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Does Different Application Procedures Effect Hardness of Self Adherable Materials?

Farklı Uygulama Prosedürleri Kendinden Bağlanabilen Restoratif Materyallerin Sertliğini Etkiler mi?

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Abstract

Objective: To assess the effect of application procedures on the hardness of self-adherable materials after energy drink exposure.

Materials and Methods: Alkasite (self-cured), alkasite (dual-cured), (HGI), HGI + coating, HGI + heating, (GC), GC + coating, GC + heating, and nanohybrid composite (control) used. Samples from the main group were distributed into three subgroups (n=12): Red Bull, Burn, artificial saliva. The samples were dipped in solutions 2-min daily, up to 6 months. Surface hardness measurements were done after the specimen preparation and after they were kept in the solution for 1 week, 1 month and 6 months. Statistical analyses were done with Friedman tests, Kruskal-Wallis and Bonferroni post hoc tests ($p<0.05$).

Results: Dual-cured alkasite presented lower changes in Vickers hardness number after 6 months of immersion than self-cured alkasite ($p<0.05$). Coating application on HGI resulted in hardness advancement and coating application on GC significantly reduced hardness decrease in the Red Bull and Burn subgroups ($p<0.05$). Heating application, significantly decreased the hardness reduction in both HGI and GC ($p<0.05$).

Conclusion: Both coating and heating procedures on HGI may protect the hardness. Also, coating was more effective on HGI than on GC. Heating can be preferred than coating for GC. Dual-cured alkasite may present more resistance than self-cured alkasite

Keywords
Energy drinks, alkasite, glass ionomer, surface hardness, glass carbomer

Anahtar Kelimeler
Enerji içeceği, alkasit, cam iyonomer, yüzey sertliği, cam karbomer

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Öz

Amaç: Çalışmanın amacı farklı sertleştirme prosedürlerinin, enerji içeceklerine maruz kaldıktan sonra restoratif materyallerin sertliği üzerindeki etkisini değerlendirmektir.

Gereç ve Yöntemler: Alkasit (self-cured), alkasit (dual-cured), hibrit cam iyonomer (HGI), HGI + kaplama, HGI + ısıtma, cam karbomer (GC), GC + kaplama, GC + ısıtma ve nanohibrit kompozit (kontrol) kullanıldı. Her grup üç alt gruba ayrıldı (n=12): Red Bull, Burn, yapay tükürükte bekletme. Örnekler 6 ay boyunca günde 2 dakika solüsyonlara daldırıldı. Yüzey sertliği değerlendirmeleri başlangıçta, 1 hafta, 1 ay ve 6 ay sonra yapıldı. İstatistiksel analizler Friedman testi, Kruskal-Wallis ve Bonferroni post-hoc testleri kullanılarak yapıldı ($p<0,05$).

Bulgular: Dual sertleşmiş alkasit, 6 aylık bekletme sonrasında kendi kendine sertleşen alkasite göre Vickers sertlik sayısında (ΔVHN) daha düşük değişiklikler

gösterdi (p<0,05). Red Bull ve Burn alt gruplarında HGI üzerine kaplama uygulaması sertlik artışı ile sonuçlanmış ve GC üzerine kaplama uygulaması sertlik düşüşünü önemli ölçüde azaltmıştır (p<0,05). Isıtma uygulaması hem HGI hem de GC'de sertlik azalmasını önemli ölçüde azaltmıştır (p<0,05).
Sonuç: HGI üzerinde hem kaplama hem de ısıtma işlemi materyal sertliğini koruyabilir. Ayrıca kaplama uygulaması HGI üzerinde GC'ye göre daha etkili olmuştur. GC için kaplama yerine ısıtma uygulaması tercih edilebilir. Dual sertleşen alkasit, kendi kendine sertleşen alkasite göre daha fazla direnç gösterebilir.

Introduction

In an attempt to overcome drawbacks of conventional glass ionomers, such as prolonged setting time, dehydration, initial moisture sensitivity, enhanced high viscous glass hybrid materials have been developed (1,2). This glass technology has been modified with ultrafine, reactive glass particles and built up a much stronger matrix structure which allow extended indications of use even in stress-bearing areas (3). Also, nanotechnology offers a glass ionomer subgroup which is called glass carbomer. Material contains nano-sized powder particles and fluorapatite (4,5).

Since restorative materials are faced with many different erosive stimuli in oral environment, it has become important to strengthen mechanical properties with some additional applications. One of the additional enforcement is the use of heat. Heat application can be performed by using high-energy LED, halogen light source or ultrasonic excitation and it is expressed that heating significantly increases hardness of glass ionomers (6,7). An alternative application that has been shown as reinforcement is surface coating (8).

