ABSTRACT

Objective: To determine how filler content and an acidic environment affect the retention of sealants placed on smooth enamel surfaces.

Materials and Methods: A sample of 120 teeth was randomly divided into six subsamples. Three experimental sealants with identical formulas, with the exception of the amount of filler content (18%, 30%, 50%), were applied according to manufacturers’ recommendations. Half of the subsamples were exposed to an acid environment (pH of 2.5) for 96 hours. With the use of a tooth-brushing simulator, each tooth was exposed to 15,000 brushing strokes, while a slurry of 1:3 toothpaste/neutral sodium bicarbonate cycled through the machine. Initial and final photographs were analyzed subjectively and objectively. Scanning electron microscope photomicrographs were used to evaluate the tooth surface.

Results: Subjective analyses showed significant \((P < .05)\) filler effects, with the 18% filled sealant showing the least change, followed by the 30% sealant, then the 50% filled sealant, which showed the greatest loss. Objective analyses showed the same pattern of loss, but the differences between sealants were not statistically significant. Exposure to an acidic environment had no significant effect on sealant retention. SEMS showed a layer of sealant remaining on all of the sealed teeth evaluated.

Conclusions: Filler content of resin sealant material affects the retention of sealants on smooth enamel surfaces; exposure to an acid environment has no effect on sealant retention. Within the limits of this study, highly filled resin sealants once saturated have the ability to endure the oral environment and remain on a smooth enamel surface, regardless of the amount of filler content. (Angle Orthod. 2011;81:136–142.)

KEY WORDS: Sealants; Filler content; Acid environments; Retention; Simulated tooth brushing

INTRODUCTION

Enamel decalcifications/white spot lesions (WSL) caused by plaque accumulation and bacterial attack are among the most unpleasant sequelae of orthodontic treatment. Excellent orthodontic results can be masked by unsightly white spot lesions, the occurrence of which range from 24.9% to 96%. Lesions can occur in as little as 4 weeks. Although lesions are preventable with proper oral hygiene, the compliance of orthodontic patients is often less than optimal.

Demineralization during orthodontic treatment can be decreased by using fluoride mouth rinses or fluoride toothpaste, but the success of these approaches also depends on patient compliance. In-office delivery of fluoride varnish provides protection without relying on patient compliance, but it does not prevent white spots from occurring. Fluoride-releasing bonding agents are effective, but the amount of fluoride released from bonding agents decreases dramatically over very short periods. Antimicrobial agents have been suggested as preventive agents for white spot lesions, but they rely on the patient to comply with rinsing instructions. Because unfilled resin sealants do not remain on the teeth, they cannot be expected to
protect the enamel surface throughout orthodontic treatment. Recently, Benham et al. showed that highly filled resin sealants significantly decrease the occurrence of WSL in patients; this finding supports in vitro studies showing that filled sealants decrease the number and intensity of white spot lesions. Highly filled sealants might be expected to better withstand the challenges of toothbrush abrasion and the acidic effects of mouth fluids because filler particles provide the strength and wear resistance properties of composite resin materials. Because filler particles are embedded in a weaker resin matrix that can be abraded or eroded away, more filler particles embedded in the resin matrix should result in less resin matrix on the surface exposed to these challenges. The primary purpose of the present study was to determine the effects of filler content on the retention of sealants subjected to mechanical toothbrush abrasion and simulated mouth fluids. A secondary purpose was to evaluate whether or not an acidic environment has an effect on sealant retention.

MATERIALS AND METHODS

One hundred twenty extracted human teeth, with noncarious labial surfaces, were collected from dental practices in Arkansas and Texas, including 54 molars, 48 premolars, 12 canines, and 6 incisors. The teeth were randomly divided into six groups of 20, with each group consisting of 9 molars, 8 premolars, 2 canines, and 1 incisor.

