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Comparative Evaluation of the Effect of Three Different Beverages on the Microhardness of Four Different Tooth Coloured Restorative Materials: An In-Vitro Study

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ABSTRACT

Aim

The aim of the present research is to assess how various common drinks affect the microhardness of different cosmetic restorative materials.

Materials and Methods

72 round discs of tooth-coloured restorative materials with diameter of 7mm and thickness of 2mm, were

prepared that includes 18 discs each of nanohybrid composite resin, zirconomer, resin modified glass ionomer cement and conventional glass ionomer cement. They were subdivided according to the immersion media of tea, coffee and coca cola, each consisting of 6 samples. Microhardness was measured for each disc indivisually before and after immersion regimen of 3 hours per day in the immersion medium followed by immersion in artificial saliva for the rest of the day, for 7 days.

Results

Coca Cola showed the maximum reduction in microhardness irrespective of all restorative materials. For tea and coffee, maximum decrease in microhardness was seen in RMGIC followed by GIC, zirconomer and nanohybrid composite. For cola, maximum decrease in microhardness was seen in GIC followed by RMGIC, zirconomer and nanohybrid composite.

Conclusion

Acid attack is reported to be positively related to the type of acid and the pH of the drink and thus Coca-Cola showed highest erosive effect on the restorative material.

Prolonged time and frequent contact between the beverages and restorative material increases the opportunity for erosion to occur.

Keywords

Vicker's Microhardness Test, Nanohybrid Composite Resin, Zirconomer, Resin Modified Glass Ionomer Cement.

INTRODUCTION

Nowadays, commercial soft drinks consumption is becoming popular especially among teenagers and young adults. The continuing increase in soft drink consumption among the adolescents raise a national concern, both on general and dental health. One of the most common dental related problems associated with consumption of soft drink is dental erosion. [1]

Routine consumption of snacks and drinks play a major role in dental health. Many food and drinks affect the properties of restorative materials (Mclean et al., 1994), and consumption of acidic foods and beverages is a common cause of dental erosion. Cold drinks, particularly juice boxes, are popular worldwide. (Mante et al., 1999; Wongkhantee et al., 2006). [2]

Once in the oral cavity, restorative materials are exposed to a variety of adverse conditions including the presence of acidic food and drinks (Chanothai et al., 2011). The increased incidence of dental erosion highlights the need for understanding degradation processes in restorative materials (Honorio et al., 2007).

Materials and Method

72 round discs of tooth-coloured restorative materials were prepared with the diameter of 7mm and thickness of 2mm, which included 18 discs of Nanohybrid Composite (Polofil NHT, VOCO), 18 discs of Zirconomer (SHOFU INC.), 18 discs of Resin Modified Glass Ionomer Cement (GC Gold Label II LC, Fuji II LC) and 18 discs of Conventional Glass Ionomer Cement (GC Corporation, Tokyo Japan).

- Criteria for selection of specimen:

  Inclusion criteria

  Round and Smooth surface

  Exclusion criteria:

  Any surface cracks or fracture.

PREPARATION OF SPECIMEN

- A metallic straw is used and putty impression material (Zhermack, Hydrorise) is wrapped around to make a mold of dimension 7mm in diameter and cut into a certain depth of 2mm thickness using a diamond cutting disc (JINGUANG).

- Light cure Nanohybrid Composite Resin Material is injected by their own syringes and condensed within the mold individually at the specified dimensions.
- Zirconomer, RMGIC and GIC material as supplied in powder/liquid forms, is mixed according to the manufacturers' instructions and placed into the mold so that a disc of restorative material of is formed.
- A glass slide is taken as a base over which molds are placed into which all the restorative materials are placed so that we get a smooth base for all the discs of different materials.
- The material's top surface is covered with a Mylar strip (Unident Instruments (INDIA) Pvt. Ltd.)and pressed flat to squeeze the excess material. The glass slide is held under the material firmly during setting to avoid the presence of air bubbles and to obtain a smooth surface.
- Each specimen of light cure Nanohybrid Composite Resin and RMGIC is irradiated for 40 seconds using a light-curing unit (WOODPECKER LED D).
- Zirconomer and GIC is allowed to set by auto polymerization at room temperature for at least 1 hour. After setting, the Mylar strip is removed and the surface of the specimen is left undisturbed.
- After all the specimen of restorative materials are prepared, they are subjected to Vicker's Microhardness Tester at a 100-g force for 20 seconds.
- The tea solution is formed by immersion of two tea bags (Brooke Bond, Taj Mahal) into 300 mL of boiling water for 10 mins. The coffee solution is prepared by dissolving 2 tablespoon of instant coffee (NESCAFE) powder into 300 mL of boiling water for 10 mins.
- The pH of the dietary fluids are pre measured using a standardized pH meter (HANNA pHep).
- The specimens made of tooth coloured restorative materials are divided into 4 groups each containing nanohybrid composite resin material, zirconomer, RMGIC and GIC material. Each group is containing 18 samples of the disc.

