Surface hardness evaluation of different composite resin materials: influence of sports and energy drinks immersion after a short-term period

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ABSTRACT

Objectives: This study evaluated the effect of sports and energy drinks on the surface hardness of different composite resin restorative materials over a 1-month period. Material and Methods: A total of 168 specimens: Compoglass F, Filtek Z250, Filtek Supreme, and Premise were prepared using a customized cylindrical metal mould and they were divided into six groups (N=42; n=7 per group). For the control groups, the specimens were stored in distilled water for 24 hours at 37°C and the water was renewed daily. For the experimental groups, the specimens were immersed in 5 mL of one of the following test solutions: Powerade, Gatorade, X-IR, Burn, and Red Bull, for two minutes daily for up to a 1-month test period and all the solutions were refreshed daily. Surface hardness was measured using a Vickers hardness measuring instrument at baseline, after 1-week and 1-month. Data were statistically analyzed using Multivariate repeated measure ANOVA and Bonferroni's multiple comparison tests (α=0.05). Results: Multivariate repeated measures ANOVA revealed that there were statistically significant differences in the hardness of the restorative materials in different immersion times (p<0.001) in different solutions (p<0.001). The effect of different solutions on the surface hardness values of the restorative materials was tested using Bonferroni's multiple comparison tests, and it was observed that specimens stored in distilled water demonstrated statistically significant lower mean surface hardness reductions when compared to the specimens immersed in sports and energy drinks after a 1-month evaluation period (p<0.001). The compomer was the most affected by an acidic environment, whereas the composite resin materials were the least affected materials. Conclusions: The effect of sports and energy drinks on the surface hardness of a restorative material depends on the duration of exposure time, and the composition of the material.

Key words: Surface hardness. Composite resins. Sports drinks. Energy drinks.

INTRODUCTION

The consumption of sports and energy drinks has gained high popularity among the adolescent population, especially 18- to 35-year-olds in recent years¹⁴,²⁵. Although the purpose of those drinks is to enhance performance and endurance and prevent dehydration for individuals involved in physical activity, they are being widely consumed by the general population instead of carbonated drinks⁶. However, previous studies have shown that these beverages potentially cause dental erosion⁸,¹⁵ and, due to their acidity, may be detrimental to the properties of restorative materials.

The use of resin-based restorative materials in dentistry has substantially increased over the past few years because of their good aesthetic appearance, improvements in formulations, ease of handling, and ability to establish a bond to
Study was to evaluate the effect of short-term immersion in sports and energy drinks on the surface hardness of polyacid-modified composite resin, compomer, microhybrid composite, and nanofilled composites. The tested null hypotheses were that (1) there would be no significant effect of the type of solutions on the surface hardness of the restorative materials and (2) two minutes daily exposure time in the tested solutions for a 1-month evaluation period would have no significant effect on the surface hardness of resin-based restorative materials.

MATERIAL AND METHODS

Preparation of specimens

In the present study four types of resin-based composite materials namely; a polyacid-modified composite resin-compomer (Compoglass F, Ivoclar-Vivadent, Schaan, Liechtenstein), a microhybrid composite resin (Filtek Z250, 3M ESPE, St. Paul, MN, USA) and two nanocomposites (Filtek Supreme, 3M ESPE, St. Paul, MN, USA; Premise, Kerr-Hawe, Orange, CA, USA) of A2 shade were tested. The list of the materials with their compositions is provided in Figure 1. A total of 168 disc-shaped specimens (n=42 for each composite), 8 mm in diameter and 2 mm thick, were prepared using a customized cylindrical metal mould. In order to obtain a flat polymerized surface without bubble formation, the specimens were covered on both sides (top and bottom) with a polyester matrix strip (Mylar Strip, SS White Co., Philadelphia, PA, USA) and a thin, rigid glass microscope slide (1-mm thick). Finger pressure was applied on the slide to extrude the excess material. The composite material was then polymerized through the glass slide and polyester matrix strip for 20 s, according to the manufacturer’s recommendations, using a halogen light curing unit (VIP, Bisco Inc., Schaumburg, IL, USA) operating in standard mode and emitting not less than 600 mW/cm², as measured with a light meter that was placed on the curing unit before beginning the polymerization. The guide of the light curing unit was placed perpendicular to the specimen’s surface and the distance between the light source and the specimen was standardized by using a 1-mm glass slide. Afterward, all specimens were stored in distilled water in a lightproof container for 24 hours at 37°C to ensure complete polymerization. The top surfaces of all specimens were serially polished with a series of three grades (medium, fine, and super-fine) of Sof-Lex disks (3M ESPE, St. Paul, MN, USA) with a slow-speed handpiece under dry conditions for 30 seconds before the surface hardness evaluation. After each polishing step, the specimens were thoroughly rinsed with water for 10 seconds to remove debris, air dried for 5 seconds,
and then polished with another disk of lower grit for the same period of time before the final polishing.

