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ORIGINAL RESEARCH ARTICLE

Effects Of Various Beverages And Tooth Brushing On Microhardness Of Restorative Materials Used In Pediatric Dentistry

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Abstract

Purpose: The objective of this study was to assess the impact of beverages and tooth brushing on the microhardness of different restorative materials.
Materials and Methods: Disk-shaped samples (10 mm diameter x 1.5 mm height) of compomer (Dyract XP), glass ionomer cement (GIC) (Ionofil Molar AC), and composite resin (Filtek Z250) were prepared. The samples were randomly allocated to four groups and conditioned in various beverages (cherry juice, cola, chocolate milk, and distilled water) for 3 hours per-day over 60 days. Each group was further subdivided to a brushing and a non-brushing subgroup. In the brushing group, samples were brushed once daily with toothpaste and an electric toothbrush for 5 seconds to each surface. The surface hardness of the samples was measured at baseline and after 60 days.
Results: In all four solutions, there was a significant increase in the surface hardness of the composite resin group ($p<0.05$). The compomer group exhibited a decrease in microhardness after immersion in cola and cherry juice ($p<0.05$). The surface hardness of the GIC was measured to be lower in all solutions ($p<0.05$). Brushing had no effect on the microhardness in any of the groups ($p>0.05$).
Conclusions: In comparison to commonly used materials in pediatric dentistry such as compomer and GIC, the Filtek Z250 composite demonstrated superior surface hardness values. Cola and cherry juice decreased the microhardness of compomer and GIC.

Key words: compomer; composite resin; glass ionomer cement; microhardness; tooth brushing

Introduction

In recent decades, the search for the development of ideal materials that offer esthetic results, simple clinical application procedures, and favorable mechanical properties has led to the emergence of several new restorative materials. Resin-based restorative materials and glass ionomer cement are widely used in pediatric dentistry because of their advantages such as simple clinical application and aesthetic restorations in primary teeth.[1–3] Despite significant improvements in physical, mechanical and optical properties, restorative materials are adversely affected by pH changes in the oral environment.[4]

Restorative materials are exposed to many conditions that affect their integrity and longevity due to the dynamic nature of the oral cavity.[5] One of these exposures is chemical degradation.[6] Saliva, food/drink compounds, and their interactions may contribute to degradation of restorations in time.[7] These situations could lead to a change in microhardness, a crucial property of restorations directly associated with the physiochemical properties and surface characteristics.[8]

The consumption of acidic beverages and fruit juices increased significantly in adolescents and children with the change of lifestyle in recent decades.[9] However, there is limited available data regarding the impact of these beverages on restorative materials.[10,11] Moreover, the effect of tooth brushing after the use of beverages has not been previously reported to our knowledge. The study aimed to investigate the impact of different beverages and tooth brushing on the microhardness of commonly used restorative materials in

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Table 1. Restorative materials used in the study

Material type	Material	Composition	Manufacturer
Compomer	Dyract XP compomer	Urethane dimethacrylate (UDMA), Carboxylic acid modified dimethacrylate (TCB resin), Triethyleneglycol dimethacrylate (TEGDMA), Trimethacrylate resin (TMPTMA), Dimethacrylate resins, Camphorquinone , Ethyl-4(dimethylamino)benzoate, Butylated hydroxy toluene (BHT), UV stabilizer, Strontium-alumino-sodium-fluoro-phosphor-silicate glass, Highly dispersed silicon dioxide, Strontium fluoride, Iron oxide pigments and titanium oxide pigments	Dentsply DeTrey Konstanz, Germany
Composite Resin	Filtek TM Bulk Fill composite	Bisphenol A Diglycidyl Ether Dimethacrylate (Bis-GMA), Bisphenol A Polyethylene Glycol Diether Dimethacrylate (Bis-EMA), Diurethane Dimethacrylate (UDMA),Triethylene Glycol Dimethacrylate (TEGDMA), Silane Treated Ceramic, Aluminum Oxide, N,N-Dimethybenzocaine	3M ESPE GmbH, Seefeld, Germany
Glass ionomer cement	Ionofil Molar	Water, pure polyacrylic acid, tartaric acid, aluminofluorosilicate glass and pigments	Voco, Cuxhaven, Germany

pediatric dentistry.

