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Effect of Aging on Surface Roughness and Color Stability of a Novel Alkasite in Comparison with Current Direct Restorative Materials

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Clinical Significance

Although this novel alkasite is a promising material due to its strong mechanical properties, as reported in the literature, the material may not be as successful as composite resins in terms of meeting esthetic expectations.

SUMMARY

Aim: To compare the surface roughness and color stability of a novel alkasite with current direct restorative materials with and without an aging step.

Methods and Materials: Twenty-six specimens of each of the following materials were prepared: alkasite, ormocer, giomer, high-viscosity glass ionomer, glass carbomer, and nanohybrid composite (control). Half of the specimens in each group were stained, the other half of the specimens were aged and then stained. Color and surface roughness evaluations were conducted at baseline, after aging and after staining, using a dental spectrophotometer, and a three-dimentional (3D) noncontact optical profilometer, respectively. Statistical analyses were completed using one-way analysis of variance, post hoc Tukey test, and paired samples *t*-test.

Results: At baseline and after aging, the surface of alkasite was found to be rougher than nanohybrid composite and ormocer surfaces ($p<0.05$). However, in terms of roughness increase caused by aging, ormocer, nanohybrid composite, and alkasite were affected in a similar way ($p>0.05$). In terms of color stability, alkasite was more colored than nanohybrid composite and ormocer ($p<0.05$), and performed similar to giomer ($p>0.05$).

Conclusions: The surface roughness and color stability characteristics of alkasite material was between composite resins and glass ionomer-based materials after aging.

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INTRODUCTION

Although composite resin restorations have almost completely replaced amalgam restorations due to the alleged mercury toxicity and dark color of the latter, they do have disadvantages, including technique-

sensitive adhesive application steps, a susceptibility to polymerization shrinkage leading to microleakage, their high wear rate, and their propensity for discoloration and cytotoxicity, which are all unresolved concerns for clinicians. These concerns have motivated the search for a new esthetic material with the ability to withstand occlusal and masticatory forces in the posterior teeth, a low marginal leakage, high color stability, and longevity.

In an attempt to overcome the drawbacks of composite resin restorations described above, different alternative materials have been developed such as high-viscosity glass ionomer, giomers, glass carbomers, and ormocers.[1] Although some of these materials have specific advantages, such as acceptable physical properties, wear resistance, and the self-adherable bonding ability to dentin of high viscosity bulk replacement glass ionomers[2] and glass carbomers,[3] satisfying optical properties, antibacterial effects, durability, potential for fast treatment of giomers,[4] and high abrasion resistance and biocompatibility of ormocers,[5] composite resins have not been completely replaced by these alternative restorative materials due to their lower mechanical, esthetic, or color stability properties.

As a result, researchers have long sought a real alternative to the current direct restorative materials. This sought-after material should be cheap, easy to use without the need for complicated equipment, strong, high in compressive strength, and esthetically pleasing.[6] Recently, Cention N (Ivoclar Vivadent, Liechtenstein) has been introduced as an innovative material with these sought-after features. This novel category alkasite restorative material consists of a separately packaged powder and liquid.[7] The liquid contains dimethacrylates and initiators, while the powder contains various initiators, pigments, and alkaline glass fillers, which release acid neutralizing fluoride, calcium, and hydroxide ions when the pH of the oral cavity decreases.[8] It is a self-curing material with optional light-curing, leading to increased strength and longevity of the restoration.[7]

In previous studies evaluating this novel alkasite material, its shear bond strength,[9] microtensile bond strength,[10] compressive strength,[11] and fracture resistance[12] was found similar to composite resins and higher than glass ionomer-based materials. In addition, the microleakage of the material in the enamel–restoration junction was found lower than composite resins.[8,13] However, since the demand for esthetic restorations is increasing, materials with similar or better surface roughness and color stability compared to composite resins are required in restorative dentistry.

There are only three studies in the literature analyzing the novel alkasite material in terms of surface roughness and color stability. In one of these studies, the color stability of the alkasite material was compared only with a high-viscosity glass ionomer material[14], and in the others, the surface roughness of the alkasite was compared with a composite resin[9,15] and a glass ionomer-based material.[9] Aging is of great importance in this respect, and it should be investigated in the literature. However, it is seen that the effects of aging have not been evaluated in these studies. Therefore, the aim of this laboratory study was to compare the effect of aging on the surface roughness and color stability properties of this novel alkasite material with all the current direct restorative alternatives including composite resin, orcmocer, high-viscosity glass ionomer, glass carbomer, and giomer. The tested null hypotheses were that (1) aging would not affect the surface roughness of alkasite more than the other tested direct restorative materials, (2) aging would not affect the color of alkasite more than the other tested direct restorative materials, and (3) staining would not affect the color of alkasite more than the other tested direct restorative materials, whether aging was performed or not.

METHODS AND MATERIALS

Specimen preparation

A total of 156 disc-shaped specimens (10 mm in diameter and 2 mm in thickness) were prepared using a Teflon mold following the manufacturer's application instructions, as described in Table 1. All the materials selected were of the same shade (A2) (n=26). The materials were placed into the molds with a slight overflow and covered with a transparent band (Mylar, DuPont, Wilmington, DE, USA). The excess material was removed by applying pressure with a glass lamina measuring 1 mm in thickness. The chemically activated materials were allowed to set for a period of time according to the manufacturer's instructions, and the resin-based materials were polymerized using a LED lamp at a distance of 1 mm (1000 mW/cm^2) using the standard power curing mode of a VALO Cordless (Ultradent Products, South Jordan, UT, USA).