**Surface hardness evaluation**

Forty-two specimens of each restorative material were divided into six groups (n=7/group). The hardness value of each specimen was determined using a microhardness tester (Micromet 5114, Buehler, Lake Bluff, IL, USA) with a diamond Vickers indenter. Three indentations were made and measurements were obtained at different points on each specimen, with a 200 g load for a 15 s dwell time. The average value was converted into a Vickers Hardness Number (VHN). The measurements were taken automatically 1 mm from each other.

**Immersion of specimens in solutions**

After the baseline microhardness evaluation, 7 specimens from each experimental group were individually stored in vials containing 5 mL of distilled water (pH 6.58) for 24 hours, and kept in an incubator at 37°C as a control solution and the distilled water was renewed daily up to 1-month. The other specimens from each experimental group were individually immersed (n=7) in vials containing 5 mL of Powerade sports drink (The Coca-Cola Co., Atlanta, GA, USA; pH 3.79), Gatorade sports drink (The Gatorade Co., Chicago, IL, USA; pH 3.27), X-IR energy drink (Nice Trading Inc., Istanbul, Turkey; pH 3.15), Burn energy drink (The Coca-Cola Co., Atlanta, GA, USA; pH 2.67) and Red Bull energy drink (Red Bull GmbH, Am Brunnen, Austria; pH 3.54) for 2 minutes daily at room temperature (23±1°C). After the immersion period in the test solutions, the samples were washed with distilled water and the specimens were maintained in distilled water at 37°C during the rest of the day. The vials were sealed to prevent evaporation of both the control and test solutions. All the solutions were refreshed and the pHs of the solutions were measured daily with a pH meter (HI 221, Hanna Instruments Inc., Woonsocket, RI, USA) before immersing the specimens. For the entire experimental period, newly opened test solutions were used for each day. Thereafter, in order to evaluate the change in surface hardness over time, the microhardness test was carried out 1-week and 1-month after the start of storage for the control and immersion for the experimental groups.

**Statistical analysis**

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software, version 17.0 (SPSS Inc., Chicago, IL, USA). This study was performed to evaluate the effect of immersion times (1-week and 1-month) and different solutions on the surface hardness of different composite resins as the main effects and all possible combinations of these variables as the interaction effects (immersion times*solutions). The results were primarily analyzed using the Kolmogorov-Smirnov test to determine the existence of a normal distribution. Since the data was normally distributed, the statistical analysis was performed by using a multivariate repeated