Material and Methods

Sample preparation

As a result of the power analysis conducted to determine the required sample size, it was established that a total of 120 samples would provide a test power (1-β) of 0.80. Glass ionomer cement (GIC) (Ionofil Molar, VOCO, Cuxhaven, Germany) (n=40), compomer (Dyract XP, Dentsply DeTrey GmbH, Germany) (n=40), and composite resin (Filtek Z250, 3M/ESPE, St. Paul, MN, USA) (n=40) were used (Table 1). The method used in the study was described previously.[10]

Briefly, the samples were prepared in teflon molds 10 mm in diameter and 1.5 mm high. Glass ionomer cement was let to undergo the setting process for 15 minutes and waited for 24 hours before the polishing procedure. Compomer and composite resin samples were cured by a light-curing unit (Freelight Elipar, 3M ESPE, Ireland). The samples were polished by discs (Sof-Lex, 3M ESPE, St. Paul, MN, USA).

Storage of the samples

The samples were rehydrated by storing in distilled water at 37ºC for 24 hours to secure monomer conversion and mimic oral conditions.

Following obtaining baseline microhardness data, each restorative material group was allocated to four groups (n=10) by storage media: distilled water, cherry juice, cola and chocolate milk. The samples contained in distilled water were accepted as the control group.

The solutions' pH values were measured using a digital pH electrode, which was calibrated promptly. The samples were immersed in one of the four solutions for 3 hours daily over a 60-day test period and returned to distilled water after immersion. Each group was further divided to brushing and non-brushing groups (n=5). The samples were brushed daily with an electrical toothbrush (Braun Oral-B Plaque Remover,) containing toothpaste (Oral-B Stages Fruit Blast, London, UK) in the brushing group. Each surface was brushed for 5 seconds. The pressure sensor of the brush was utilized to prevent excessive pressure application. Brushing procedure was carried out by the same investigator to provide standardization.

Measurement of Microhardness

The samples were removed from the storage media, lightly washed by using distilled water, partially dried by air spray, and was set to be completely air dried before the microhardness measurement. The Vickers Hardness Number was calculated using a microhardness tester (Matsuzava MTH 2, Microhardness Tester, Olympus, Tokyo, Japan) at baseline and 60-day after the immersion. For each sample, three indentations were made on the top surface, with a 50-gram load applied for 15 seconds, 1 mm apart from each other. Then, the average of the three values was recorded.

Statistical analysis

Computer statistical software (SPSS 21.0 for windows; SPSS Inc., Chicago, IL, USA) was used for the statistical analysis. Data was analyzed by two-way ANOVA and Friedman tests ($p<0.05$). T-test was used for the independent groups ($p<0.05$).

Results

The mean microhardness values of the restorative materials at baseline were given in Table 2. The microhardness of the composite resin group was higher than the GIC and compomer groups ($p<0.05$).

The mean microhardness values of the restorative materials in distilled water after 60 days were given in Table 3 and Figure 1. The microhardness of GIC and compomer groups decreased; however, it was statistically significant only in the GIC group ($p<0.05$). The highest microhardness value was found for composite resin ($p<0.05$).

The mean microhardness values of the restorative materials in cola after 60 days were given in Table 3 and Figure 1. While the microhardness of the compomer and GIC groups decreased, the microhardness of the composite resin group increased significantly ($p<0.05$). After 60-day immersion in cola, the highest microhardness value was found for composite resin and followed by GIC and compomer, respectively ($p<0.05$).

The mean microhardness values of the restorative materials in chocolate milk after 60 days were given in Table 3 and Figure 1. The microhardness of GIC and compomer groups decreased; however, it was only significant for GIC ($p<0.05$). In contrast, the microhardness of the composite increased significantly ($p<0.05$). The highest microhardness value was found for composite resin ($p<0.05$).