Another novel self adherable material, which stands out with its high compressive strength is alkasite. This product incorporates dimethacrylates in liquid and glass fillers, initiators, and pigments in powder (9-11). Setting reaction of this material can be done by two mechanisms: Self-cure and dual-cure (10).

Energy drinks, which are commonly preferred by students, long way drivers and athletes, have an erosive affect on restorative materials (11). It is reported that energy drinks may decrease the hardness of restorations due to their low pH and buffering capacity (11,12). However, there are few studies in literature about how heating or coating effect mechanical properties of glass ionomers.

Therefore, the aims of this study were to determine the effect of energy drinks on hardness regarding to additional heating or coating application on glass ionomers and different setting reaction mechanisms of alkasite (1,2). The following null hypotheses tested were: There would be no differences in the hardness of glass ionomers when coating or heating is applied; there would be no differences in the hardness of the alkasite whether hardened with self-cure or dual-cure (1,2).

Materials and Methods

In the power analysis (F=0.5), it was determined that 80% power could be obtained at 95% confidence level when at least 12 samples were taken per group in the study.

Three hundred and twenty four samples were prepared using a disc-shaped mold according to the manufacturer instructions (Table 1). Artificial saliva was prepared using 0.33 g of KH_2PO_4, 0.34 g of Na_2HPO_4, 1.27 g of KCl, 0.16 g of NaSCN, 0.58 g of NaCl, 0.17 g of $CaCl_2$, 0.16 g of NH_4Cl, 0.03 g of glucose, 0.2 g of urea, 0.002 g of ascorbic acid and 2.7 g of mucin in 1000 mL of distilled water. For the complete polymerization, specimens were stored in artificial saliva (37 °C, 24 hours) (13).

Dry polishing regimen was applied to the upper surfaces of all specimens with aluminum oxide impregnated discs by applying a light hand pressure, using a 10,000 rpm micromotor at low-speed. For the glass ionomer based materials, coatings were applied before and after polishing. Each group was randomly divided into three subgroups (n=12 per group) according to following immersion solutions: Red Bull (pH: 3.81, Red Bull GmbH, Austria); Burn (pH: 3.03, The Coca-Cola Company, Atlanta, GA, USA) and artificial saliva.

Before experiment, pH of energy drinks was measured with a pH meter (Waterproof pHep® 5 pH/Temperature Tester, Hanna Instruments Inc., Woonsocket, RI, USA). Samples were soaked in immersion solution for 2 minutes per day (23±1 °C). The samples were then washed with distilled water

and stored in fresh artificial saliva until the same application the next day. This cycle was repeated daily for six months over three immersion periods (14). All containers were closed to prevent immersion solutions from vaporizing. Energy drinks and artificial saliva were changed daily.

Microhardness measurements were done after specimen preparation and after they were kept in solution for 1-week, 1-month and 6-months. Using a microhardness tester (Duroline M, Metkon Instruments Inc., Bursa, Turkey) and a Vickers indenter, three tracks were made on the material surface at 100 mm intervals from each other by applying a static load of 200 g.

Statistical Analysis

Shapiro-Wilk test was used to evaluate whether the variables in the study were compatible with normal distribution. In comparing values obtained at different times for each groups, F statistic was applied for variables with normal distribution, and Friedman test for variables that were not normally distributed. Bonferroni post hoc test was preferred for binary comparison. Kruskal-Wallis test statistics were used to compare variables that did not show normal distribution. A value of <0.05 was considered as statistically significant.

Results

The mean hardness values of each group at baseline and after 1-week, 1-month, and 6-months of Redbull, Burn and artificial saliva immersion are presented in Table 2, Table 3 and Table 4, respectively. The column graphic showing changes of Vickers hardness number ΔVHN 1w (difference between baseline-1-week), ΔVHN 1m (difference between baseline-1-months) and ΔVHN 6m (difference between baseline-6-month) of each group is given in Figure 1.

Dual-cured alkasite presented the highest hardness values (p=0.0001). This group was followed by self-cured alkasite and nanohybrid composite resin, respectively (p=0.0001). The hardness values in hybrid glass ionomer (HGI) + coating were higher than HGI. On the other hand, there is no statistically significant difference between the hardness of glass carbomer + coating and the glass carbomer in all subgroups at baseline (p>0.05). Hardness of HGI + heating was higher than HGI (p=0.0001). Similarly, glass carbomer + heating presented higher values than glass carbomer (p=0.0001). The hardness values obtained after heating were found significantly higher than coating (p=0.0001).

