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Effects of Beverages on Microhardness of a New Restorative Material Coated with a Surface Sealant

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ABSTRACT

Objective: Many factors in the mouth affect the clinical lifetime of materials. Acids, enzymes, acidic properties of food and beverages formed in the plaque could change the physicochemical properties of restorative materials. The aim of the study is to examine the effect of acidic beverages on the microhardness of alkasites, and conventional glass ionomers, with changes in surface coating applications. **Materials and Methods:** Forty specimens in eight mm diameter and two mm thick discs were made with each Cention N and Ionofil U. Half of the specimens were covered with surface sealant. In each of the four subgroups: cola, orange juice, sparkling mineral water and distilled water, 10 discs were stored for 5 minutes, three times a day for a week. Microhardness measurements were made after they were kept in an acidic environment. **Results:** Acidic beverages significantly reduce the microhardness of restorative materials. The highest microhardness value was observed in the Cention N group with surface sealant. The lowest microhardness value was observed in the Ionofil restorative material group without sealant. **Conclusion:** The acidic agents tested (cola, orange juice, and sparkling mineral water) have an effect on the reduction of surface microhardness of restorative materials. For clinical decision-making, Cention N is the most suitable material for restorations in patients who are at high risk for erosive conditions.

Keywords: Glass Ionomer, hardness tests, food and beverages, dental sealants.

İçeceklerin Yüzey Örtücüsü Uygulanmış Yeni Bir Restoratif Materyalin Mikrosertliği Üzerine Etkileri

ÖZ

Amaç: Ağızdaki birçok faktör, malzemelerin klinik ömrünü etkilemektedir. Asitler, enzimler, plakta oluşan yiyeceklerin ve içeceklerin asidik özellikleri restoratif malzemelerin fizikokimyasal özelliklerini değiştirebilmektedir. Çalışmanın amacı, asidik içeceklerin alkasitlerin mikrosertliği ve geleneksel cam iyonomerler üzerindeki etkisini, yüzey örtücü uygulamaları ile değişimlerinin incelenmesidir. **Gereç ve Yöntem:** Sekiz mm çapında ve iki mm kalınlığında disk şeklindeki kırk örnek Cention N ve Ionofil U ile hazırlandı. Örneklerin yarısı yüzey örtücü ile kaplandı. Kola, portakal suyu, maden suyu ve distile su olmak üzere dört alt grupta her birinde 10 disk olacak şekilde bir hafta boyunca günde üç kez 5 dakika saklandı. Mikro sertlik ölçümleri asidik bir ortamda tutulduktan sonra yapıldı. **Bulgular:** Asidik içecekler restoratif malzemelerin mikrosertliğini önemli ölçüde azaltmıştır. En yüksek mikrosertlik değeri, yüzey örtücüsü kullanılmış Cention N grubunda gözlenmiştir. En düşük mikrosertlik değeri, yüzey örtücüsü kullanılmayan İononofil U grubunda gözlenmiştir. **Sonuç:** Test edilen asidik ajanlar (Kola, portakal suyu ve köpüklü mineral suyu) restoratif malzemelerin yüzey mikrosertlikleri üzerinde azaltıcı bir etkiye sahiptir. Klinik kullanım açısından Cention N, eroziv koşullarda yüksek risk altında olan hastalarda restorasyonlar için en uygun materyaldir.

Anahtar Kelimeler: Cam iyonomer, sertlik testleri, yiyecek ve içecekler, dental örtücüler.

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INTRODUCTION

The physical properties of materials used in dentistry are continuously under development. Many factors in the mouth affect the clinical lifetime of materials. One of them is the changes in the physical properties of the materials caused by the acidic environment (Szczesio-Wlodarczyk et al., 2020). Acids, enzymes, and acidic properties of food and beverages formed in the plaque change the physicochemical properties of restorative materials by lowering the pH of the environment (Szczesio-Wlodarczyk et al., 2020).