<table>
<thead>
<tr>
<th>Restorative Material</th>
<th>Classification</th>
<th>Filler Weight (%)</th>
<th>Filler Volume (%)</th>
<th>Filler Type</th>
<th>Filler Size</th>
<th>Monomer Composition</th>
<th>Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compoglass F (Ivoclar-Vivadent, Schaan, Liechtenstein)</td>
<td>Poly-acid modified resin composite (Compomer)</td>
<td>77</td>
<td>55</td>
<td>SiO$_2$, YbF$_3$, (Ba) FAiSi</td>
<td>1 μm</td>
<td>Bis-GMA, UDMA, TEGDMA, CDCDMA</td>
<td>A2</td>
</tr>
<tr>
<td>Filtek Z 250 (3M ESPE, St Paul, MN, USA)</td>
<td>Minifilled hybrid</td>
<td>82</td>
<td>60</td>
<td>Zirconia/silica</td>
<td>0.6 μm</td>
<td>Bis-EMA, UDMA, Bis-GMA</td>
<td>A2</td>
</tr>
<tr>
<td>Filtek Supreme (3M ESPE, St Paul, MN, USA)</td>
<td>Nanofilled</td>
<td>78.5</td>
<td>59.5</td>
<td>ZrO$_2$/SiO$_2$ nanocluster,SiO$_2$ nanofiller</td>
<td>5-20 nm with 20 nm silica filler</td>
<td>Bis-GMA, Bis-EMA, UDMA, TEGDMA</td>
<td>A2B</td>
</tr>
<tr>
<td>Premise (Kerr-Hawe, Orange, CA, USA)</td>
<td>Nanohybrid</td>
<td>84</td>
<td>69</td>
<td>Barium alumino borosilicate glass, silica nanofiller, PPF, barium glass, discrete nanofiller</td>
<td>Glass: 0.4 μm, silica: 0.02 μm</td>
<td>Bis-GMA, Bis-EMA, TEGDMA</td>
<td>A2</td>
</tr>
</tbody>
</table>

**Figure 1** - Composition of the restorative materials used in the study
RESULTS

The mean and standard deviations in the surface hardness values of the restorative materials tested were statistically significant differences in the immersion times (p<0.001). The interaction of the immersion time and energy drinks differed among the solutions for the Filtek Z250 and Filtek Supreme (p<0.05), and for the other restorative materials at the 1-week period (p<0.001) and 1-month were evaluated by using the one-way ANOVA test. According to the results of the one-way ANOVA test, significant differences for the Filtek Z250 and Filtek Supreme (p<0.05), and for the other restorative materials at the 1-week period (p<0.001) and 1-month were summarized in Table 1. Multivariate ANOVA was used to compare the effect of each restorative material for each evaluation period. The means were then compared by Bonferroni’s multiple comparison test. The statistical significance level was established at p<0.05. The results of this study reveal that the mean surface hardness values of all the restorative materials before storage were statistically significant differences in the immersion times (p<0.001). The interaction of the immersion time and energy drinks decreased the mean surface hardness values of all the restorative materials after 1-month immersion when compared to the baseline. After the storage period, all restorative materials immersed in sports drinks decreased the mean surface hardness values of the restorative materials (Table 2). The results of this study reveal that the mean surface hardness values of all the restorative materials after storage in distilled water for 24 hours and after storage in distilled water for 24 hours and after storage in any of the test solutions for two minutes daily at 1-week and 1-month were statistically significant differences in the immersion times (p<0.001). The interaction of the immersion time and energy drinks differed among the solutions for the Filtek Z250 and Filtek Supreme (p<0.05), and for the other restorative materials at the 1-week period (p<0.001) and 1-month.

Table 1 - Mean ± standard deviation surface hardness values of tested restorative materials before and after immersion in solutions