Table 1. Materials used for each group and their application procedure

Groups/Codes	Material/Manufacturer/ Batch Number	Application
Alkasite (self-cured)/ASC	Cention N/Ivoclar Vivadent AG, Bendererstrasse, Schaan, Liechtenstein/ W93722	Dispense powder and liquid, mix and add the remaining powder until a homogeneous consistency is achieved (45-60 s) (no light curing).
Alkasite (dual-cured)/ADC		Apply additional light for 20 s polimerized using a LED lamp at a distance of 1 mm (standard power curing mode of VALO™ Cordless, Ultradent, South Jordan, UT 84095, USA)
Hybrid glass ionomer/HGI	Equia Forte/ GC, Tokyo, Japan/1804061	Activate the capsule and mix in a high frequency mixer.
Hybrid glass ionomer + Coat/HGIC	Equia Forte Coat/ GC Europe, Leuven, Belgium	Apply Equia Forte Coat and apply light for 20 s (standard power curing mode of VALO™ Cordless).
Hybrid glass ionomer + Heat/HGIH		Additional light for 60 s with a LED lamp (standard power curing mode of VALO™ Cordless).
Glass Carbomer/GC	GCP Glass Fill/GCP Dental, Vianen, Netherlands/71712907	Activate the capsule and mix in a high frequency mixer for 15 s.
GlassCarbomer + Coat/GCC	GCP Gloss/GCP Dental, Vianen, Netherlands	Coat the surfaces with GCP Gloss and light cure for 60 s (GCP CarboLED, GCP Dental).
Glass Carbomer + Heat/ GCH		Additional light for 90 s (GCP CarboLED, GCP Dental).
Nanohybrid Composite/NC	Grandio So/VOCO GmbH, Cuxhaven, Germany/1806497	Apply the composite resin material and light cure for 40 s (standard power curing mode of VALO™ Cordless)
GCP: Good clinical practice		

Table 2. The mean surface hardness values and standard deviations of each group at baseline and after 1-week, 1-month, and 6-months of Redbull immersion

Group codes	Baseline	1-week	1-month	6-months
ASC	165.3±0.06^{a,A}	161.5±0.08^{a,B}	156.4±0.08^{a,C}	147.5±0.08^{a,D}
ADC	168.5±0.08^{b,A}	164.4±0.07^{b,B}	160.5±0.08^{b,C}	156.5±0.08^{b,D}
HGI	112.4±0.07^{c,A}	98.5±0.08^{c,B}	80.4±0.07^{c,C}	69.4±0.07^{c,D}
HGIC	118.4±0.09^{d,A}	115.4±0.08^{d,B}	98.4±0.09^{d,C}	77.4±0.08^{d,D}
HGIH	128.4±0.07^{e,A}	123.5±0.09^{e,B}	118.5±0.09^{e,C}	110.5±0.07^{e,D}
GC	70.5±0.08^{f,A}	60.5±0.08^{f,B}	49.5±0.08^{f,C}	30.4±0.07^{f,D}
GCC	68.3±0.07^{g,A}	64.6±0.09^{g,B}	52.5±0.07^{g,C}	35.5±0.08^{g,D}
GCH	83.5±0.08^{h,A}	79.6±0.07^{h,B}	71.4±0.06^{h,C}	54.5±0.09^{h,D}
NC	148.4±0.07^{i,A}	144.5±0.07^{i,B}	139.4±0.08^{i,C}	134.5±0.078^{i,D}

*Values indicated by different small letters on the same column and different big letters on the same line are statistically significantly different ($p<0.0001$)

Table 3. The mean surface hardness values and standard deviations of each group at baseline and after 1-week, 1-month, and 6-months of Burn immersion, intergroup comparisons in each evaluation point and intragroup comparisons between evaluation points

Group codes	Baseline	1-week	1-month	6-months
ASC	162.4±0.08^{a,A}	158.4±0.09^{a,B}	153.4±0,06^{a,C}	144.4±0.08^{a,D}
ADC	166.5±0.08^{b,A}	162.4±0.07^{b,B}	158.4±0.08^{b,C}	155.4±0.08^{b,D}
HGI	110.4±0.07^{c,A}	95.4±0.06^{c,B}	65.4±0.08$^{c.C}$	57.5±0.07^{c,D}
HGIC	115.4±0.07^{d,A}	112.5±0.08^{d,B}	94.4±0.06^{d,C}	84.4±0.07^{d,D}
HGIH	131.5±0.07^{e,A}	127.5±0.09^{e,B}	123.5±0.09^{e,C}	118.5±0.08^{e,D}
GC	65.4±0.06^{f,A}	58.4±0.06^{f,B}	47.5±0.09^{f,C}	30.5±0.09^{f,D}
GCC	66.5±0.08^{f,A}	62.5±0.08^{g,B}	51.4±0.07^{g,C}	35.4±0.08^{g,D}
GCH	81.5±0.07^{g,A}	77.5±0.07^{h,B}	71.4±0.07^{h,C}	58.5±0.07^{h,D}
NC	150.5±0.08^{h,A}	146.4±0.08^{i,B}	142.4±0.07^{i,C}	137.5±0.08^{i,D}