Glass ionomer cements, which have been in use for a long time, are distinguished from other restoratives by their sensitivity to moisture, relatively low mechanical properties, and less translucency (Tan et al., 2015; Xie et al., 2000). With the introduction of high viscosity glass ionomers, it is aimed to overcome the disadvantages of the mechanical properties of the conventional glass ionomers (Shiozawa et al., 2014). However, the properties of dimensional stability and fluor release made the conventional glass ionomer restorative materials still in use frequently today (Baig & Fleming, 2015).

Recently a new material released in the market, named as alkasites, contains calcium fluorosilicate glass and barium-aluminum silicate glass powders and urethane dimethacrylate monomer and derivatives. It is placed in the subgroups of resin composites in classification (Francois et al., 2020). The material can reach its final hardness with chemical reaction, as well as with light (Fousiya et al., 2022). In an acidic environment, it releases ions such as calcium, hydroxide and fluoride, which will increase the ambient pH of the particles in the powder part (Kim, 2022). It has been known for a long time that consumption of foods or drinks may reduce the hardness of dental hard tissues. Acidic drinks can cause erosion in the hard tissues of the teeth due to the consumption of fresh fruits and the acids in their contents (Wongkhantee et al., 2006). Similarly, it also causes degradation and wear of restorative materials, but also affects the life of the material in the mouth (Yap et al., 2021). The degradation of restorative materials cannot be explained by abrasion alone. Chemical degradation also plays a role. In the mouth, material is intermittently or continuously exposed to sources that can cause chemical degradation, such as saliva, food and beverages (Wongkhantee et al., 2006). The aim of our research is to examine the effect of acidic beverages on the microhardness of alkasites, and conventional glass ionomers, with changes in surface coating applications. The hypothesis of our research is that beverages with low pH change the physical properties of bioactive restorative materials.

MATERIALS AND METHODS

This in vitro study hold in November 2022, Istanbul University-Cerrahpaşa, Faculty of Dentistry. In order to examine the effect of two bioactive restorative materials of the same color, coated and uncoated, on the surface microhardness of the materials, 8 mm diameter and 2 mm thick samples were obtained in accordance with the recommendations of the manufacturers (Table 1). After the materials were placed in Teflon molds, they were closed with Mylar tape. After the overflowing part was removed, it was closed with a glass coverslip until its hardening was completed (Valo Grand, Ultradent, USA). The setting time of Ionofil U was 2.5 minutes, and the setting time of Cention N material was 4 minutes.

Table 1. Materials used in the present study.

Product	Type of material	Composition	Manufacturer
Cention N	Alkasite	· UDMA · DCP · Aromatic aliphatic UDMA · PEG-400 DMA · Barium aluminium silicate glass · Ytterbium trifluoride · Isofiller · Calcium fluorosilicate glass · Calcium barium aluminium fluorosilicate glass	Ivoclar Vivadent, Schaan, Liechtenstein
Ionofil U	Glass Ionomer	Calcium-alumino-fluorosilicate glass, Polyacrylic acid, tartaric acid, water	Voco GmbH, Cuxhaven, Germany
EQUIA Forte Coat	Surface Sealant	Methyl methacrylate, camphorquinone	GC, Tokyo, Japan

The sample size was calculated considering 95% power and a significance level of 0.05. The total sample size was calculated to be 28 (n : 7). Since the lowest sample size of each material was calculated as 7. 10 samples were prepared for each group, in this study. It was prepared as 80 samples of each material. The discs obtained were divided into two groups, each containing 40 samples from each material, surface sealant was applied to the surfaces of the samples in one group after the materials have completed their hardening period, and no other treatment was applied to the samples in the other group (Figure 1). Resin containing surface sealant material polymerized for 20 seconds using a light device (Valo Grand, Ultradent, USA). The hardening of the materials was stored at 37 °C in a humid environment for 24 hours. From the obtained groups, 4 subgroups were formed so that 10 discs would fall into each group. The samples in the first group were kept in cola (Coca Cola; The Coca-Cola Company, Istanbul, Turkey), the second group in orange juice (Cappy 100% Orange Juice, The Coca-Cola Company, Bursa, Turkey) the third group in sparkling mineral water (Uludag Turkish Limited Co, Bursa, Turkey), and the fourth group in distilled water for 5 minutes three times a day for a week. All of the samples were kept in distilled water outside the acidic aging times (Tedesco et al.,2018).