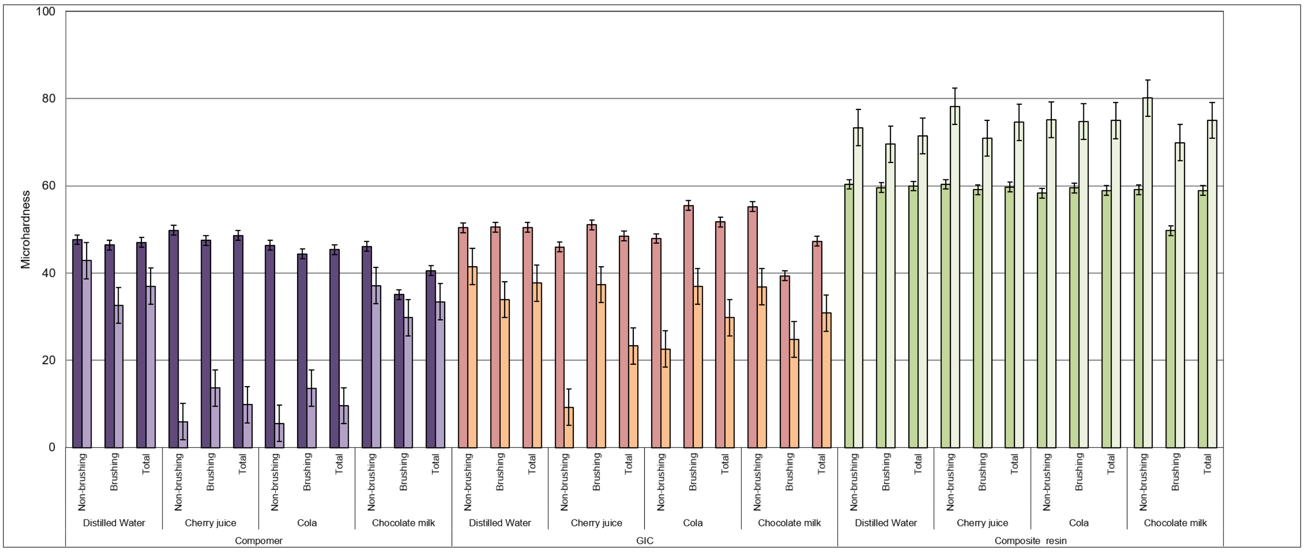

Figure 1. Mean microhardness values of restorative materials at baseline and on the 60th day in different beverages. The first column of each group presents microhardness at baseline, and the second column of each group presents microhardness on the 60th day.

Table 2. Mean microhardness values of restorative materials in solutions at baseline

Materials	Storage Media											
	Distilled water			Cherry juice			Cola			Chocolate milk		
	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total
GIC	50.55 ± 7.04	50.38 ±12.34	50.46 ±9.47Aa	51.03 ±5.62	45.94 ±13.10	48.48 ±9.87Aa	55.48 ±3.73	47.91 ±11.55	51.69 ±9.02Aa	39.35 ±23.20	55.23 ±8.69	47.29 ±18.52Aa
Compomer	46.41 ± 1.96	47.65 ±1.71	47.03 ±1.85Aa	47.47 ±3.54	49.79 ±2.57	48.63 ±3.16Aa	44.38 ±2.27	46.37 ±1.50	45.38 ±2.10Ab	35.06 ±19.60	46.08 ±0.78	40.57 ±14.31Aa
Composite Resin	59.56 ±1.973	60.34 ± 0.60	59.95 ±1.43Ab	59.13 ±1.49	60.34 ±3.80	59.73 ±2.79Ab	59.50 ±0.54	58.32 ±1.46	58.91 ±1.21Ac	49.74 ±28.04	59.13 ±1.12	58.91 ±1.21Aa

In the same column. the groups identified by different superscript lowercase are statistically different and in the same line, the groups identified by different superscript uppercase are statistically different (p<0.05)

The mean microhardness values of the restorative materials in cherry juice after 60 days were given in Table 3 and Figure 1. While the microhardness of GIC and compomer groups decreased, the microhardness of the composite resin group increased significantly ($p<0.05$). The highest microhardness value was found in the composite resin group ($p<0.05$).

In compomer groups, samples in distilled water exhibited significantly higher values than samples in cherry juice and cola after 60-day immersion ($p<0.001$). Similarly, samples in chocolate milk also exhibited significantly higher values than samples in cherry juice and cola ($p<0.001$). In the GIC and composite resin groups, there was no significant change between the beverages. ($p>0.05$).