GROUP 1: NANOHYBRID COMPOSITE RESIN

GROUP 2: ZIRCONOMER

GROUP 2: RMGIC

GROUP 3: GIC

Each group of restorative material is further subdivided according to the methods of immersion in the test solutions into 3 subgroups each containing 6 number of samples

SUBGROUP A: IMMERSED IN TEA

SUBGROUP B: IMMERSED IN COFFEE

SUBGROUP C: IMMERSED IN COCA COLA

IMMERSION METHOD:

➢ The first subgroup group is immersed in 20ml of tea solution for 3 hours per day at room temperature.

- The second subgroup group is immersed in 20ml of coffee solution for 3 hours per day at room temperature.
- The third subgroup group is immersed in 20ml of coca cola (The Coca-Cola Company**)** for 3 hours per day at room temperature.
- After the immersion period, specimens from each group are rinsed with water for 20 seconds and then transferred to artificial saliva, and sored for the rest of the day, at room temperature. This immersion regimen is repeated in an uninterrupted manner for 7 days. All solutions are changed at every 24 hours before the new immersion period.
- Microhardness measurements are again obtained after the immersion regimen by using a Vickers microhardness testing machine (Leica, Walter UHL) at a 100-g force for 20 seconds. The microhardness number computed are based on the length of the indentation made on the specimens' surface where indentations are created for each specimen at the surface only.

STATISTICAL ANALYSIS

The collected data were tabulated using Microsoft Excel 2021 and analyzed with IBM SPSS Statistics for Windows, Version 27.0 (Armonk, NY: IBM Corp). A Shapiro-Wilk's test and a visual inspection of the histograms, normal Q-Q plots, and box plots showed that the collected data were approximately normally distributed for all Groups. Parametric tests such as the Paired t-test and repeated measures Analysis of Variance (ANOVA) test were employed for the Intra-group comparisons and one-way ANOVA test for inter-group comparisons. Descriptive statistics for quantitative variables were presented as a mean to represent central tendency, with standard deviation as measure of dispersion. A *P* value of ≤0.05 was considered statistically significant.

RESULTS

Table 1: Descriptive statistics and Intra-Group comparisons of the microhardness values (VHN) before and after the immersion of the specimens in specific beverages for 7 days

Groups	Subgroups	Before	After	*P* value [a]
Group I(n=18)	Tea (n'=6)	69.23±0.64	64.56±0.22	<0.0001*
	Coffee (n'=6)	67.63±0.26	61.84±0.58	<0.0001*
	Cola (n'=6)	68.52±0.55	60.66±0.77	<0.0001*
Group II(n=18)	Tea (n'=6)	68.4±0.6	60.89±0.3	<0.0001*
	Coffee (n'=6)	68.93±0.71	60.76±0.48	<0.0001*
	Cola (n'=6)	70.51±0.16	53.2±3.04	<0.0001*
Group III(n=18)	Tea (n'=6)	69.99±0.69	59.15±0.47	<0.0001*
	Coffee (n'=6)	69.73±0.6	58.76±0.11	<0.0001*
	Cola (n'=6)	69.15±0.93	56.74±0.65	<0.0001*
Group IV(n=18)	Tea (n'=6)	68.99±0.84	58.66±0.76	<0.0001*
	Coffee (n'=6)	67.68±0.74	57.55±0.77	<0.0001*
	Cola (n'=6)	67.82±0.43	55.4±0.39	<0.0001*