The prepared specimens were stored in distilled water for 24 hours at 37°C to allow for polymerization completion. This rehydration simulated the first

Table 1: *Materials Used for Each Group, Their Composition, and Application Procedure*

Groups	Material/Manufacturer/ Batch Number	Material Composition	Application Procedure
Alkasite (CN)	Cention N/Ivoclar Vivadent AG, Bendererstrasse, Schaan, Liechtenstein/W96066	**Filler:** Barium aluminium silicate glass, ytterbium trifluoride, isofiller (Tetric N-Ceram technology), Calcium barium aluminium fluorosilicate glass, Calcium fluoro silicate glass. **Liquid:** UDMA, DCP, Tetramethyl-xylylen-diurethane dimethacrylate, PEG-400 DMA	-Manually mix 2 measuring spoons of powder and 2 drops of resin till a smooth consistency. -The mixing time should not exceed 60 seconds. -Leave the material for 10 minutes from the start of mixing (no light curing).
Ormocer (AF)	Admira Fusion x-tra/VOCO GmbH, Cuxhaven, Germany/1807658	**Resin matrix:** Aromatic and aliphatic dimethacrylates, methacrylate-functionalized polysiloxane **Inorganic filler:** Barium , aluminum, glass, silicon dioxide, **Photoinitiator:** Camphorquinone	-Apply the material in layers that are a maximum of 4-mm thick, -Adapt with an instrument and light cure (20 seconds for shade A2)
Giomer (BF)	Beautifil Flow Plus/Shofu Inc, Kyoto, Japan/PN2002	***Base resin*:** Bis-GMA (15 wt%)/ TEGDMA (13wt%) resin ***Filler*:** Multi functional glass filler and S-PRG filler based on fluroboroaluminosilicate glass. **Photoinitiator:** Camphorquinone	-Apply the material in layers that are a maximum of 2-mm thick, -Adapt with an instrument and light cure (20 seconds for shade A2)
High-viscosity glass ionomer (EF)	EQUIA Forte/GC Corp, Tokyo, Japan/1804061	**Liquid:** Polyacrylic acid, distilled water, polybasic carboxylic acid **Powder:** Fluoro-alumino-silicate glass, polyacrylic acid powder, pigment	-Activate the capsule and mix in a high-frequency mixer. -Apply EQUIA Forte® directly into the cavity preparation after mix for 10 seconds on a mixing device. -Remove excess material.
Glass Carbomer (GC)	GCP Glass Seal/GCP Dental, Boelewerf, Ridderkerk, The Netherlands/71712907	**Powder:** Fluoroaluminosilicate glass, apatite **Liquid:** Polyacids.	-Activate the capsule and mix in a high-frequency mixer (GCP CarboMix, GCP Dental) for 15 seconds. -Light-cure the material with a high output light device (GCP CarboLED, GCP Dental) for 90 seconds. -Coat the surfaces with GCP gloss (GCP Dental) and light-cure for 90 seconds.
Nanohybrid Composite (GS)	GrandioSo/ VOCO GmbH, Cuxhaven, Niedersachsen, Germany / 1806497	**Inorganic fillers:** glass ceramic filler (particle size 1 μm), silicon dioxide nanoparticles (20-40 nm), Bis-GMA, Bis-EMA, TEGDMA, initiators, inorganic pigments, BHT	-Apply the composite resin material in one increment and light cure for 20 seconds.

Abbreviations: *Bis-GMA: bisphenol-A-diglycidyl methacrylate; TEGDMA: triethyleneglycol dimethacrylate; S-PRG filler, surface pre-reacted glass-ionomer filler; UDMA, urethane dimethacrylate; DCP, tricyclodecan-dimethanol dimethacrylate; PEG-400 DMA, polyethylene glycol 400 dimethacrylate; DMA, dimethacrylate;* GIC, glass ionomer cement; Bis-EMA, *ethoxylated bisphenol-A dimethacrylate*; BHT, *butylhydroxytoluene*.

day of service for materials in the oral conditions. After 24 hours, the specimens were removed from distilled water and dried. Next, the upper surfaces of all the specimens were polished with medium (15 seconds), fine (15 seconds), and superfine (15 seconds) aluminum oxide-impregnated discs (Sof-Lex, 3M Oral Care, St. Paul, MN, USA), respectively, with a 10,000 rpm micromotor set to low speed and moved with a one-way rotation under light hand pressure and dry conditions. A new disk was used for each sample. For the chemically activated materials, surface coatings were applied as recommended by the manufacturers. The unpolished lower surfaces of each specimen were marked with a code name to identify each sample.

The prepared specimens were randomly divided into two subgroups (n=13). Half of the specimens in each group were stained after the baseline measurements. The other half were aged immediately after the baseline evaluations. The flow diagram of the study is shown in Figure 1.

Aging of the specimens

Half of the specimens in each group were thermal loaded (n=13, Figure 1). The specimens were