The mean microhardness values of the brushing and non-brushing groups at baseline and after 60 days were given in Table 2,Table 3 and Figure 1. There was no significant change between any of the groups. Following the calibration of the digital pH electrode, the solutions' pH values were measured as 2.4; 6.4; 3.1 and 7 for cola, chocolate milk, cherry juice, and distilled water, respectively.

Discussion

This study investigated the effect of beverage and tooth brushing on the microhardness of restorative materials. The microhardness values of the specimens in different beverages changed significantly over time. The microhardness of restorative materials is affected by various factors such as the type of beverage, the length and frequency of exposure time to beverage, the content of restorative material, immersion period, and indenter load.[9,12–14]

A typical hardness test involves an indenter pressing on the surface of the tested material at a proper load. The hardness is inverse proportion to size of the created indentation.[15] The indenter load used in the hardness measurement is critical and incorrect results may occur when an inappropriate load is applied.[13] This was the reason 50-grams load was applied for 15 seconds in the present study.

The storage time of the specimens in the solution is a significant factor that may influence microhardness. In some previous studies, the specimens were contacted with beverages for varying times from 1 week to 1 year.[8,9,16,17] and the washing capacity of saliva was not taken into account.[9,17] Similar to the study of Nasim et al.[18], samples were conditioned in the solutions for 3 hours every day and replaced in distilled water following the immersion for 60 days. The duration of immersion was based on previous studies reporting that 12 hours of immersion is equivalent to a daily mouth rinse of 2 minutes for 1 year.[14,19] In the present study, 3 hours of immersion for 60 days is predicted to be comparable to 30 minutes of daily consumption for 1 year. This study design is believed to reflect the conditions of frequent consumption of acidic drinks and keeping them in the mouth for long time. Although it is reported that the pH values of Cola and fruit juices did not change when left open for 1 week[9], the solutions were prepared freshly every day to mimic children's daily consumption of beverages.

The erosive effect of a solution is determined by the pH value, the type and concentration of acid contained, and the titratable acidity.[20] Cherry juice contains malic and citric acids while cola contains phosphoric acid.[21,22] The erosive potential of these acidic beverages have been reported in many studies.[8,23,24] In accordance with this result, both cola and cherry juice reduced the microhardness significantly both in glass ionomer cement and compomer

Table 3. Mean microhardness values of restorative materials in solutions on the 60th day.

Materials	Storage Media											
	Distilled water			Cherry juice			Cola			Chocolate milk		
	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total	Brushing (ΔE ± SD)	Non-brushing (ΔE ± SD)	Total
GIC	33.91 ±9.08	41.49 ±6.06	37.7 ±8.30 Aa	37.34 ±27.32	9.24 ±9.17	23.29 ±24.26Aa	36.94 ±8.94	22.59 ±13.09	29.76 ±12.99Ab	24.79 ±14.6	36.88 ±7.31	30.83 ±12.61Aa
Compomer	32.57 ±10.08	42.83 ±5.53	37.70 ±9.38Ba	13.64 ±7.58	5.95 ±13.38	9.79 ±10.48Aa	13.61 ±4.86	5.54 ±7.81	9.57 ±7.46Aa	29.75 ±9.42	37.12 ±3.03	33.44 ±7.65 Ba
Composite Resin	69.57 ±3.30	73.33 ±9.29	71.45 ±6.86Ab	70.89 ±15.60	78.23 ±4.34	74.56 ±11.47Ab	74.75 ±4.77	75.15 ±5.36	74.95 ±4.79Ac	69.90 ±4.34	80.13 ±4.32	75.01 ±6.76Ab

In the same column. the groups identified by different superscript lowercase are statistically different and in the same line, the groups identified by different superscript uppercase are statistically different ($p<0.05$)

groups in the present study. It is stated that fruit juices, despite having a higher initial pH compared to cola, exhibit greater erosive potential due to their titratable acidity and buffering capacities.[9,14] This could explain the relatively higher microhardness values of the cola group compared to cherry juice for compomer and GIC.