<table>
<thead>
<tr>
<th>Material</th>
<th>Test Period</th>
<th>Distilled water</th>
<th>Powerade</th>
<th>Gatorade</th>
<th>X-IR</th>
<th>Burn</th>
<th>Red Bull</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compoglass F</td>
<td>Baseline</td>
<td>51.73±0.62a,1</td>
<td>51.76±1.54a,4</td>
<td>51.70±0.09a,1</td>
<td>51.80±1.35a,1</td>
<td>51.79±1.49a,1</td>
<td>51.74±0.90a,1</td>
<td>15.16625.769</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>1 Week</td>
<td>51.95±2.16a,1</td>
<td>47.06±1.69a,2</td>
<td>46.06±1.19b,2</td>
<td>46.60±1.41b,2</td>
<td>44.72±1.86b,2</td>
<td>46.64±1.60b,2</td>
<td>23.598</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>1 Month</td>
<td>45.05±3.00a,3</td>
<td>38.08±1.49a,4</td>
<td>37.30±0.86a,4</td>
<td>36.75±1.07a,4</td>
<td>36.10±1.29a,4</td>
<td>37.98±1.62a,4</td>
<td>25.769</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Filtek Z250</td>
<td>Baseline</td>
<td>80.16±0.65a,4</td>
<td>80.21±0.54a,4</td>
<td>80.53±0.10a,3</td>
<td>79.94±0.67a,1</td>
<td>80.01±0.82a,1</td>
<td>80.37±1.14a,1</td>
<td>0.518</td>
<td>0.601</td>
</tr>
<tr>
<td></td>
<td>1 Week</td>
<td>81.50±5.69a,4</td>
<td>77.25±4.13a,4</td>
<td>75.76±2.34a,4</td>
<td>75.59±3.70a,1</td>
<td>73.69±2.15a,2</td>
<td>77.39±4.25a,1</td>
<td>3.198</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>1 Month</td>
<td>72.21±1.31a,3</td>
<td>64.46±1.84a,4</td>
<td>64.35±1.83a,4</td>
<td>63.13±2.39a,4</td>
<td>62.66±3.76a,4</td>
<td>66.14±2.26a,4</td>
<td>11.505</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Filtek Supreme</td>
<td>Baseline</td>
<td>73.53±1.83a,4</td>
<td>73.59±1.76a,4</td>
<td>73.40±0.94a,4</td>
<td>73.74±2.24a,1</td>
<td>73.77±1.33a,1</td>
<td>73.63±1.80a,1</td>
<td>0.239</td>
<td>0.627</td>
</tr>
<tr>
<td></td>
<td>1 Week</td>
<td>74.15±5.11a,2</td>
<td>70.34±2.92a,2</td>
<td>70.17±2.79a,3</td>
<td>69.92±3.52a,2</td>
<td>68.07±1.88a,2</td>
<td>69.80±2.80a,1</td>
<td>2.553</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>1 Month</td>
<td>65.47±2.99a,3</td>
<td>59.37±1.40a,4</td>
<td>59.04±2.21a,1</td>
<td>57.08±1.74a,4</td>
<td>55.03±0.74a,5</td>
<td>58.04±1.86a,4</td>
<td>23.598</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Premise</td>
<td>Baseline</td>
<td>61.09±0.87a,1</td>
<td>61.11±1.44a,4</td>
<td>61.07±1.33a,1</td>
<td>61.06±1.36a,1</td>
<td>61.03±1.14a,1</td>
<td>61.09±1.31a,1</td>
<td>0.239</td>
<td>0.627</td>
</tr>
<tr>
<td></td>
<td>1 Week</td>
<td>62.75±3.39a,5</td>
<td>58.96±1.82a,2</td>
<td>57.27±1.09a,2</td>
<td>57.92±1.62a,2</td>
<td>55.81±2.81a,2</td>
<td>58.93±1.94a,3</td>
<td>7.659</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>1 Month</td>
<td>53.90±2.13a,3</td>
<td>47.61±1.23a,4</td>
<td>48.74±1.76a,4</td>
<td>46.45±1.40a,5</td>
<td>47.07±2.04a,4</td>
<td>49.74±1.10a,4</td>
<td>18.613</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Within each material group for each solution the same small letters in the same column represent statistical insignificance, whereas different small letters represents statistical significance for the Bonferroni test at p<0.05. Within each material group for each test period the same numbers in the same row represent statistical insignificance, whereas different numbers represents statistical significance for the Bonferroni test at p<0.05.
reduction after immersion in sports and energy drinks compared to the other resin-based composite materials after the 1-month evaluation period (p<0.05). However, surface hardness reductions among the tested resin-based composites was insignificant (p>0.05; Table 2) for the same evaluation period.

For the Compoglass, there were significant differences between the effect of distilled water and the effect of other solutions on the surface hardness (p<0.001), whereas no significant differences in surface hardness were observed among the sports and energy drink immersed samples (p>0.05).

For Filtek Z250, there were no significant differences between the effects of distilled water and sports and energy drinks on the surface hardness (p>0.05) except for Burn (p=0.028), whereas no significant differences in surface hardness were detected among the sports and energy drink immersed samples (p>0.05).

For Filtek Supreme, no significant differences in surface hardness were observed among the sports and energy drink samples (p>0.05), whereas significant differences in surface hardness were observed among the samples stored in distilled water and immersed in other solutions (p<0.05) except for Powerade (p=0.063).

For Premise, there were no significant differences in surface hardness among the sports and energy drink immersed samples (p>0.05); however, significant differences in surface hardness were observed between the samples stored in distilled water and other solutions (p<0.05) except for Red Bull (p=0.114).