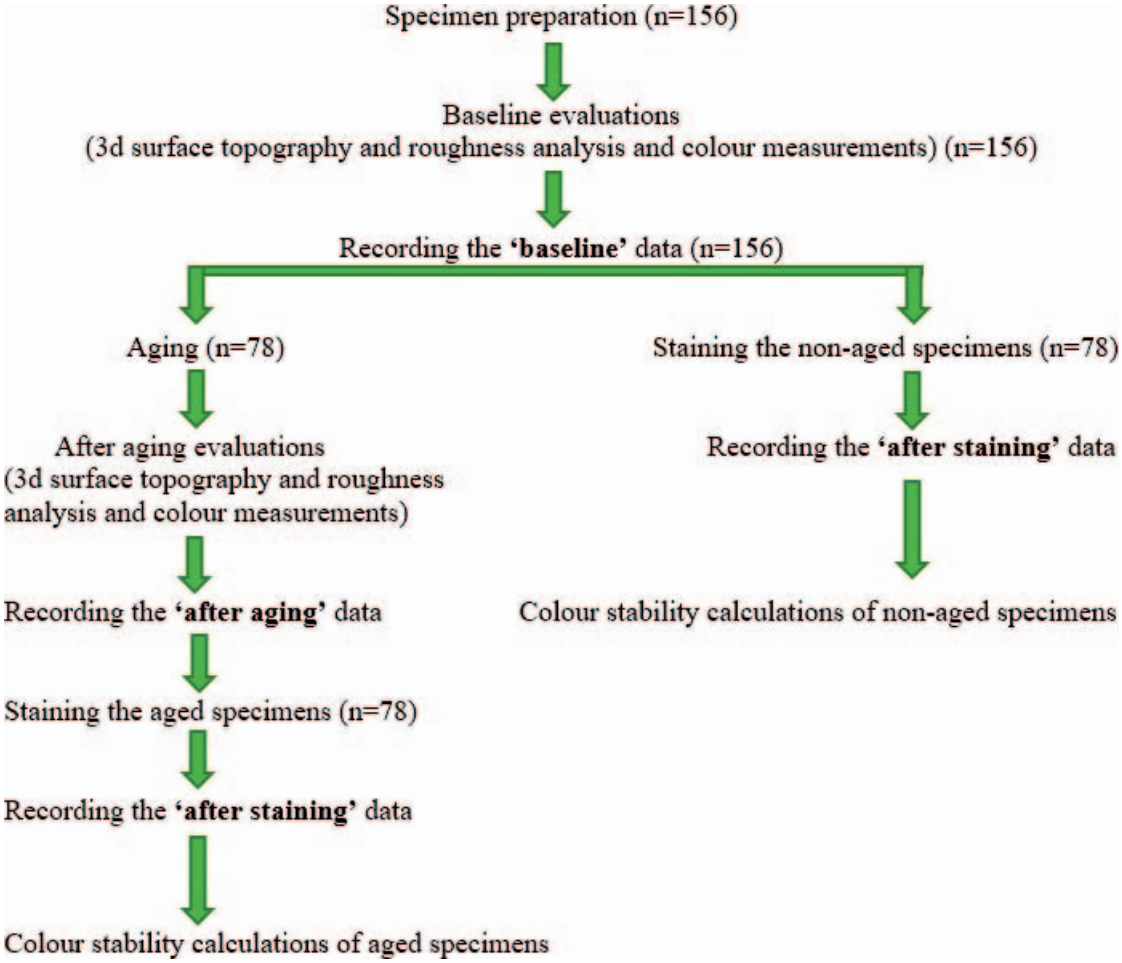

Figure 1. *The flow diagram of the study.*

subjected to 20,000 thermal cycles between 5°C and 55°C with a 60-second dwell time using a thermal cycler device (ModDental, Esetron Smart Robotechnologies, Ankara, Turkey).

Staining of the specimens

Coffee solution was selected for staining. The solution was prepared by adding a spoonful of soluble coffee (Nescafe Classic, Nestle, Vevey, Switzerland) to 250 ml of boiling water, which was then stirred and cooled to room temperature. The staining process was conducted at room temperature with daily 3-hour coffee immersion periods, followed by daily storage in distilled water for 28 days (Figure 1).[1] The specimens from each group were placed in separate containers, and the coffee solution in each container was changed daily. The stained specimens were removed from the solution and washed for 10 seconds with distilled water, then dried with paper for 10 seconds before the color measurements.

Surface roughness measurement

To determine the surface roughness, a three-dimentional (3D) noncontact optical profilometer (PS50, Nanovea, Irvine, CA, USA) was used. An area of 1 × 1 square millimeter was used for the roughness analysis. The scanning process was conducted in steps of 5 μm for both X and Y directions with a 5 mm/s velocity. The evaluations of 3D surface roughness were completed using Mountains Software Version 6.2.7487 (Digital Surf, Besançon, France). Profile roughness lines were taken from the 3D scanned surfaces.

A surface roughness recording was made after specimen preparation (baseline) and after aging (Figure 1).

Color evaluation

Color measurements were performed with a dental spectrophotometer (VITA EasyShade Advance 4.0, VITA Zahnfabrik, Bad Säckingen, Germany). The device was calibrated before starting and after com-

Table 2: *The Surface Roughness Values (R_a) For Each Group at Each Evaluation Point, Intergroup and Intragroup Comparisons p-Values, and Significant Pairs*

Groups		Surface Roughness Values: Baseline R_a Values (After Polishing)	Surface Roughness Values: After Aging R_a Values	Intergroup Comparisons *p*-Values
Alkasite (CN)	Mean ± SD	0.087 ± 0.006	0.139 ± 0.005	0.0001*
	Med (min-max)	0.085 (0.080-0.094)	0.137 (0.130-0.148)	
Ormocer (AF)	Mean ± SD	0.065 ± 0.004	0.120 ± 0.005	0.0001*
	Med (min-max)	0.064 (0.058-0.072)	0.121 (0.112-0.131)	
Giomer (BF)	Mean ± SD	0.084 ± 0.005	0.135 ± 0.004	0.0001*
	Med (min-max)	0.083 (0.077-0.091)	0.136 (0.127-0.142)	
High Viscosity Glass Ionomer (EF)	Mean ± SD	0.128 ± 0.005	0.203 ± 0.005	0.0001*
	Med (min-max)	0.128 (0.121-0.135)	0.203 (0.195-0.211)	
Glass Carbomer (GF)	Mean ± SD	0.230 ± 0.004	0.682 ± 0.004	0.001*
	Med (min-max)	0.229 (0.225-0.236)	0.681 (0.676-0.689)	
Nanohybrid Composite (GS)	Mean ± SD	0.077 ± 0.005	0.129 ± 0.007	0.0001*
	Med (min-max)	0.075 (0.072-0.087)	0.129 (0.116-0.139)	
Intragroup comparisons p values		0.0001**	0.0001**	
Significant pairs		AF & GS, AF & BF, **AF & CN**, AF & EF, AF & GF, GS & BF, **GS & CN**, GS & EF, GS & GF, BF & EF, BF & GF, **CN & EF**, **CN & GF**, EF & GF	AF & GS, AF & BF, **AF & CN**, AF & EF, AF & GF, GS & BF, **GS & CN**, GS & EF, GS & GF, BF & EF, BF & GF, **CN & EF**, **CN & GF**, EF & GF	

*Paired samples t-test and repeated-measures ANOVA, $p<0.05$.
**One-way Analysis of Variance (ANOVA), the post hoc Tukey test, $p<0.05$.

pleting the measurements of every five specimens. The specimens were placed on a standardized flat white floor (Leneta Company, Mahwah, NJ, USA) inside of a black box. Doing so ensured that the spectrophotometer was the only source of illumination. The tip of the spectrophotometer was placed perpendicular to the specimen surface. Color recordings were taken after specimen preparation (baseline), after aging, and after the staining of both the nonaged and aged specimens (Figure 1). All color measurements were conducted by the same operator (BY).