In the study, the compomer group exhibited the worst microhardness values compared to GIC and composite resin after 60-day immersion in cola and cherry juice. This result could be related to the chemistry and water absorption capacity of the tested materials. Compomers, having a higher proportion of the organic matrix, are more vulnerable to water absorption and the following surface deterioration in an aqueous environment.[25–27] Similarly, Munack et al.[11] stated that surface hardness was higher in various compomer specimens when they were kept dry. In another study, numerous pits were observed in Dyract compomer immersed in citric acid under scanning electron microscopy evaluation.[24] Authors attributed this result to hydrolytic disintegration observed in the compomer during wet storage.

There was no significant change between the microhardness of distilled water and chocolate milk groups in any restorative materials. The pH value was 6.4 for chocolate milk and 7 for distilled water. Nearly equal pH values might contribute to this finding.[28] In addition, high concentrations of calcium and phosphate could restrain the dissolution under erosion-like conditions.[29,30] However, due to the high sugar content, chocolate milk could be classified as cariogenic and is not recommended as a regularly consumed beverage for children.[28]

The composite resin group was found to exhibit the highest surface hardness in all storage media. The composition of the resin matrix and the filler percentage directly impact the microhardness of resin-based restorative materials.[8,31,32] An increased filler content contributes to reduced water absorption, consequently leading to decreased surface degradation.[16] The inclusion of UDMA and Bis-EMA in the formulation produces a more hydrophobic network.[33] 60% filler ratio by volume and hydrophobic resin network may be the reasons for superior surface hardness for Filtek Z250 composite. The microhardness of the composite resin group increased in time, as well. This situation could be explained by the progressive cross-linking reaction during the post-curing process of resin-based restorative materials.[34]

The microhardness values of the GIC group decreased significantly in all storage media after the 60-day immersion. Many studies concluded that exposure to aqueous media causes disintegration and solubility in glass ionomer cement resulting in deterioration their physico-mechanical properties.[35–37] Moreover, a higher level of erosive wear on GIC was observed in the presence of acidic solutions.[9,36,38] Diffusion of H+ ions from the solution to GIC causes dissolution of metal cations and various components in the polyacrylic acid matrix.[38] The unstable structure of the cement with rough surface and microcavities may lead to lower surface hardness.[39]

The literature review revealed conflicting results regarding the effect of tooth brushing. Some studies stated that toothpaste reduces microhardness.[40–42] On the contrary, recent research reported that the microhardness values of tested restorative materials significantly increased after the application of whitening toothpaste and tooth brushing stimulation.[43] Brushing did not cause any significant change on the microhardness of restorative materials in the present study. The ingredients of the toothpaste, differences in brushing techniques, and content of the restorative materials might have lead to differences in the findings.[43–45]

This study has some limitations. First, microhardness of the samples was measured for 60 days. However, dental restorations interact dynamically with food and beverages for long years. Besides, factors like enzymes in saliva or the the oral cavity temperature were not considered. Second, the GIC samples were prepared according to the manufacturer's recommendations by a single researcher. However, capsulated versions of GIC's could have been used to provide a better standardization than hand-mixed preparation. Third, only one brand of each dental restorative material and limited number of beverages were used to evaluate microhardness. The differences in the components of dental restorative materials and different ingredients of beverages could have lead to variance in the results. Further research is needed to understand the exact mechanisms of dental erosion.

Conclusion

The evaluation of material microhardness serves as crucial parameter due to the widespread consumption of these beverages among children, and the prolonged presence of dental restorations in the oral environment in pediatric patients. Within the limits of this study, the following conclusions could be drawn: Cola and cherry juice decreased the microhardness of compomer and GIC groups. The erosive effect of cherry juice was found to be higher than cola. In all solutions, the surface hardness of GIC group significantly decreased. Filtek Z250 composite exhibited better surface hardness values than compomer and GIC. Brushing had no impact on the microhardness of restorative materials.

Author Contributions

C.Ç and Ö.B.S.; data collection; L.Ö. and F.T.Ö.; carried out the experiment. C.Ç and Ö.B.S.; analysis and draft manuscript preparation L.Ö. and F.T.Ö.; reviewed the results and approved the final version of the manuscript.

Conflict of Interest

Authors declare that they have no conflict of interest.

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