**DISCUSSION**

The present study was aimed to determine the surface microhardness of different restorative materials after exposure to different solutions. During consumption, food or drink contacts teeth or restoration surfaces for only a short time before it is washed away by saliva. However, in previous studies, substrates usually had contact with acidic food or drink for a prolonged period of time and the situation did not account for the role of saliva 

<table>
<thead>
<tr>
<th>Effect</th>
<th>F-value</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compoglass</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immersion time</td>
<td>495.287</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Solution</td>
<td>22.331</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Immersion time * solution</td>
<td>5.439</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Filttek Z250</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immersion time</td>
<td>73.243</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Solution</td>
<td>2.761</td>
<td>0.033</td>
</tr>
<tr>
<td>Immersion time * solution</td>
<td>0.708</td>
<td>0.714</td>
</tr>
<tr>
<td><strong>Filttek Supreme</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immersion time</td>
<td>244.099</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Solution</td>
<td>5.814</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Immersion time * solution</td>
<td>2.184</td>
<td>0.085</td>
</tr>
<tr>
<td><strong>Premise</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immersion time</td>
<td>270.701</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Solution</td>
<td>5.983</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Immersion time * solution</td>
<td>2.675</td>
<td>0.005</td>
</tr>
</tbody>
</table>

**Table 2** - Multivariate ANOVA results of the effects of interest (immersion time and solution) and interactions between these effects (immersion time * solution)
that "there would be no significant effect of the type of solutions on the surface hardness of the restorative materials", was rejected.

The surface hardness values of all restorative materials after 1-week of storage in distilled water are higher than the baseline surface hardness values. This could possibly be explained by the increased monomer conversion and/or additional post-curing cross-linking reactions in the resin phase over the course of time. However, when comparing baseline surface hardness values and after 1-week of sports and energy drink immersion, all of the restorative materials showed lower surface hardness values. This could be due to the fact that all of the restorative materials displayed a tendency to erode under acidic conditions and the acids in these drinks promoted the release of unreacted monomers by penetrating into the resin matrix, thereby resulting in lower surface hardness values. Particularly, compomer displayed a significantly higher hardness reduction than the other restorative materials after 1 week of immersion in all the sports and energy drinks. Previous studies have revealed that compomers release higher amounts of fluoride into acidic buffers than into neutral buffers, indicating that the structure of compomers could have been solved at a low pH. The compomer tested in this study showed the greatest surface hardness reduction of all the restorative materials when immersed in the acidic sports and energy drinks. In accordance with our findings, Abu-Bakr, et al. evaluated the effect of low-pH drinks on the surface hardness of tooth-colored restorative materials for 7 days, and reported that a compomer immersed in a low-pH soft drink exhibited significantly lower hardness values than a compomer immersed in deionized water for the same period.

The hardness results obtained in the present study indicate that immersion time in the solutions has a critical influence on the surface hardness of the restorative materials. Therefore, the second null hypothesis, which stated that "two minutes daily exposure time in the tested solutions for a 1-month evaluation period would have no significant effect on the surface hardness of resin-based restorative materials", was also rejected. In general, regardless of the solutions used, all restorative materials demonstrated significantly lower surface hardness values after 1-month evaluation period than after 1-week. This is because the materials deteriorate by way of liquid absorption. Storage in distilled water decreased the surface hardness of the restorative materials studied. This can be explained by the fact that "water serves as a plasticizing molecule within the composite matrix", causing a softening of the polymer resin component by swelling the network and reducing the frictional forces between polymeric chains.

The sports and energy drinks tested in the present study are low-pH beverages with a pH ranging from 2.67 to 3.79, and this could explain the lower surface hardness values of the restorative materials that were obtained in the study for the entire experimental period. It has been previously reported that resin materials immersed in "low-pH drinks have a high solubility, and this solubility causes surface erosion and dissolution, negatively affecting wear, hardness, and surface integrity by softening the matrix and causing a loss of structural ions". In addition, increased interaction between the solutions and resins, as well as the water uptake and greater erosive effect of acidic conditions on restorative materials, resulted in the decreased surface hardness values observed in the present study. However, the effect of the pH of the tested solutions on the surface hardness of the restorative materials was not evaluated in the study. Further research is necessary to evaluate this effect.