n:sample size per group

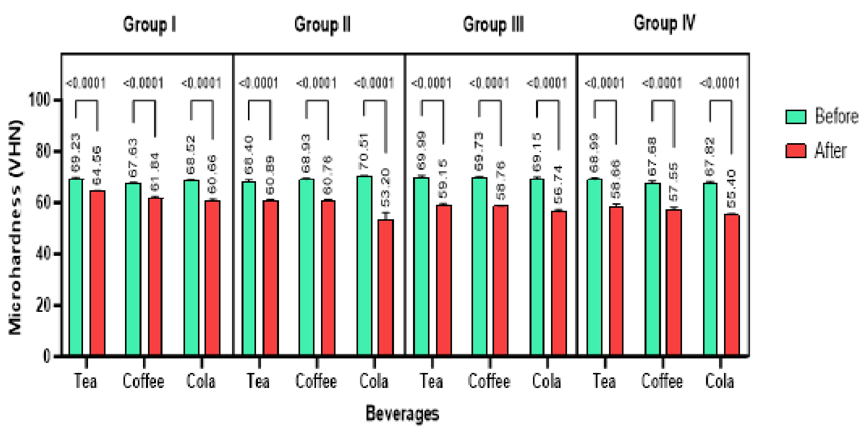
n':sample size per subgroup

a:analyzed by the Paired t-test

*: Statistically significant (*P*<0.05)

There was a significant decrease in microhardness values after immersion in specific beverages across all groups.

- In **Group I**, tea immersion led to a reduction in microhardness from 69.23±0.64 to 64.56±0.22 (*P*<0.0001), coffee from 67.63±0.26 to 61.84±0.58 (*P*<0.0001), and cola from 68.52±0.55 to 60.66±0.77 (*P*<0.0001).
- In **Group II**, the decrease in microhardness was observed with tea, from 68.4±0.6 to 60.89±0.3 (*P*<0.0001), coffee from 68.93±0.71 to 60.76±0.48 (*P*<0.0001), and cola from 70.51±0.16 to 53.2±3.04 (*P*<0.0001).
- In **Group III**, microhardness decreased with tea from 69.99±0.69 to 59.15±0.47 (***P***<0.0001), coffee from 69.73±0.6 to 58.76±0.11 (*P*<0.0001), and cola from 69.15±0.93 to 56.74±0.65 (*P*<0.0001).
- In **Group IV**, tea reduced microhardness from 68.99±0.84 to 58.66±0.76 (***P***<0.0001), coffee from 67.68±0.74 to 57.55±0.77 (*P*<0.0001), and cola from 67.82±0.43 to 55.4±0.39 (*P*<0.0001).



Bar Graph: Intra-group comparisons of the microhardness values (VHN) before and after the immersion of the specimens in specific beverages for 7 days

Table 2: Descriptive statistics and Evaluation of the effect of Beverages and the Restorative Materials on the change in the microhardness values (VHN) after the immersion for 7 days relative to the baseline values

Restorative Materials/ Beverages	Group I	Group II	Group III	Group IV	*P* value§
Tea	$4.75\pm0.49^{A,a}$	$7.72\pm0.33^{B,a}$	$10.72\pm0.82^{C,a}$	$10.43\pm1.33^{C,a}$	<0.0001*
Coffee	$5.71\pm0.64^{A,a}$	$8.32\pm0.53^{B,a}$	$10.88\pm0.6^{C,a}$	$10.26\pm1.17^{C,a}$	<0.0001*
Cola	$8.06\pm0.63^{A,b}$	$9.97\pm0.52^{B,b}$	$12.24\pm0.62^{C,b}$	$12.45\pm0.33^{C,b}$	<0.0001*
***P* value‡**	<0.0001*	<0.0001*	0.0006*	<0.0001*	

*: Statistically significant (P<0.05)

§: Inter-group comparisons (between the Restorative Materials) analysed by the one-way ANOVA test; ‡: intra-group comparisons (between the beverages within each study group) analysed by the repeated measures ANOVA test

ns:not significant (P >0.05), *: statistically significant (P <0.05), **: highly statistically significant (P<0.01)

Different lowercase superscript letters indicate a significant difference between the beverages in each study group

Different UPPERCASE superscript letters indicate a significant difference between the restorative materials in each follow-up period

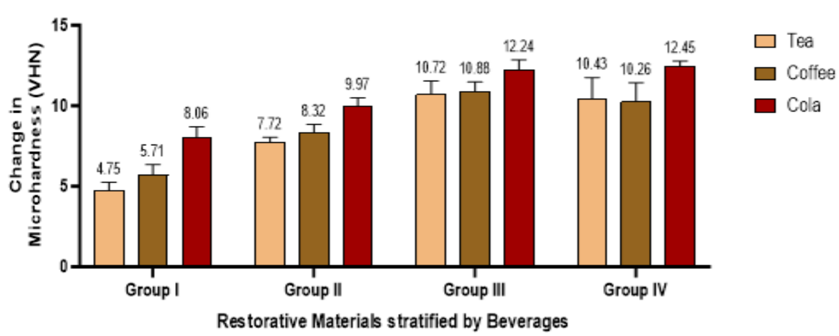
Effect of Beverages

Within each group, the pairwise comparisons of beverages revealed:

- In **Group I**, tea vs. coffee was not significant (P=0.0661), while tea vs. cola and coffee vs. cola both showed significant differences (P<0.0001).
- In **Group II**, tea vs. coffee was not significant (P=0.334), but tea vs. cola (P<0.0001) and coffee vs. cola (P=0.0007) were significant.
- In **Group III**, tea vs. coffee was not significant (P=0.9235), but tea vs. cola (P=0.0018) and coffee vs. cola (P=0.0056) were significant.
- In **Group IV**, tea vs. coffee was not significant (P=0.914), while tea vs. cola and coffee vs. cola both showed significant differences (P<0.0001).

Effect of Restorative Materials

- For **tea**, the highest decrease was seen in Group III (10.72±0.82), followed by Group IV (10.43±1.33), Group II (7.72±0.33), and Group I (4.75±0.49). Pairwise comparisons were significant between all groups (P<0.0001), except between Group III and Group IV (P=0.9008).
- For **coffee**, the highest decrease was in Group III (10.88±0.6), followed by Group IV (10.26±1.17), Group II (8.32±0.53), and Group I (5.71±0.64). Pairwise comparisons were significant between all groups (P<0.0001), except between Group III and Group IV (P=0.4594).
- For **cola**, the highest decrease in microhardness was observed in Group IV (12.45±0.33), followed by Group III (12.24±0.62), Group II (9.97±0.52), and Group I (8.06±0.63). Pairwise comparisons showed significant differences between all groups, except for Group III vs. Group IV (P=0.9589), with all other comparisons showing P<0.0001.



Bar Graph: Evaluation of the effect of Beverages and the Restorative Materials on the change in the microhardness values (VHN) after the immersion for 7 days relative to the baseline values

DISCUSSION

In the present in-vitro study, we have investigated the effect of three different dietary fluids namely tea, coffee and Coca Cola on the microhardness of four different tooth coloured restorative materials namely GIC, RMGIC, zirconomer and nanohybrid composite resin material. Artificial saliva is taken in relation to other dietary beverages to simulate the ideal oral conditions.

The restorative material discs were immersed in the above said dietary beverages for 3 hours per day, then washed with water for 20 seconds and stored in artificial saliva the rest of the day to simulate the oral conditions. This procedure was repeated in an uninterrupted manner for 7 days.

The present study focuses on a Nanohybrid Dental Composite, chosen for its advanced properties that combine the benefits of Nanofilled and traditional Hybrid Composites. It has gained significant popularity in recent years due to their excellent esthetics, improved mechanical properties, and enhanced polishability. It contains a mixture of nanometer-sized particles (typically 20–75 nm) and larger particles (0.4–1 μm), providing a balance between strength and esthetics. They exhibit higher flexural strength, improved wear resistance, and better color stability due to their unique particle size distribution and composition. The nanoparticles can fill the spaces between larger particles, resulting in a smoother surface finish and potentially reducing the risk of bacterial adhesion and staining. [3]

Glass Ionomer Cements are based on the reaction of silicate glass powder and polyalkenoic acid. They are particularly useful in treating erosive and carious lesions in low stress areas, and for this reason many modifications in these materials have been developed, such as RMGIC, dual- and tri-cured GIC, and metal-reinforced GIC. (Kenneth, 2003).

RMGIC is a light-cured combination of glass ionomer cement and composite resin. (Shabanian and Richards, 2002; Mckenzie et al., 2003). [1] It contains the same essential components as GIC, but also include a monomer component and associated initiator system. The monomer is typically Hydroxy Ethyl Methacrylate, and the initiator is camphorquinone. It sets by the twin processes of neutralization (acid-base reaction) and addition polymerization, and the resulting material has a complicated structure based on the combined products of these two reactions. [4]

Zirconomer used in the study is a new tooth-colored biocompatible restorative material developed by incorporation of nanozirconia particles in the glass component of GIC. It has the advantage of fluoride-releasing capacity of GICs along with increased strength of amalgam without the risks of mercury exposure. [5]

In RMGIC, traditional neutralization is complemented by polymerization due to the presence of side groups that can be cured through free radical mechanisms. [6]