*Values indicated by different small letters on the same column and different big letters on the same line are statistically significantly different ($p<0.0001$)

Table 4. The mean surface hardness values and standard deviations of each group at baseline and after 1-week, 1-month, and 6-months of artificial saliva immersion, intergroup comparisons in each evaluation point and intragroup comparisons between evaluation points

Group codes	Baseline	1-week	1-month	6-months
ASC	168.4±0.07^{a,A}	166.4±0.08^{a,A}	164.4±0.06^{a,B}	159.4±0.07^{a,C}
ADC	171.4±0.07^{b,A}	170.4±0.08^{b,A}	169.5±0.08^{b,A}	166.4±0.07^{b,B}
HGI	115.4±0.08^{c,A}	112.4±0.09^{c,A}	98.5±0.08^{c,B}	92.5±0.08^{c,C}
HGIC	120.5±0.07^{d,A}	119.4±0.07^{d,A}	114.5±0.08^{d,B}	108.4±0.07^{d,C}
HGIH	131.5±0.08^{e,A}	130.5±0.07^{e,A}	126.4±0.08^{e,B}	122.4±0.08^{e,C}
GC	74.5±0.08^{f,A}	70.5±0.08^{f,B}	64.5±0.07^{f,C}	53.4±0.07^{f,D}
GCC	73.4±0.07^{f,A}	71.5±0.08^{f,A}	65.4±0.07^{f,B}	53.3±0,05^{f,C}
GCH	82.4±0.08^{g,A}	81.3±0.04^{g,A}	78.4±0.08^{g,B}	72.5±0.07^{g,C}
NC	153.4±0,08^{h,A}	152.5±0.08^{h,A}	151.4±0.06^{h,B}	146.4±0.08^{h,C}

*Values indicated by different small letters on the same column and different big letters on the same line are statistically significantly different ($p<0.0001$)

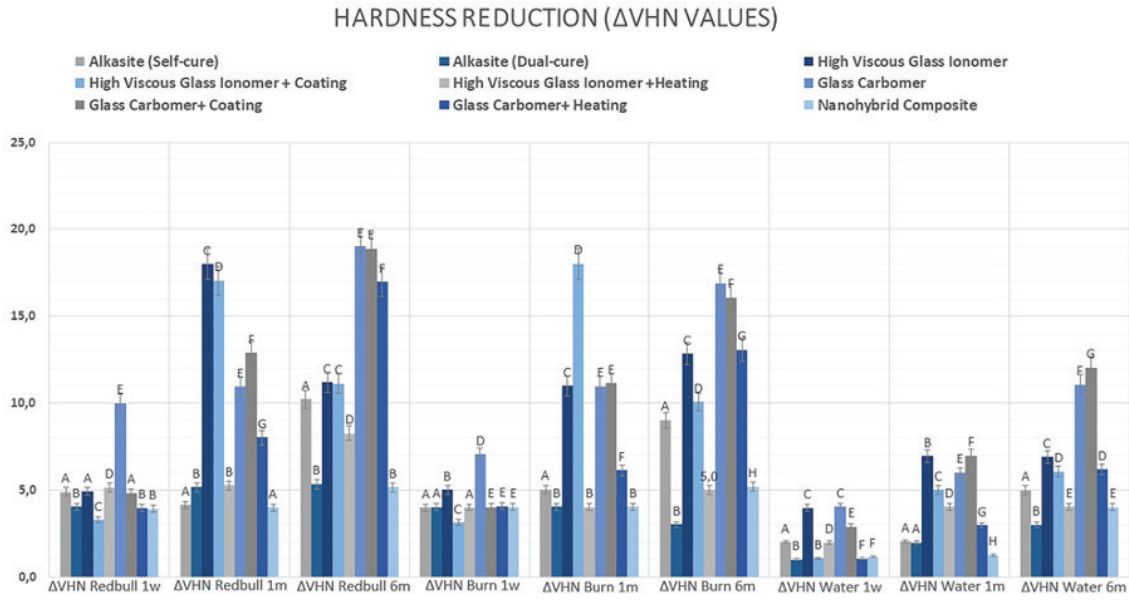

Figure 1. Column chart showing mean hardness change values of all groups after 1 week (ΔVHN 1w), 1 month (ΔVHN 1m) and 6 months (ΔVHN 6m)

After Red bull and Burn immersion, hardness was significantly decreased with the elapsed time in all groups (p=0.0001).