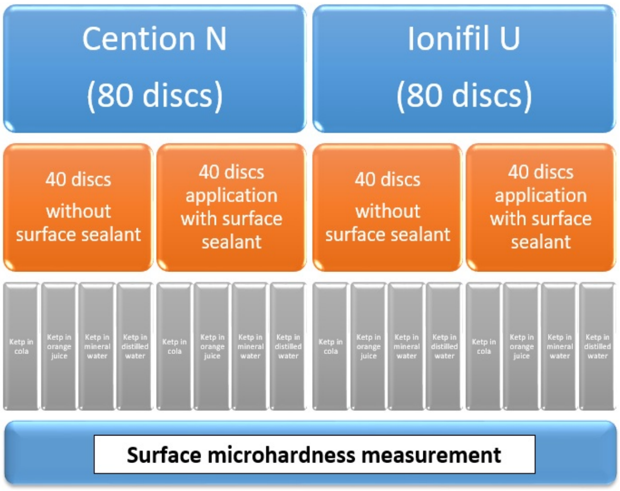

Figure 1. Flowchart of the study

Surface microhardness measurements

A microhardness testing machine (HMV-2; Shimadzu, Kyoto, Japan) was used to measure the Vickers hardness number (VHN) of each sample. Vickers microhardness levels were measured at 100g and 10 seconds. The value obtained by taking five measurements from each sample and taking the average of the values was included in the statistical analysis. Measurements were made after they were kept in an acidic environment for 7 days.

Statistical analysis

The normality of the results was checked with the Shapiro-Wilk test. The homogeneity was confirmed by the Levene test. The differences between the groups examined with the One-way ANOVA test were determined by the Tukey post hoc test. All analyzes were performed at an overall significance level of 0.05, using Statistical Package for Social Sciences (SPSS) 20 (IBM, Armonk, NY, USA).

Ethics approval

Our study is an in vitro microhardness analysis study. Ethical approval is not required.

RESULTS

The microhardness values of the study groups are shown in Table 2. The highest microhardness value was observed in the Cention N group with surface sealant. The lowest microhardness value after acidic aging was observed in the Ionofil U restorative material group without sealant. In the groups kept in different liquids, higher microhardness value was determined in the groups that were applied sealant compared to those without sealant. No statistically significant difference was observed between the microhardness values in the Cention N group, which was treated with a surface sealant kept in different beverages ($p>0.05$). Microhardness values were found to be statistically significantly lower in the Cention N group without surface sealant between the groups kept in cola and mineral water than in the groups kept in other solutions ($p<0.05$). There was no statistically significant difference between the microhardness values of Ionofil U groups, which were kept in different solutions with and without surface sealant ($p>0.05$). In the groups kept in distilled water, the Cention N group with application of surface sealant showed statistically the highest microhardness value ($p<0.05$), while the Ionofil U group without surface sealant showed the lowest microhardness value ($p<0.05$). In the groups kept in orange juice, the highest microhardness value was observed in Cention N group with surface sealant applied ($p<0.05$), while the lowest microhardness values were observed in Ionofil U groups with and without surface sealant ($p<0.05$). While the highest microhardness value was found in the Cention N group, which was with applied surface sealant, among the groups kept in colas ($p<0.05$), no significant difference was observed between the other groups ($p>0.05$).

In the groups kept in mineral water, the highest microhardness value was observed in the Cention N group with surface sealant applied, while the lowest microhardness values were determined in the Ionofil U groups with and without surface sealant.

Table 2. Mean surface microhardness values of restorative materials after immersion in various storage media over a period of 7 days.