Three measurements were taken from each specimen, and the averages of the obtained L^*, a^*, and b^* values were recorded. The total color difference (ΔE) for each specimen was calculated using the following equation:

$$\Delta E^* = [(\Delta L*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

where $\Delta L^* = L(\text{Final}) - L(\text{Initial})$, $\Delta a^* = a(\text{Final}) - a(\text{Initial})$, and $\Delta b^* = b(\text{Final}) - b(\text{Initial})$.

Statistical analysis

Shapiro-Wilk tests were used for testing normality. A one-way analysis of variance (ANOVA) was used for comparisons among the groups. The post hoc Tukey test was used when the ANOVA determined a significant difference. For pairwise comparisons, a paired samples *t*-test and repeated measures ANOVA were used. All statistical analyses were conducted with the IBM SPSS Statistics 25.0. A *p*-value of <0.05 was considered significant.

RESULTS

Surface roughness results

Table 2 presents the surface roughness values (R_a) for each group at each evaluation point, the *p*-values of surface roughness for intragroup comparisons (between evaluation points), and intergroup comparisons in each evaluation point and significant pairs. Table 3 presents the values of increased surface roughness (ΔR_a) after aging for each group and *p*-values of ΔR_a for intragroup comparisons and significant pairs.

At both evaluation points (baseline and after aging), the surface roughness of alkasite was significantly higher than ormocer and nanohybrid composite and significantly lower than high viscosity glass ionomer and glass carbomer ($p<0.05$, Table 2).

Table 3: *The Surface Roughness Increase Values (ΔR_a) after Aging for Each Group and Intragroup Comparisons p-Values and Significant Pairs*

Groups		Roughness Increase Values After Aging ΔRa values ($R_{aAfter\ aging\ -Baseline}$)
Alkasite (CN)	Mean ± SD	0.052 ± 0.007
	Med (min-max)	0.056 (0.041-0.063)
Ormocer (AF)	Mean ± SD	0.056 ± 0.006
	Med (min-max)	0.057 (0.04-0.062)
Giomer (BF)	Mean ± SD	0.051 ± 0.008
	Med (min-max)	0.055 (0.037-0.064)
High Viscosity Glass Ionomer (EF)	Mean ± SD	0.075 ± 0.008
	Med (min-max)	0.057 (0.04-0.062)
Glass Carbomer (GF)	Mean ± SD	0.452 ± 0.007
	Med (min-max)	0.450 (0.443-0.463)
Nanohybrid Composite (GS)	Mean ± SD	0.053 ± 0.001
	Med (min-max)	0.053 (0.029-0.064)
Intragroup comparisons *p*-values		0.0001*
Significant pairs		AF & EF, AF & GF, GS & EF, GS & GF, BF & EF, BF & GF, **CN & EF**, **CN & GF**, EF & GF

*One-way analysis of variance (ANOVA), the post hoc Tukey test, $p<0.05$.

Furthermore, at baseline and after aging, alkasite and giomer presented similar roughness values ($p>0.05$, Table 2).

The aging led to a statistically significant increase in roughness values of all groups ($p<0.05$, Table 2). The amount of increase (ΔR_a) in the roughness of alkasite was the lowest and was statistically similar to the ΔR_a values of giomer, ormocer, and nanohybrid composite ($p>0.05$, Table 3), followed by the ΔR_a values of high viscosity glass ionomer and ΔR_a values of glass carbomer ($p<0.05$, Table 3).

Figure 2 presents the surface topography images of the alkasite material at baseline (2a) and after aging (2b). Additionally, Figure 3 presents the surface topography images of the glass carbomer material at baseline (3a) and after aging (3b). The surface topography of all the specimens was observed to be rougher after aging. Similar topographic images were obtained in the other groups, except glass carbomer. The glass carbomer group showed higher surface deterioration, and, in some areas, cleavages were observed.

Color stability results

Table 4 shows the values of color change after aging ($\Delta E_{\text{AFTER AGING-BASELINE}}$), after staining of nonaged specimens ($\Delta E_{\text{AFTER STAINING-BASELINE}}$), and after staining of aged specimens ($\Delta E_{\text{AFTER STAINING-AFTER AGING}}$) for each group, and the p values of color change values for intragroup comparisons and significant pairs.

After aging and staining of both nonaged and aged specimens, the color change of alkasite was found to be higher than ormocer and nanohybrid composite ($p<0.05$, Table 4), similar to the color change of giomer ($p>0.05$, Table 4), and lower than the color change of high-viscosity glass ionomer and glass carbomer ($p<0.05$, Table 4).

Staining with coffee caused more color differences than aging ($p<0.05$).

DISCUSSION

Surface roughness

Based on the results of the present study, our first null hypothesis was rejected, since the surface roughness increased in all of the groups after aging.

The current study used a 3D noncontact optical profilometer, which had a higher resolution than a mechanical stylus and eliminated the possibility of surface damage from contact with a mechanical sensor that could cause errors in the results.[16] In our study, the R_a values measured after polishing (at baseline) ranged from 0.065 μm to 0.230 μm. Although a threshold for unacceptable surface roughness has not yet been agreed on, it has been reported that an R_a above 0.2 μm results in an increase of plaque accumulation and a higher risk for caries.[17] Other reports found that when the R_a was lower than 0.3 μm, the surfaces were visibly smooth.[18]

Studies have used various methods to simulate the aging of materials, such as cyclic loading, water storage, and thermal cycling. The recommended thermal cycle time ranges from 3000 to 100,000 cycles.[19] It has been reported that 10,000 cycles may represent a 1-year usage period.[20] In our study, 20,000 cycles, which are clinically equivalent to about 2 years of wear, were used for the aging process.