Dual-cured alkasite presented lower ΔVHN 6m than self-cured alkasite (p=0.0001). Coating on HGIs significantly resulted in hardness advancement and coating on glass carbomers significantly decreased hardness reduction in Red bull and Burn subgroups (p=0.0001). Heating, on the other hand, significantly decreased hardness reduction in both HGIs and glass carbomers (p=0.0001).

Discussion

Present study aimed to investigate whether different applications would effect surface hardness. In previous *in vitro* studies, materials were left in contact with acidic drinks for a long time (15,16). However, in oral environment, during consumption of drinks, restoration surfaces remain in contact with beverages for a very short time before being washed with saliva. Therefore, in this study, as descibed before by Erdemir et al. (14), the materials were dipped in energy drinks 2 minutes a day and then left in artificial saliva.

The present results reveal that coating and heating on HGI concluded in a decrease in the hardness reduction after energy drinks exposure. Therefore, first null hypothese was rejected. This result is in agreement with Burdur and Sirin Karaarslan (17) who revealed varnish application increased the hardness of Equia Forte. Furthermore, in a different study it is reported that coated glass ionomer presented significantly higher hardness when compared no protection (18). Higher hardness obtained from coating can be interpreted as covering the surface against moisture is important for maintaining the hardening of the material. Jafarpour et al. (19) supported this interpretation with their study. It is reported that water sorption and solubility of restorative materials may decrease the mechanical properties and surface coating protects initial water contamination (17).

In this study, heating on glass carbomer increased hardness. However, coating on glass carbomers has not been found to be as successful as heating. Similarly, in a clinical study (20) researchers stated that good clinical practice (GCP) Gloss, had no effect on mechanical properties of restorative material, unlike GC Equia Coat. While the GCP Gloss varnish did not contain monomers, the varnishes used to protect the conventional glass ionomer cements consisted mainly of acrylic or methacrylic monomers. In many studies, light-curing, nano-filled, resin-based varnishes have been shown to be more successful than other surface coating materials (20).

In both HGI and glass carbomer, heating increased hardness more than coating. This finding is in line with the results of previous studies investigating the effect of heat treatment on the hardness of glass ionomers (21,22). Heat provided by LED light-curing units increases ion mobility during the initial stage of setting and causes acceleration in the hardening resulting in an improved setting reaction (23). This study revealed that heating using a high output light device is useful with regards to glass carbomer. Unlike the results of this study, some other studies indicated that heating had no effect on mechanical behaviour of the glass carbomer. This result was related to the structure of the glass carbomer material in these studies (6,24).

Alkasite presented the highest hardness, whether hardened as self-cure or dual-cure. This may be related to nanoparticle size of inorganic filling ingredient (25). However, when hardened with dual-cure, highest results were obtained. Therefore, second null hypothese was rejected. The higher hardness of dual-cured alkasite can be attributed to material's high polymer network density and high degree of conversion with a stable, efficient self-cure initiator (25). Unlike the results of present study, by Ilie (24) reported that additional light curing initially accelerates the polymerization kinetics and shortens the curing process, but does not change the final hardness. Different results of the present study may be attributed to additional light application can lead to higher values of degree of conversion and crosslinking, both straight related to the hardness. However, many factors which can affect result such as energy density, size and distribution of inorganic fillers should also be considered.

With all these results, there is a need for more *in vitro* and clinical studies to be carried out and only the hardness parameter was evaluated in the present study, and the amount of wear after long-term energy drinks exposure was not measured.

Conclusion

According to present study results:

- Heating can be preferred then coating in both HGIs and glass carbomers.

- Coating is more effective on HGIs than glass carbomers.

- Dual-cured alkasite may present more resistance than self-cured ones.

- Dual-cured alkasite may be a better alternative for patients on acidic diet when compared with glass ionomers.

Ethics

Ethics Committee Approval: Ethical approval is not required for this type of an *in vitro* material research article which does not involve humans, animals or exracted tooth.

Informed Consent: This study does not require patient consent.

Peer-review: Externally peerreviewed.

Authorship Contributions

Consept: D.R., B.Y., Design: D.R., B.Y., Data Collection or Processing: D.R., B.Y., Analysis or Interpretation: B.Y., Literature Search: D.R., B.Y., Writing: D.R., B.Y.

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