Acids interaction depends not only on acid characters, but that it varies with the structural features of acid molecules too. H+ ions' concentration and the formation constants for soluble complexes between acid anions and metal cations in the set cement control the degree of glass-ionomer cement's erosion in organic acid solutions. [6]

Nicholson et al. demonstrated that a variety of commercial glass-ionomer cements, including one resin-modified material, were capable of increasing the pH of lactic acid solutions in which they were stored. Nicholson et al., at a later date, showed that both phosphoric and lactic acid solutions appeared relatively benign towards a glass-ionomer cement, and reported that there was a distinct buffering effect, i.e., the materials increased the pH of the medium towards neutral. Nicholson et al. also demonstrated that there is a link between buffering of aqueous lactic acid and erosive loss of conventional GIC. [6]

El-Badrawy et al. reported that phosphoric acid is capable of forming stable complexes with metal ions in the ionomer.

Okada et al. found that saliva has a remarkable effect of increasing surface hardness of Fuji IX GP with time, and reported that H2O ligand attached to aluminium and strontium ions in the hydrogel matrix of the cement could easily switch to the phosphorus ions originated from saliva. These connections would lead to the formation of a thin layer on the cement's surface, which may contain calcium phosphate and aluminium phosphate with high ionic bonding and low solubility. The authors reported that the conventional GIC absorbed some inorganic ions and increased the surface hardness. [6]

This is in contrast to the present study, where both GIC and RMGIC showed no significant increase or decrease in microhardness after immersion in the artificial saliva for 7 days uninterruptedly.

The reduction in surface hardness with Fuji II LC restorative may be attributed to the selective attack on the polysalt matrix among the residual particles. The polysalt matrix of the set cement results from the formation of contact cation-anion ion pairs or complexes between the carboxylic groups of the polyalkenoic acid and metallic ions. This study also showed Fuji II LC having less erosion compared to conventional GIC. This may be due to the formation of a leachable layer that can inhibit degradation of the material and ability to reduce the acidity of the acidic solutions. The minimal surface alteration in microhardness could also be explained by the type of beverage used for pH cycling and the time of acidic exposure. [7]

In contrast to our study, Nikolina Nika Veˇcek et al. demonstrated that glass ionomers are not softened by water immersion but rather undergo a maturation process, i.e., the continuation of the setting reaction which gradually improves the material’s mechanical properties. The finding of Equia Forte HT Fil (GC, Tokyo, Japan) shows an increase in microhardness after 30 days of immersion in distilled water. For this material, the microhardness increase amounted to 24% of its initial value.

It has been shown that a majority of leachable organic components elute from the composite resin materials within the first seven days after curing using distilled water as a solvent. With increased storage time, the filler surface and/or the filler matrix bond will be affected by the storage solution. It is also known that water and weak intraoral acids (citric and lactic acids) can damage the inorganic fillers, and phosphoric acid has the ability to etch glass particles. Silica leaches out of composite materials as a result of stress corrosion attacks upon the glass fillers, and loss of structural ions from the glass phase of polyacid-modified composites has been shown to occur by acidic attack. Degradation of the inorganic filler may play a role in reducing hardness. The leakage of filler constituents has been shown to produce cracks at the resin-filler interface, which may result in weakening of the composite material. [6]

In the present study we investigated erosion by static immersion of restorative materials in various dietary beverages for a period of 7 days while monitoring changes in microhardness. The time period was chosen to permit stabilization of acid–base reactions in the GIC and post-irradiation hardening of the composite (Mohamed-Tahir et al., 2005).

The surface microhardness of GIC samples decreased more than RMGIC and nanohybrid composite resin. These results are similar to those of Chanothai et al. (2011), who reported that composites resisted acidic solutions better than Fuji II LC.

In the present study, the surface microhardness of zirconia reinforced cement was significantly higher than conventional GIC. This may be explained due to the fact that available zirconia powders have varying additives and grain sizes, such as alumina and yttrium oxide, which can be distributed equally throughout the material or in greater quantities near grain boundaries. Zirconomer’s glass component is micronized under regulated conditions to get the ideal particle size and properties. The grain size determines a special property of zirconia known as transformation toughening, which increases its hardness, corrosion resistance, strength, and toughness. When it is evenly distributed in the glass component, it strengthens the material for long term endurance and bearing occlusal load stresses.