During thermal cycling, the resin matrix absorbs water.[21] The hygroscopic expansion caused by this water absorption accelerates the weakening of the matrix–filler interface. Then, the thermal cycles cause repeated shrinkages and expansions due to

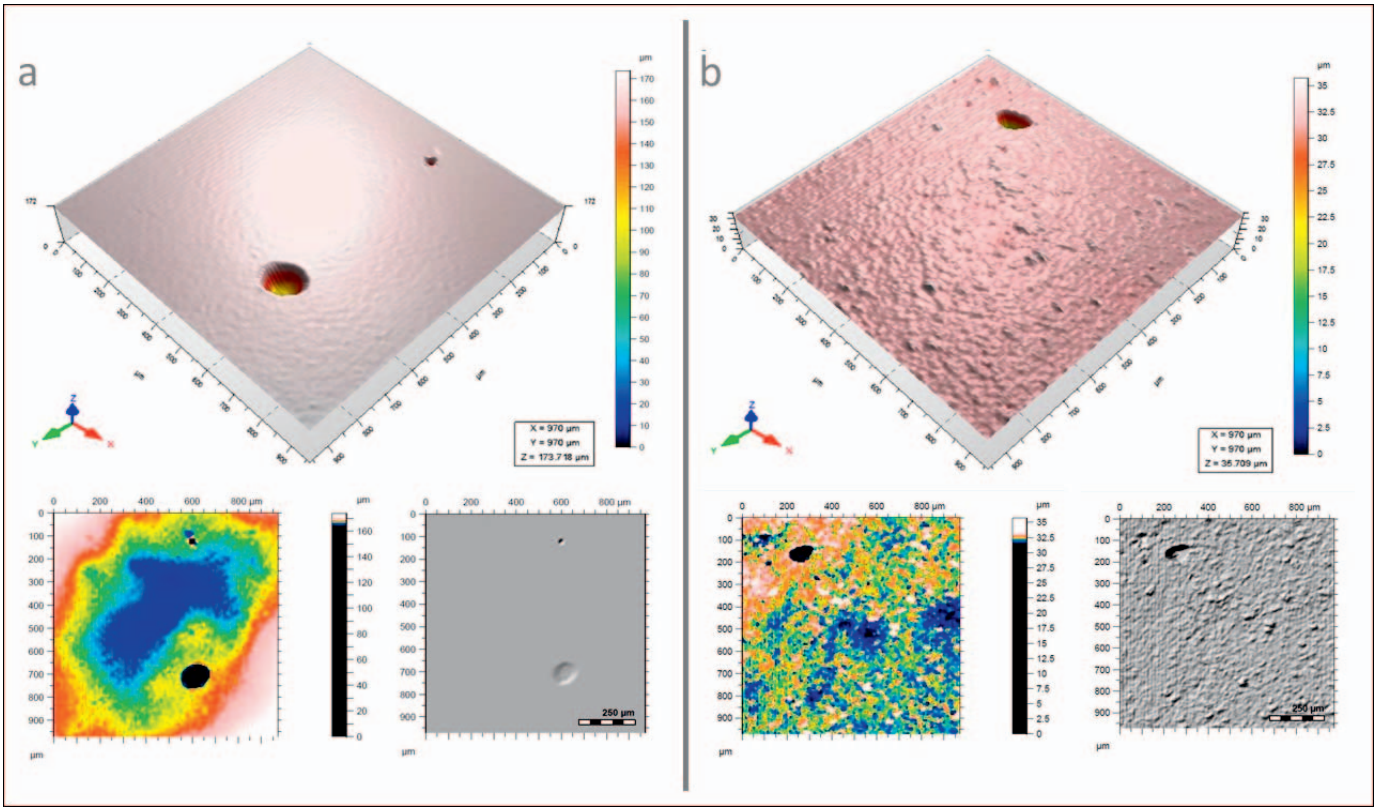

Figure 2. *Three-dimensional (3D) Optical Profilometery images: a) Surface topography of an alkasite at baseline, b) surface topography of an alkasite after aging.*

differences in the thermal expansion coefficient or thermal conductivity coefficient between the resin matrix and filler particles. As a result, the filler particles become disjoined.[22]

In this study, the alkasite material exhibited a smoother surface than glass ionomer-based materials and a rougher surface than composite resins at baseline and after aging. According to the studies evaluating the surface roughness of the alkasite material, similar to the results of our study, the surface roughness of the alkasite was higher than that of nanohybrid composite at baseline (after polishing).[9] The greater roughness of the alkasite material compared to the nanohybrid composite at baseline (after polishing) might be the result of greater average particle sizes of the Cention N fillers (0.1-35 μm)[23] than composite fillers (0.1-1.0 μm).[24]

However, different from the results of the present study, the mechanical aging (50,000 cycles in chewing simulator) was reported to affect the surface roughness of nanohybrid composite more than the alkasite.[9] In our study, the samples were aged with a thermal cycle. The rougher surface of the alkasite material than nanohybrid composite after thermal cycling may be due to the high ion release property of the material. Water diffusion capacity caused by the ion release property of the material may cause a chemical degradation and de-bonding of the matrix.

According to our results, the surface roughness and surface characteristic of alkasite was between the composite resins and glass ionomer-based materials after aging. The smoother surface of alkasite when compared with the glass ionomer-based materials may be explained by the dissolution of the matrix surrounding the glass particles in the glass ionomers [1,25]. Also, the relatively higher ΔR_a values of the glass ionomer-based materials when compared to alkasite and composite resins may be due to their water absorption capacity.