A resin-based restorative material may include different types of inorganic fillers. It has been noted that composite materials containing "zinc, barium glass, and zirconia/silica fillers were shown to be more susceptible to aqueous attack than those containing quartz fillers". In the present study, the tested restorative materials contained barium glass and zirconia/silica fillers; hence, the filler composition of the materials could be a possible reason for the decreased surface hardness values of the restorative materials in all of the tested solutions. This could be due to the softer barium glass particles in the restorative materials leached more easily compared to the quartz particles and bond decreasing of smaller filler surface of spherical shaped zirconia/silica fillers to the resin matrix as previously described.

Although all of the restorative materials showed significantly decreased surface hardness after 1-month, Compoglass F presented a particularly significant decrease in surface hardness when immersed in the sports and energy drinks compared to the other resin-based restorative materials. This might be related to the chemistry of the materials and the influence of the acidic beverages on the different chemical components. The resin-based composite materials used in the present study incorporate a high volume fraction of filler particles with a narrow particle size distribution, the average particle size being below 1 μm. Also, the chemical composition of resin based composites may have an effect on their susceptibility to softening and degradation. Compoglass F contains commonly used resin monomers; Bis-GMA and UDMA, which are known to be inclined to softening after exposure to chemical agents. However, all three
resin-based composite materials contain Bis-EMA and a reduced amount of TEGDMA, characteristics which promote better resistance to the action of chemical substances\(^{19}\). Therefore, differences in chemical composition among the compomer and resin-based composites might have contributed to the differences in surface hardness among these materials. Yap, Low and Ong\(^{35}\) (2000) have examined the effects of food-simulating liquids on the surface roughness and hardness of compomers and composite resins. In agreement with the present study’s results, they observed differences in the hardness of various materials after conditioning them in different food-simulating liquids.

Furthermore, the kind of acid in the solutions might have reduced the surface hardness of the tested restorative materials. It has been reported that organic fillers can be damaged by citric acid\(^{1,21}\). In this study, all of the sports and energy drinks contained citric acid, and they were found to be the most aggressive storage medium for the compomers. Compoglass F showed the greatest surface hardness reduction in this medium, thus indicating that citric acid is the most aggressive storage medium for the compomers\(^{1,21}\). Compoglass F showed the greatest surface hardness reduction in this medium, and a reduced amount of TEGDMA, characteristics of tooth-colored restorative materials in various clinical relevant acid solutions and reported that the compomer showed the greatest loss of mass in citric acid, thus indicating that citric acid is the most aggressive storage medium for compomers.

A material’s loss of hardness may contribute to its deterioration in a clinical environment, including loss of anatomical form and discoloration\(^{10}\). Furthermore, chemical softening may have a negative effect on wear and abrasion rates and, consequently, on the life span of a restorative material\(^{35}\). However, it must be noted that the experimental conditions cannot completely replicate the oral cavity testing environment\(^{12}\). In the present study, the role of saliva was simulated by using distilled water. In the oral cavity, parameters such as temperature changes, pH level, salivary enzymes, and the ionic composition of food or beverages might also affect the properties of restorations.

The present study evaluated the in vitro effects of different solutions on the surface hardness of restorative materials for 1-month; further long-term clinical and in vitro studies are needed to investigate and elucidate the effects of these solutions on the surface hardness of the restorative materials. Although this study could not completely replicate the complex oral cavity, it confirms the deleterious effects of some commercially available sports and energy drinks on restorative materials, effects which patients should be aware of.

CONCLUSIONS

Under the conditions of this 1-month in vitro study, the following conclusions were drawn:

Surface hardness values of the composite resin materials were significantly decreased, either immersed in distilled water or immersed in sports and energy drinks after the 1-month evaluation period.

Distilled water exhibited less reduction than the sports and energy drinks on surface hardness values of the composite resin specimens over time.

The compomer was the most affected material than the other restorative materials in terms of surface hardness change.

Duration of exposure time and the composition of the composite resin material have a significant effect on the surface hardness change of a restorative material.

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