Gu et al. in 2005 did scanning electron microscopy experiments and discovered that the matrix of zirconomer had an excellent mixture of both large and tiny particles. There were no particle pullouts from grinding to polishing along the cross-section, indicating that the particle–hydrogel salt matrix bonding is relatively robust.

Lokhande and Shivanna in 2015 concluded that zirconia-reinforced GIC showed better microhardness compared to that of type II GIC.

Bethapudy et al. discovered that zirconomer had much higher microhardness and increased resistance to water sorption and solubility than RM GIC and type IX GIC, and it can be employed to tolerate occlusal stress as a posterior restorative material. [5]

Another possible explanation for greater degradation of Zirconomer compared to nanohybrid composite could be the presence of voids as a result of trapped air during mixing of the powder and liquid. These voids could act as an entry for water sorption causing hydrolytic degradation. [18]

Ibrahim (2011) also concluded that low pH beverages aggressively attacked RMGIC materials, while composite resins were relatively less affected. Reasons for the greater reduction in RMGIC include selective acid attack on the poly salt matrix between the residual particles and release of fluoride from the material following immersion in acidic environments. The fluoride release occurs during dissolution of the matrix-forming constituents within the material (Wilde et al., 2006).

Reduction in the microhardness of composite material may be due to hydrolytic breakdown of the silane/filler particle bond or hydrolytic degradation of the filler materials (So¨derholm et al., 1984; Medeiros et al., 2007; Bagheri et al., 2008). [1]

Several mechanisms may account for the observed reductions in surface hardness. It is likely that where the reduction in hardness is catastrophic, the effect is due to a combination of mechanisms rather than to any single one. Composite materials are known to absorb a small percentage of water which changes the magnitude of some physical properties. The surface hardness of dental composites may be significantly affected by both water absorption and the contact time with the aqueous media (Hansen, 1983). The surface of the material is affected before the bulk (Braden *et al.*, 1976). [8]

Microhardness is the parameter in this study that showed bidirectional changes with aging. This behaviour occurred because microhardness changes resulted from two concurrently occurring processes that affect the material's micromechanical properties in opposing directions: (I) the slow continuation of the setting reaction that has been reported to occur for up to one month in composites and even one year in glass hybrid cement, and (II) the gradual degradation of material structure caused by water uptake from the surrounding solution. Our results reflect the outcomes of the competition between these two processes. This was especially evident for resin composites in our study, which showed highly material-dependent behaviour where the plasticization/softening processes dominated and led to an overall microhardness reduction. [9]

The reduction in hardness is a consequence of the separation of the polymer chains by a molecule that does not form primary chemical bonds with the chain, but simply serves as a space occupier (i.e. plastification). Thus the main effect of the solvent is to reduce interchain interactions, such as entanglements and secondary bonding.

Another possibility could be the chemical degradation occurring via hydrolysis. After water or solvents enter the polymer bulk, the intrusion of water triggers chemical polymer degradation, leading to the creation of oligomers and monomers. Such progressive degradation changes the microstructure of the composite bulk through the formation of pores, via which oligomers, residual monomers, degradation products and additives are released. [10]

The unreacted monomers of the resin can also be released due to the softening action of acidic liquids. The softening effects are probably due to the combined action of the unreacted monomers and the water which is known to plasticize the resin and absorb water. Thus, the composite becomes softer because of polymer network swelling and reduced cohesion between polymer chains. [11]

An important finding in this study was that the hardness of all the materials was significantly reduced between day 1 and day 7. In the case of RMGIC this may be due to a negligible amount of residual particles remaining available for further acidic attack and in the composite materials no further hydrolytic breakdown of the bond between the silane and filler particles was possible.

In general, regardless of the type of low pH beverages used, all the restorative materials showed statistically significant reduction in surface microhardness results after 7-days immersion duration. This may be due to liquid absorption, and the plasticizing effect of water molecules inside the resin matrix, leading to expansion of the matrix and softening of the resin polymer, decreasing the frictional forces between the polymer bands. [12]

This result agree with Lim et al., and Han et al., who found that any portion of the organic matrix resin which is insufficiently polymerized can be dissolved by alcoholic and acidic solutions, and particles can thus easily fall out. They gave another possible cause of surface degradation which was that the filler and matrix resin were too weakly bonded. This might be related to the surface treatment of fillers, whereby insufficient surface treatment with silane was thought to result in filler erosion.