The crowns of the teeth were sectioned from the roots (Figure 1A) and mounted in acrylic rings (Figure 1B) that inserted into the tooth-brushing simulator (Proto-Tech, Portland, Ore). Retention grooves were carved inside the acrylic mounting rings with an acrylic bur to retain the Exaflex Putty (GC America, Alsip, Ill) that was used as the mounting medium. The crowns were centered in the impression putty and were depressed so that only the buccal surface, from the mesiobuccal line angle to the distobuccal line angle, remained exposed (Figure 1C).

Reliance Orthodontic Products (Itasca, Ill) fabricated three different formulations of ProSeal; all were identical except for the amount of filler content. The ProSeal sealant on the market is 18% filled; 30% and 50% filled sealants were fabricated specially for the project. The filler in all three sealants was silane treated and consisted of disc-shaped glass particles averaging 5 μ in size. The sealants incorporate a fluorescing agent, which made them visible under black light.

The labial surface of each mounted tooth was cleaned using a slurry of nonfluoridated flour of pumice and water for 5 seconds with a prophylaxis cup, and a
slow-speed handpiece with light pressure. This was followed by a rinse under running water and drying with an oil-free air supply. Thirty-seven percent phosphoric acid etchant gel (Reliance) was applied to the entire buccal/labial surface for 15 seconds and then was rinsed completely under running water. The surface was dried with an oil-free air supply, and each tooth was checked to ensure that the surface appeared “frosty” and well etched. Blinded as to the sealant's makeup, the primary investigator applied a thin coat of sealant to the entire buccal surface with a microbrush, followed by a 2 second burst of air applied 2 inches from the tooth to thin and even out the sealant material. A halogen curing light (Reliance) was used to cure the sealants for 20 seconds, with the light tip placed as close to the sealant material as possible.

The effects of acid exposure before toothbrush abrasion were evaluated using a phosphoric acid solution maintained at a pH of 2.5, which simulated the acidic content of soft drinks, energy drinks, sports drinks, etc, that orthodontic patients often consume during treatment. Three of the groups were randomly selected and submerged in the acidic solution for 96 consecutive hours after sealant placement. The duration of acid exposure was based on a study by Buren et al.; this value represents approximately 2 years of exposure based on studies reporting that adolescents in the United States consume 1.78 beverages per day.

A Canon 20D camera with a 100 mm macro lens (Canon Inc, Tokyo, Japan) and a Kodak #2E filter (Eastman Kodak, Rochester, NY) was placed on a tripod for stability and standardization. Photographs were taken with an exposure time of 2.5 seconds, a film speed of 200, and an F-stop of 8. Two black lights angulated at approximately 45° were positioned 10 inches away on either side of the specimen. Each specimen was placed 7 inches away from the lens and under water to reduce glare. Photographs of the buccal surface were taken before and immediately after acid exposure and tooth brushing. A 10 mm section of wire included in each photo was used for calibration (Figure 2).

Six specimens at a time were placed in the tooth-brushing simulator (Figure 1D). Medium-bristled toothbrushes (Deluxe Denta-Brite, Eagle Home Products Inc, Huntington, NY) were centered over the buccal surface of the specimens and were oriented to brush in a mesiodistal direction. Each specimen was brushed with a new toothbrush. A constant force of 280 g of pressure was applied to the tooth’s surface by the brush. Each specimen received 15,000 strokes, representing 20 strokes per day over a period of 2 years. A slurry of 1:3 toothpaste and neutral sodium bicarbonate solution was continuously cycled through the machine during the brushing process. The solution was drained and changed for each of the six specimens placed in the tooth-brushing simulator.

A scanning electron microscope (SEM; JSM-6300, JEOL USA, Peabody, Mass) was used at the end of the experiment to evaluate the surface (1500X) of one randomly selected specimen from each of the six groups of an unprotected tooth that was acid treated according to the protocol of the study, and of one untreated control tooth. A subjective check with a sharp explorer was performed on each specimen at the end of the experiment to determine if a layer of protective sealant remained on the surface.

