of the composite in vivo quickly reduces the overlying thickness of composite, leading to early failure of the retainer.[5] Surface hardness is a determinant of resistance to wear, and thus materials with higher surface hardness values might be beneficial for the clinician and the patient. The results of this study demonstrated increased surface hardness values for both adhesives tested after accelerated aging. This may suggest that these materials might not be more susceptible to wear under occlusal forces after certain amount of clinical service, which is 1 year with the proposed test method in the present study.

On the other hand, increased surface roughness may indicate an inferior performance in terms of plaque accumulation following this time span. However, these assumptions should be used with caution for three reasons. First, polymeric adhesives used intraorally are also subjected to microbial degradation[38] and are exposed to saliva, acidic beverages, and alcohol-containing liquids, including mouth-rinsing solutions containing up to 20% alcohol, besides the humidity and temperature changes employed in this study. These factors decrease the glass transition temperature of the material and induce a plasticizing effect.[39,40] Second, the retainer adhesives are worn continuously and/or polished by food particles, tongue movements, and tooth brushing during their clinical service, which were ignored in this study. Third, the aging test employed in this study is estimated to be equivalent to 1 year of clinical service,[11,18] which is much shorter than the 2 to 3 years expected of a typical lingual retainer.

CONCLUSIONS

- Accelerated aging increases the surface hardness of light-cured lingual retainer adhesives significantly, and this effect is not similar for different materials.
- Surface roughness is also significantly increased for the Transbond Lingual Retainer following accelerated aging.

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