In the present study, the alkasite material was affected by the aging process as were nanohybrid composite, ormocer, and giomer in terms of surface roughness, which clinically approximated 2 years of aging. However, the aging process affected the surface characteristics of glass ionomer-based materials more than alkasite and composite resins. This result can be interpreted as the alkasite material presenting some structural properties similar to

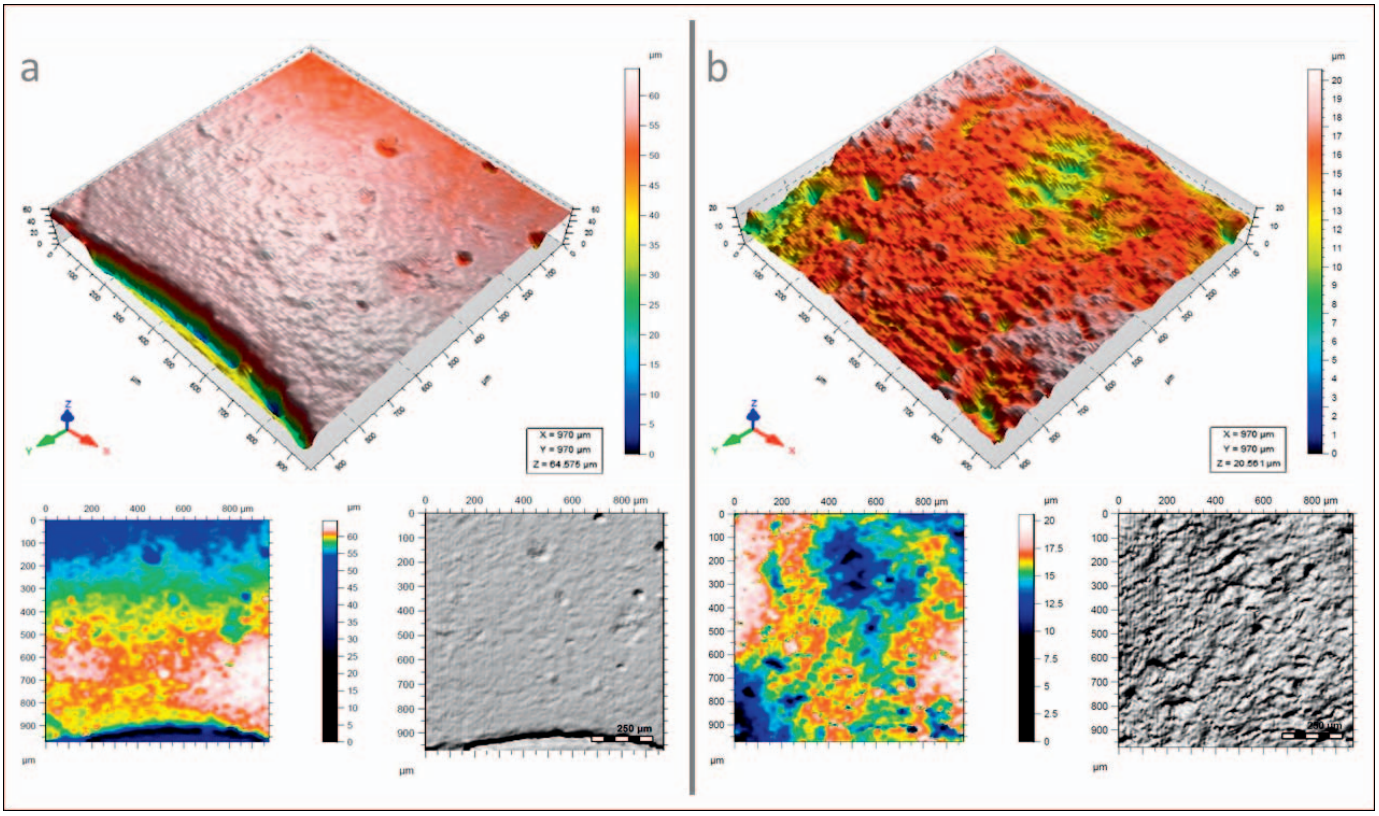

Figure 3. *Three-dimensional (3D) Optical Profilometery images: a) Surface topography of glass carbomer at baseline, b) surface topography of glass carbomer after aging.*

composite resins depending on its composition. Cention N is a dual-cure restorative material that contains urethane dimethacrylate (UDMA) in the liquid. UDMA creates rigid networks, and its stronger mechanical properties may be attributed to its higher viscosity and lack of hydroxyl side groups, which are hydrophobic in nature and consequently exhibit lower water absorption rates.[26] This restorative material includes a patented filling, which is partially silanized, reducing the contraction stress to a minimum.[27] When attached to the filler particles, silanes improve the connection between the inorganic filler (the particles of glass and quartz) and the matrix, since they can establish a chemical bond between the surface of the glass and the matrix.[28]

Color stability

Within an oral environment, restorative materials are constantly exposed to staining by food and beverage colorants as well as changes in temperature and pH.[29] This exposure results in a series of extrinsic and intrinsic changes in the materials, ultimately affecting the materials' physical, mechanical, and esthetic properties.[30]

Our second hypothesis and our third hypothesis were rejected, since not all of the materials reacted in the same way. After aging and staining, whether aging was performed or not, the color change of the alkasite material was higher than that of ormocer and nanohybrid composite, similar to the color change of giomer and lower than the color change of glass ionomer-based restorative materials.

It is currently accepted that a color difference of $\Delta E<1.0$ is imperceptible to human eye, while values of $\Delta E>3.3$ are regarded as clinically unacceptable.[29] In our study, only ormocer and nanohybrid composite presented clinically acceptable ΔE values after thermocycling (20,000 cycles), and the novel alkasite material showed clinically unacceptable color changes after aging. Although there are no other studies in the literature to support the results, alkasite was found to be less successful in this study in terms of color stability than composite resin and ormocer. This result may be associated with the absorption of large amounts of water that may cause a chemical degradation of the material, a de-bonding of the matrix, and the release of residual monomers. The ion release from a restorative material is known to be mediated by its capacity for water diffusion.