Figure 2. Example of a specimen photographed under black conditions. Sealant (S) is evident on the buccal surface as fluorescing bright white. MP indicates mounting putty; S, sealant; W, calibration wire; and AR, acrylic ring.
Data Analysis

Subjective evaluation of each specimen was performed by the primary investigator and two coinvestigators, who were blinded as to the sealant being evaluated. Initial and final photographic images of each specimen were projected onto a computer screen in a dimly lit room and were independently rated according to the following scale: 0 (no sealant loss), 1 (slight loss; 20% to 33%), 2 (moderate loss; 33% to 66%), and 3 (severe sealant loss; 66% to 100%).

Objective evaluations of sealant loss were performed using Image Tool Software, version 3.00 (The University of Texas Health Sciences Center, San Antonio, Tx). A free-form shape was drawn over the buccal surface of the initial photo, and then was copied and pasted onto the final photo, while the same dimensions were maintained. The free-form shapes were traced and a frequency distribution of pixels was saved for each specimen. Gray scales below 25 were eliminated because they represented the dark lines used to trace the free-form shape. Gray scale values above 166 were eliminated because they were out of range of the specimens. Gray scales between 26 and 165 were grouped into 14 sets, each including 10 consecutive gray scales. The number of pixels recorded for each of the sets was multiplied by weighted factors, ranging from 0.01 for the pixels with gray scales from 26 to 35, to 0.14 for the pixels with gray scales from 156 to 165, and with the weighting factor increasing by 0.01 for each consecutive set of 10 gray scales. The lower the weighted pixel score (WPS), the darker the area, and vice versa.

Statistical Analysis

Analyses were performed with the Statistical Package for the Social Sciences (SPSS), version 15.0 (SPSS Inc, Chicago, Ill), using a significance level of $P < .05$. For subjective evaluations, the Kruskal-Wallis test was used to evaluate the acid effects, and the Mann-Whitney $U$-test was used to determine whether filler effects could be noted. For objective data, an independent sample Student’s $t$-test was used to determine the effects of acid treatment, and analysis of variance (ANOVA) was used to compare the three sealants.

RESULTS

Significant differences were noted in the subjective ratings of the three sealant groups (Figure 3). The 18% filled group showed significantly ($P = .015$) less sealant loss than the 30% filled group, which in turn showed significantly ($P = .015$) less sealant loss than the 50% filled group. The subjective evaluations demonstrated no significant differences between teeth subjected to the acid environment and teeth that were not.

### Table 1. Changes in Weighted Pixel Scores (WPS) and Percent Change Based on Sealant Filler Content and Acid Etching (Greater Decrease = More Sealant Lost)

<table>
<thead>
<tr>
<th>Sealant Filler Content</th>
<th>Acid Etching</th>
<th>No Acid Etching</th>
<th>Acid/No Acid Groups Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>18%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPS</td>
<td>-5.40</td>
<td>126.89</td>
<td>-35.69</td>
</tr>
<tr>
<td>Percent Δ</td>
<td>1.15%</td>
<td>21.52%</td>
<td>-5.98%</td>
</tr>
<tr>
<td>30%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPS</td>
<td>-35.61</td>
<td>89.30</td>
<td>-30.34</td>
</tr>
<tr>
<td>Percent Δ</td>
<td>-7.56%</td>
<td>18.25%</td>
<td>-6.64%</td>
</tr>
<tr>
<td>50%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPS</td>
<td>-59.68*</td>
<td>107.60</td>
<td>-59.38*</td>
</tr>
<tr>
<td>Percent Δ</td>
<td>-8.12%*</td>
<td>7.02%</td>
<td>-10.81%*</td>
</tr>
<tr>
<td>Filler content groups combined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WPS</td>
<td>-33.06*</td>
<td>110.15</td>
<td>-41.80*</td>
</tr>
<tr>
<td>Percent Δ</td>
<td>-4.69%</td>
<td>19.15%</td>
<td>-7.81%*</td>
</tr>
</tbody>
</table>

* Significant ($P < .05$) change in filler content over time.
On the basis of objective evaluations, an overall loss of sealant was noted in all groups (Table 1 and Figure 4). The 50% filled group showed the greatest loss, followed by the 30% and 18% filled groups, respectively. Significant ($P < .05$) amounts of sealant were lost in the 30% and 50% filled groups; the 18% filled group showed no statistically significant changes over time. Group differences in the amount of sealant loss were not statistically significant. The non–acid treated group lost approximately 3% more sealant than the groups that were acid treated, but none of the differences related to acid etching were statistically significant.