Restorative Material	Surface sealer	Distilled water	Orange juice	Cola	Mineral water	p
		Mean±(SD)	Mean±(SD)	Mean±(SD)	Mean±(SD)	
Cention N	+	62.53±(2.69)aA	62.61±(2.20)aA	60.81±(3.51)aA	61.73±(1.65)aA	0.610
Cention N	-	55.68±(2.19)aB	52.15±(3.22)aB	48.11±(2.23) bB	50.38±(3.07)bB	0.001
Ionofil U	+	47.45±(1.46)aC	46.60±(1.94)aC	45.68±(2.19)aB	45.78±(1.25)aC	0.297
Ionofil U	-	45.01±(2.03)aD	43.76±(1.07)aC	42.50±(1.06)aB	43.01±(1.62)aC	0.054
p		0.000	0.000	0.000	0.000	

*One-way ANOVA, A statistically significant difference at 0.05 level of significance ($p<0.05$). **One-way ANOVA, Different uppercase letters mean statistically significant differences in column ($p<0.05$). Different lowercase letters mean statistically significant differences in lines ($p<0.05$).

DISCUSSION

The clinical life of composite resin or glass ionomer cements is highly dependent on the correct identification and evaluation of materials, as well as influencing the success of oral rehabilitation.

The surface hardness of a restorative material is an important parameter that affects the mechanical properties (Schulze et al., 2003). The surface hardness of the material is directly related to the abrasion, and the low surface hardness causes the surface roughness of the material to increase. In the clinic, this can lead to material discoloration, secondary caries, plaque accumulation, and susceptibility to gingival irritation (Baseren, 2004; Mandikos et al., 2001; Poggio et al., 2012). The aim of our study is to evaluate the effects of acidic beverages, which are frequently consumed in daily life, on the changes in the surface hardness of bioactive restorative materials, as well as the changes in the surface hardness of the material by surface sealants. The chemical composition of the material and the glass filler size are important factors for the surface hardness of restorative materials (Hamid et al., 2018). In this study, the restorative material, which is a new type and classified as alkasite, and the traditional glass ionomer restorative material used in the clinic were stored in an erosive acidic environment. In the current study, surface hardness decreased after the materials were exposed to an acidic environment. Conventional glass ionomer restorative material is more affected by the acidic environment compared to Cention N restorative material which reveals that fillers (calcium-alumino-fluorosilicate glass) contained in the material without resin matrix are more susceptible to deterioration.

Cention N material, which is included in the classification of composites with an alkaline property, was used as well as conventional glass ionomer cements (Donly & Liu, 2018). Commercial Cention N® contains three different glass compositions, including an inert barium alumino-boro-silicate glass, a calcium fluoro-alumino-silicate glass, and a reactive SiO_2-CaO-CaF_2-Na_2O glass (Khalid et al., 2021). In vitro studies have shown that this restorative material contains a reactive glass that releases Na^+, Ca^{2+}, and F^- ions, raising the pH, and showing apatite formation when immersed in artificial saliva (Donly & Liu, 2018).

It is known that cola and orange juice used in acidic aging have erosive potential in the clinic (Scaramucci et al., 2011; West et al., 1998). Cola contains phosphoric acid and its titration is low. Orange juice contains citric acid, which has a high titration and buffering capacity (Francisconi et al., 2008). Mineral waters contain a wide variety of mineral compositions. The presence of these ions may affect the dissolution balance of biological apatite in enamel and hydroxyapatite. It also suggests that it can create changes in the properties of the restorative material (Parry et al., 2001). Therefore, a mineral water that was available on the market, was used as another experimental group in addition to cola and orange juice in this study.

In addition, in previous studies evaluating the effect of erosive agents on the surface properties of materials, distilled water was used as a control group (Arafa et al., 2022; Culina et al., 2022; Hamouda, 2011; Tanweer et al., 2022). Ilday et al. used baseline measurements as a control group to evaluate the effects of acidic solutions on materials (Ilday et al., 2013). In this study, distilled water was used as the control group, since our primary aim was to determine the effects of acidic solutions on materials and to compare the differences between acidic beverages.

In previous studies, the exposure time of samples to acidic beverages was specified as 1, 3 and 4 weeks (Scribante et al.,2020; Tedesco et al., 2018). Considering previous studies, the pH cycle model used by Tedesco et al. was applied to the samples in this study (Tedesco et al., 2018).