Table 4: *The Color Change (ΔE) Values for Each Group, Intragroup Comparisons p-Values, and Significant Pairs*

Groups		ΔE Values		
		$\Delta E_{\text{AFTER AGING-BASELINE}}$	$\Delta E_{\text{AFTER STAINING-BASELINE}}$	$\Delta E_{\text{AFTER STAINING-AFTER AGING}}$
Alkasite (CN)	Mean ± SD	4.44 ± 0.158	9.01 ± 0.169	7.97 ± 0.23
	Med (min-max)	4.33 (4.26-4.66)	9.06 (8.76-9.28)	8.05 (7.64-8.28)
Ormocer (AF)	Mean ± SD	2.34 ± 0.077	6.25 ± 0.129	5.86 ± 0.144
	Med (min-max)	2.31 (2.25-2.48)	6.22 (6.12-6.54)	5.92 (5.58-6.01)
Giomer (BF)	Mean ± SD	3.83 ± 0.154	8.81 ± 0.134	7.32 ± 0.223
	Med (min-max)	3.87 (3.64-4.15)	8.84 (8.56-8.98)	7.32 (6.93-7.64)
High-Viscosity Glass Ionomer (EF)	Mean ± SD	6.19 ± 0.089	11.41 ± 0.175	9.40 ± 0.114
	Med (min-max)	4.33 (4.26-4.66)	9.06 (8.76-9.28)	8.05 (7.64-8.28)
Glass Carbomer (GF)	Mean ± SD	8.26 ± 0.132	14.99 ± 0.104	12.03 ± 0.172
	Med (min-max)	8.25 (8.05-8.46)	14.99 (14.75-15.19)	12.04 (11.75-12.24)
Nanohybrid Composite (GS)	Mean ± SD	2.57 ± 0.097	6.41 ± 0.281	4.74 ± 0.19
	Med (min-max)	2.57 (2.39-2.76)	6.32 (6.12-7.25)	4.81 (4.42-5.01)
Intragroup comparisons p values		0.0001*	0.0001*	0.0001*
Significant pairs		AF & BF, **AF & CN**, AF & EF, AF & GF, GS & BF, **GS & CN**, GS & EF, GS & GF, BF & EF, BF & GF, **CN & EF**, **CN & GF**, EF & GF	AF & BF, **AF & CN**, AF & EF, AF & GF, GS & BF, **GS & CN**, GS & EF, GS & GF, BF & EF, BF & GF, **CN & EF**, **CN & GF**, EF & GF	AF & BF, **AF & CN**, AF & EF, AF & GF, GS & BF, **GS & CN**, GS & EF, GS & GF, BF & EF, BF & GF, **CN & EF**, **CN & GF**, EF & GF

*One-way analysis of variance (ANOVA), the post hoc Tukey test, $p<0.05$.
*$\Delta E_{\text{AFTER AGING-BASELINE}}$: Colour change after aging.
*$\Delta E_{\text{AFTER STAINING-BASELINE}}$: Colour stability of nonaged specimens.
*$\Delta E_{\text{AFTER STAINING-AFTER AGING}}$: Colour stability of aged specimens.

On the other hand, although alkasite is an ion-releasing material, in this study it was found to be more successful than glass ionomer-based materials in terms of color stability. In another laboratory study, parallel with the results of this study, Cention N showed a higher color stability than glass ionomers.[14] It is thought that the results obtained may be due to the differences of the setting reaction of the alkasite material from the setting reaction of glass ionomers. In addition, alkasite does not contain polyacrylic acid. Also, satisfying color stability in alkasite can be attributed to the presence of resin components in its composition.

In the present study, coffee was used for staining due to its high capacity. According to Guler and others,[31] the average time for consumption of 1 cup of coffee is 15 min, and, among coffee drinkers, the average consumption is 3.2 cups per day. Therefore, 15 days of storage was approximately equal to 1 year of coffee consumption.

The present study was a laboratory study. Therefore, one of the limitations was that it did not precisely simulate clinical conditions. Moreover, the aging was only performed with thermal cycling. The responses of these materials to mechanical loads were not evaluated. Consequently, further clinical studies are needed to expand the clinical applications of the tested materials.

CONCLUSIONS

Within the limitations of this study, the following conclusions were reached:

- The alkasite material performed better than glass ionomer-based materials, in terms of surface roughness and color stability after aging.
- At baseline (after polishing) and after aging, the surface of the alkasite material was found to be rougher than nanohybrid composite and ormocer surfaces. However, in terms of increased roughness caused by aging, the ormocer, nanohybrid composite, and the alkasite material were affected in a similar way.
- In terms of color stability, the alkasite material was more colored than nanohybrid composite and ormocer, and performed similar to giomer.

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Conflicts of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this manuscript.