Scanning electron microscopy (SEM) clearly showed that sealant remained on the enamel surface after it was subjected to toothbrush abrasion and acid attack, regardless of the amount of filler added or acid exposure (Figure 5). The expected honeycomb etch pattern evident on unprotected teeth, especially on the acid-etched control, was not evident on any of the sealed teeth. Filler particles and holes where filler particles had been evident in all sealed teeth. The subjective explorer check performed on specimens at the end of the experiment also indicated that sealants covered the entire labial surface of all teeth.

**DISCUSSION**

Sealant retention was affected by filler content, with the least filled sealant demonstrating the greatest retention. Studies reporting better resistance to attrition and abrasion with higher filler content have been based on comparisons of different products with differing formulations, or have evaluated filler particles that were substantially smaller than those in the present study (0.04 $\mu m$ vs 5 $\mu m$, respectively). The present results suggest that filler content alone does not determine the wear resistance of a material; adding more filler particles to the existing resin matrix does not necessarily make the material more durable.

Simply adding more filler particles to the matrix without adding more diluent makes the material more viscous and more difficult to apply. Even though blinded, the primary investigator realized that the 50% filled material was the most difficult to apply and spread onto the surface of the tooth, followed by the 30% and 18% filled sealants, respectively. It is important to note that the sealants that were more difficult to apply were less retentive than the 18% filled material, which flowed evenly onto the enamel surface and withstood the effects of acid treatment and toothbrush abrasion. Because the organic matrix base of the resin material used can hold only a given quantity of filler particles of a given size, the present results suggest that 50% and 30% sealants were beyond the saturation point for the size of the particles used. The relationship between the amount of filler content and wear properties is probably not linear; wear resistance properties might be expected to increase until the product reaches a saturation point, after which wear resistance properties decrease with increased filler content (Figure 6). Smaller particles can pack more tightly into the resin matrix, leaving less of the weaker resin matrix exposed to be abraded away.
Filled sealants exposed to acidic environments did not exhibit greater loss after tooth brushing than the same sealants not exposed to acidic environments, despite the fact that acids decrease surface hardness and increase surface roughness of composite resin materials.\textsuperscript{28,29} The lack of an effect may be explained by the fact that sealant remained on the surfaces of all teeth evaluated in the present study. Although Han and coworkers\textsuperscript{30} showed that flowable resins with higher filler content were better able to withstand the effects of acid erosion than were resins with lower filler content, their conclusion remains tentative because the products used differed in more than just filler content.

Orthodontists may be concerned about using sealants for at least two reasons. Although sealant removal adds time to bonding and debonding appointments, this investment is worth avoiding the problems associated with the development of white spot lesions and toothbrush abrasion. The application of sealants before bracket placement adds only a couple of minutes to a carefully controlled bonding regimen. After treatment, the sealants can be simply polished off with a 30 fluted finishing bur and polishing points. Orthodontists should also be aware that several studies have shown that bonding brackets to a filled resin sealant does not decrease bond strength.\textsuperscript{19,31,32}

CONCLUSIONS

\begin{itemize}
  \item Sealants with higher filler content showed greater loss when subjected to a simulated oral environment than sealants with lower filler content.
  \item An acidic environment had no effect on the retention of sealants.
  \item Within the limits of this study, filled resin sealants have the ability to endure the simulated oral environment and remain on the tooth surface, regardless of the amount of filler content.
\end{itemize}

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REFERENCES