The results of the present study disagree with Yap et al., who measured surface hardness of several types composite resin in artificial saliva, citric acid, lactic acid, ethanol and heptanes. They suggested that there was an increase in hardness of composite after storage in artificial saliva and citric acid. The difference in the results of Yap et al., and the results of the present study may be because of the methodology of specimens' preparation.

In the present study, following specimens' polymerization, they were immediately immersed in the test solution for 3 hours followed by artificial saliva without any treatment for 24 hours, which was repeated for 7 days. In Yap et al.'s methodology, the specimens were stored in artificial saliva for 24 hours following polymerization to allow elution of unreacted components from the composite and to allow for post cure. Then the specimens were conditioned in the storage media for 7 days.

In the present study, elution of leachable unreacted components was in the storage media which leads to differences in the results between this study and Yap et al. [10]

The specimens were not exposed to any mechanical forces so any observed change in hardness would be a chemical reaction or dissolution. In the oral cavity, restorative materials are exposed to varying environments. Such variables are changes in temperature and acidic-base conditions from food and drinks. Therefore, the restorative materials used in the mouth should resist or show minimal change in these situations.

Degradation of the resin-filler interface and inorganic fillers also decrease the surface hardness. This explains why nanohybrid resin composite shows decrease hardness when exposed to beverages. The types of resin are influenced by water absorption of polymer-based materials. HEMA absorbs more water than one like bis-GMA. The water absorption of materials is affected by filler loading and with higher filler loading material expecting to show a lower uptake. The presence of voids during the mixing or producing these materials is the factor which influences water absorption of polymer-based tooth-coloured filling materials. [13]

Two factors are of substantial importance in the fluid sorption and surface erosion of materials. The first factor is filler loading which affects the microvoids and available free volume for fluid absorption. The higher amount of filler loading generates less micro-voids and reduces the available free volume for fluid uptake. Therefore, in the dental materials with higher filler loading, the erosion and softening may decrease after immersion in the beverages.

Monomer type is another factor to be considered in the fluid sorption procedure of the dental restorative materials. Different hydrophilicities exist between the monomers which form the resins of composites. Higher hydrophilicity is indicative of higher fluid sorption in the monomers. For example, the hydrophilicity of TEGDMA monomer is higher than both Bis-GMA and UDMA. Thus, the absence of TEGDMA decreases the fluid sorption in the composite

This finding may explain the significant decrease in both compressive strength and hardness values of nanohybrid resin composite immersed in Coca-Cola due to the presence of TEGDMA monomer in its composition. [14]

As a strength, the study demonstrates that the restorative material discs presented a standardized surface microhardness at the beginning of the study, as they presented similar values before being immersed. In addition, the microhardness was evaluated with the Vickers test, which, in comparison to the Brinell or Rockwell machines, is more accurate. 7 days of immersion was used, which is equivalent to 3 months of daily consumption; furthermore, the beverages used had their usual drinking temperature, which would reflect daily conditions. [17]

CONCLUSION

The study provides valuable insight into how different carbonated beverages affect the microhardness of restorative materials, which is critical in clinical dental practice and assist the clinicians in making more informed decisions when selecting restorative materials for patients with dietary habits that involve frequent consumption of carbonated drinks. It highlights the importance of educating patients on the potential erosive effects of these beverages on dental restorations, thereby contributing to improved treatment longevity and long-term oral health. [15]

Due to the acidity and erosive potential of various dietary beverages, the restorative materials were immersed in them for 3 hours a day, washed with water and then stored in artificial saliva for the rest of the day to simulate the washing effect of saliva in the oral cavity. [16]

LIMITATIONS

The limitations of the current study include incomplete replication of the complex oral environment and disregard for the effects of thermocycling.

The immersion period in these beverages lasted only 7 days, which is relatively short compared to long-term, real-life consumption. In a clinical scenario, only one side of a dental restoration is typically exposed to the oral environment, whereas in this research, the entire sample was submerged, allowing both sides to come into contact with the beverages.

Additionally, real-world factors such as fluctuations in pH and heat level in the oral cavity, as well as the natural aging of materials, were not fully simulated. Since this was an in vitro study, it did not account for the impact of other food and beverages consumed daily, which may also influence the features of resin based materials. Therefore, further in vivo research is necessary to better understand the long-term effects of sports and energy beverages on dental restorations. [11]

REFERENCES

1. Ibrahim M. Hamouda, PhD Effects of Various Beverages on Hardness, Roughness, and Solubility of Esthetic Restorative Materialsjerd_453 315..322 Journal of Esthetic and Restorative Dentistry Vol 23 • No 5 • 315–322 • 2011 Wiley Periodicals, Inc. *DOI 10.1111/j.1708-8240.2011.00453.x*
2. Poggio C, Viola M, Mirando M, Chiesa M, Beltrami R, Colombo M. Microhardness of

different esthetic restorative materials: Evaluation and comparison after exposure to acidic drink. Dent Res J 2018;15:166-72.