It is stated that acidic beverages significantly reduce the hardness of restorative materials and resin modified glass ionomer cements show a greater loss of hardness than resin composites. It is thought that hydrophilic organic matrices experience more hydrolysis and the reduced hardness rates are due to hydrolysis. Corrosive wear begins with the absorption of water, which is accelerated by the low pH of the material and diffuses through the resin matrix, filler interfaces, pores, and other pathways. The rates of chemical degradation of different materials are mainly dependent on the hydrolytic stability of the resin matrix. Due to the very low water absorption of the resin matrix of the composites, they are more resistant to acidic wear than hydrophilic materials such as resin modified glass ionomer cements (Asmussen, 1984; Ferracane, 2006; Mohan, 2008; Prakki et al., 2005; Sarkar, 2000).

It has been shown that immersion of Ketac-S metal-reinforced glass ionomer cement, Fuji II LC resin modified glass ionomer cement, Valiant-PhD amalgam and Filtek Z250 resin composite, which is frequently used in the restoration of teeth with erosive conditions, in acidic agents can reduce the surface hardness (Hengtrakool et al., 2011). The decrease in the microhardness values of the materials may vary depending on the titratable acidity of the acidic agent, the composition of the material and the differences in the curing reaction (Tedesco et al., 2018). In addition, bioactive restorative materials may show additional fluoride release after immersion in acidic environments, which may cause the dissolution of matrix-forming components in the restorative material, resulting in decreases in their mechanical properties (Hengtrakool et al., 2011). In the present study, the surface hardness of conventional glass ionomer stored in an acidic environment was found to be lower than that of the other restorative material group. In addition, the lowest microhardness value was determined in the cola with the lowest pH value.

It has been reported that ion release is reduced in different sizes by coating the restorative materials with hydrophobic resin (Mazzaoui et al., 2000). It has been reported that resin-coated glass ionomer cements release 45-78% less fluoride than uncoated specimens, while adhesive coating reduces fluoride release by 91-96% in fluoride-releasing composites (Mazzaoui et al., 2000). In a study, it was reported that the adhesive coating creates a barrier for fluoride and Ca ion release from restorative materials in an acidic environment (Gubler et al., 2022). Placing a protective coating on restorative materials can be beneficial in ensuring long-term clinical success in an acidic environment, especially with the abrasive effect of tooth brushing that occurs in class V restorations (Hamid et al., 2018). In the present study, the microhardness of two different bioactive materials in the adhesive coated and uncoated groups in three different acidic environments was compared. The microhardness values of the adhesive applied groups were higher. This suggests that the surface sealant contributes to the surface hardness by preventing ion release from the material. These findings are consistent with previous studies (Faraji et al., 2017; Fatima et al., 2013; Zoergiebel & Ilie, 2013).

Limitations of study

The limitation of the current study is that it is an in vitro study, as the performance and outcome of the restorative material differs from in vivo oral conditions. Unlike the performance of the restorative material in an in vitro study, the oral condition simulation of temperature and the buffering capacity of saliva cannot be sustained. Within the limitation of this study, the following findings were drawn:

- The acidic agents tested (cola, orange juice, and mineral water) have an effect on the reduction of surface microhardness of restorative materials.
- Cention N was more resistant to acid attacks and was better than traditional glass ionomer cement (Ionofil).
- Surface coating application positively affects the surface hardness of the material in an acidic environment.,
- For clinical decision-making, Cention N is the most suitable material among the materials tested in patients who are at high risk for erosive conditions

CONCLUSIONS

The surface sealant application is not the only factor affecting the surface hardness of the restorative material. The chemical composition of the material and the glass filler size are also important factors. In addition, the mechanical properties of the material exposed to the acidic environment change depending on the pH of the acidic beverage.

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Conflict of Interest

The author declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Author Contributions

Plan, design: BG, SB; **Material, methods and data collection:** BG, SB; **Data analysis and comments:** BG, SB; **Writing and corrections:** BG, SB.

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