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REFERENCES

1. Savas S, Colgecen O, Yasa B, & Kucukyilma E (2019) Color stability, roughness, and water sorption/solubility of glass ionomer-based restorative materials *Nigerian Journal of Clinical Practice* **22(6)** 824-832.
2. Kutuk ZB, Ozturk C, Cakir FY, & Gurgan S (2019) Mechanical performance of a newly developed glass hybrid restorative in the restoration of large MO Class 2 cavities *Nigerian Journal of Clinical Practice* **22** 833-841.
3. Cehreli SB, Tirali RE, Yalcinkava Z, & Cehreli ZC (2013) Microleakage of newly developed glass carbomer cement in primary teeth *European Journal of Dentistry* **7** 15-21.
4. Choi JW, Lee MJ, Oh SH, & Kim KM (2019) Changes in the physical properties and color stability of esthetic restorative materials caused by various beverages *Dental Materials Journal* 38:33-40.
5. Hickel R, Dasch W, Janda R, Tyas M, & Anusavice K (1998) New direct restorative materials *International Dental Journal* **48** 3-16.
6. Mishra A, Singh G, Singh SK, & Agarwal M (2018) Comparative evaluation of mechanical properties of Cention N with conventionally used restorative materials—An In Vitro Study *International Journal of Prosthodontics & Restorative Dentistry* **8** 120-124.
7. Jayaraj D, Simon EP, Kumar MR, & Ravi SV (2018) Cention N: A Review *Dental Bites* **5(4)** 14-21.
8. Kini A, Shetty S, Bhat R, & Shetty P (2019) Microleakage Evaluation of an Alkasite Restorative Material: An In Vitro Dye Penetration Study *Journal of Contemporary Dental Practice* **20** 1315-1318.
9. Naz F, Khan AS, Kader MA, Saad al Gelban LO, Mousa NMA, Asiri RSH, & Hakeem AS (2020) Comparative evaluation of mechanical and physical properties of a new bulk-fill alkasite with conventional restorative materials *Saudi Dental Journal* Online 7 May. https://doi.org/10.1016/j.sdentj.2020.04.012.
10. Yao C, Ahmed MH, Okazaki Y, Van Landuyt KL, Huang C & Van Meerbeek B (2020) Bonding efficacy of a new self-adhesive restorative onto flat dentin vs Class-I cavity-bottom dentin *Journal of Adhesive Dentistry* **22** 65-77.
11. Goyal M, Prasad BSK, & Rao HM (2019) Comparative analysis of four direct post endodontic restorations: A short term study *IOSR-Journal of Dental and Medical Sciences* **18** 16-21.
12. Sharma A, Das S, Thomas MS, & Ginjupalli K (2019) Evaluation of fracture resistance of endodontically treated premolars restored by alkasite cement compared to various core build-up materials *Saudi Endodontic Journal* **9(3)** 205-209.
13. Meshram P, Meshram V, Palve D, Patil S, Gade V, & Raut A (2019) Comparative evaluation of microleakage around Class V cavities restored with alkasite restorative material with and without bonding agent and flowable composite resin: An in vitro study *Indian Journal of Dental Research* **30** 403-407.
14. Bhattacharya S, Purayil TP, Ginjupalli K, Kini S, & Pai S (2020) Effect of thermocycling on the color stability of esthetic restorative materials: An in-vitro spectrophotometric analysis *Brazilian Research in Pediatric Dentistry* **20** e5174.
15. Setty A, Jyothi N, Chatra MJ, Sivanna AK, Paluvary AK, & Ashwathappa GS (2019) Comparative evaluation of surface roughness of novel resin composite Cention N with Filtek Z350 XT: In vitro study *International Journal of Oral Care and Research* **7** 15-17.
16. Janus J, Fauxpoint G, Arntz Y, Pelletier H, & Etienne O (2010) Surface roughness and morphology of three nanocomposites after two different polishing treatments by a multitechnique approach *Dental Materials* **26** 416-425.
17. Heintze SD, Forjanic M, Ohmiti K, & Rousson V (2010) Surface deterioration of dental materials after simulated toothbrushing in relation to brushing time and load *Dental Materials* **26** 306-319.
18. Ergücü Z & Türkün LS (2007) Surface roughness of novel resin composites polished with one-step systems *Operative Dentistry* **32(2)** 185-192.
19. Kim AR, Jeon YC, Jeong CM, Yun MJ, Choi JW, Kwon YH, & Huh JB (2016) Effect of activation modes on the compressive strength, diametral tensile strength and microhardness of dual-cured self-adhesive resin cements *Dental Materials Journal* **35** 298-308.
20. Morresi AL, D'Amario M, Capogreco M, Gatto R, Marzo G, D'Arcangelo C, & Monaco A (2014) Thermal cycling for restorative materials: Does a standardized protocol exist in laboratory testing? A literature review *Journal of Mechanical Behaviour of Biomedical Materials* **29** 295-308.
21. Cho LR, Yi YJ, & Heo SJ (2002) Effect of tooth brushing and thermal cycling on a surface change of ceromers finished with different methods *Journal of Oral Rehabilitation* **29** 816-822.
22. Minami H, Hori S, Kurashige H, Murahara S, Muraguchi K, Minesaki Y, & Tanaka T (2007) Effects of thermal cycling on surface texture of restorative composite materials *Dental Materials Journal* **26** 316-322.
23. Ilie N (2018) Comparative effect of self- or dual-curing on polymerization kinetics and mechanical properties in a novel, dental-resin-based composite with alkaline filler *Materials* (Basel) **11** 108.
24. Heintze SD, Eser A, Monreal D, & Rousson V (2017) Using a chewing simulator for fatigue testing of metal ceramic crowns *Journal of Mechanical Behaviour of Biomedical Materials* **65** 770-780.
25. Guler S & Unal M (2018) The evaluation of color and surface roughness changes in resin based restorative materials with different contents after waiting in various liquids: An SEM and AFM study *Microscopy Research and Technique* **81** 1422-1433.

26. Llena C, Fernández S, & Forner L (2017) Color stability of nanohybrid resin-based composites, ormocers and compomers *Clinical Oral Investigations* **21** 1071-1077.

27. Valencia JJC, Felix VMC, & Afrashtehfar KI (2019) "Alkasites, a New Alternative to Amalgam. Report of a Clinical Case". *American Society for Dermatologic Surgery* **3** 11-19.

28. Eick JD, Smith RE, Pinzino CS, & Kostoryz EL (2006) Stability of silorane dental monomers in aqueous systems *Journal of Dentistry* **34** 405-410.

29. Turgut S & Bagis B (2011) Color stability of laminate veneers: An in vitro study *Journal of Dentistry* **39 (Supplement 30** e57-e64.

30. Vichi A, Ferrari M, & Davidson CL (2004) Color and opacity variations in three different resin-based composite products after water aging *Dental Materials* **20** 530-534.

31. Guler AU, Yilmaz F, Kulunk T, Guler E, & Kurt S (2005) Effects of different drinks on stainability of resin composite provisional restorative materials *Journal of Prosthetic Dentistry* **94** 118-124.