3. Shetty P, Jayakumar HDN, Pulickal TJ, *et al*. Effects of Various Solutions on Color Stability and Surface Hardness of Nanohybrid Dental Composite Under Simulated Oral Conditions. J Contemp Dent Pract 2024;25(7):669–676.
4. Sharanbir K. Sidhu 1 and John W. Nicholson et al. A Review of Glass-Ionomer Cements for Clinical Dentistry J. Funct. Biomater. 2016, 7, 16; doi:10.3390/jfb7030016
5. Kour T, Shahi P, Sogi S, *et al*. Comparative Evaluation of Surface Microhardness of Zirconia-reinforced Glass Ionomer Cement and Conventional Glass Ionomer Cement after Immersion in an Acidic Drink: An *In Vitro* Study. Int J Clin Pediatr Dent 2025;18(1):6–12.
6. Yavuz GOMEC, Can DORTER, Handan ERSEV1, Begum GURAY EFES and Esra YILDIZ et al. Effects of Dietary Acids on Surface Microhardness of Various Tooth-colored Restoratives, Dental Materials Journal 23 (3): 429-435, 2004
7. Arun M. Xavier et al. Repeated exposure of acidic beverages on esthetic restorative materials: An in-vitro surface microhardness study J Clin Exp Dent. 2016;8(3):e3127. Journal section: Esthetic Dentistry doi:10.4317/jced.52906
8. R.G. ChadwickJ.F. McCabeA.W.G. Walls R. Storer et al. The effect of storage media upon the surface microhardness and abrasion resistance of three composites Dent Mater 6:123-128, April, 1990
9. Veˇcek, N.N.; Par, M.; Sever, E.K.; Mileti´c, I.; Krmek, S.J. The Effect of a Green Smoothie on Microhardness, Profile Roughness and Color Change of Dental Restorative Materials. Polymers 2022, 14, 2067. https://doi.org/10.3390/polym14102067
10. Dr. Zahraa Nazar Al-Wahab et al. An evaluation of the effect of different solutions onthe microhardness of aesthetic restoration Vol.:8 No.:2 2011
11. Aya Omar Tawfik et al. Evaluation Of Microhardness And Color Change Of Tooth-Colored Restorative Materials After Cyclic Immersions In Sport And Energy Drinks: In Vitro Study , Doi : 10.21608/Edj.2025.365501.3410
12. Abouelmagd and Basheer et al. Microhardness evaluation of microhybrid versus nanofilled resin composite after exposure to acidic drinks Journal of International Society of Preventive and Community Dentistry ¦ Volume 12 ¦ Issue 3 ¦ May-June 2022
13. Bhatia CM, Chandak M, Rahul A, Sedani S, Chandak R, Adwani N, *et al*. Comparative evaluation of effect of different beverages on surface hardness of nanohybrid resin composite: An *in vitro* study. J Interdiscip Dentistry 2016;6:60-3.
14. Reham M. Abdallah And Neven S. Aref et al. Compressive Strength, Microhardness And Microleakage Of Bulk Fill Resin Composite Immersed In Different Beverages E.D.J. Vol. 62, No. 3
15. Estrada-Villarroel et al. Surface microhardness of three Bulk Fill resin composites previously exposed to five carbonated beverages at different

times: an in vitro study BMC Oral Health (2025) 25:1635 https://doi.org/10.1186/s12903-025-07055-2

16. Surface hardness evaluation of different composite resin materials; influence of sports and energy drinks immersion after a short-term period http://dx.doi.org/10.1590/1678-7757201302185 J Appl Oral Sci. 2013;21(2):124-31
17. In vitro comparison of the surface microhardness of three nanohybrid resin composites immersed in different pigmented beverages for varying exposure times Wendy Ayala-Amaya Journal section: Biomaterials and Bioengineering in Dentistry doi:10.4317/jced.62640
18. Chong Hao Phin et al. Effect of Alcoholic Beverages on the Surface Microhardness of Three Restorative Materials J Int Dent Med Res 2020; 13(4): 1268-1275