



An Evaluation of Color Stability of Reinforced Composite Resin Compared With Dental Porcelain in Commonly Consumed Beverages

AHMAD GHAHRAMANLOO, DDS, MS; AZAM SADAT MADANI, DDS, MS; KEYVAN SOHRABI; AND SAEED SABZEVARI, DDS

ABSTRACT The effect of tea, cola, orange juice, and distilled water on the color stability of a porcelain (VITA VMK 95) and a reinforced composite resin (GC Gradia) was evaluated. Standardized specimens for each material were prepared. Specimens from each group were immersed in staining solutions at 50 degree Celsius for 30 days. Tea caused the most significant color change. ΔE of all of the materials was changed after the immersion in all of the staining solutions during the experimental process.

AUTHORS

Ahmad Ghahramanloo, DDS, MS, is an assistant professor, Department of Prosthodontics, Dental Research Center and Dental School of Mashhad, Mashhad University of Medical Sciences, Mashhad, Iran.

Azam Sadat Madani, DDS, MS, is an associate professor, Department of Prosthodontics, Dental Research Center and Dental School of Mashhad, Mashhad University of Medical Sciences, Mashhad, Iran.

Keyvan Sohrabi, is an undergraduate dental student, Dental Research Center and Dental School of Mashhad, Mashhad University of Medical Sciences, Mashhad, Iran.

Saeed Sabzevari, DDS, is a dentist, practicing at the Health Center in Sabzevar, Iran.

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Porcelain veneers have established themselves as ultimate conservative anterior esthetic restorations because of their natural appearance, good wear resistance, and color stability. Porcelain has color-rendering properties and optical properties that stimulate natural teeth. Although porcelains have high compressive strength and resist discoloration, which is superior to any other restorative material, they have a number of undesirable characteristics such as the time-consuming and technically demanding fabrication and abrasiveness of the porcelain when used against natural tooth structures.¹ It's

important to note that the long-term clinical success of porcelain veneers depends on a careful case selection and diagnostic approach as well as an accurate and appropriate tooth preparation.²

Recently introduced indirect composite systems try to resolve some of the problems inherent with dental porcelains. Over the last few years, the development of indirect resin-based composite resins has given the dental profession the possibility of fabricating adhesive aesthetic veneers for anterior teeth. Indirect resin composite veneers have been used minimally for several reasons: the dentists' ability to place direct resin-based composite themselves; difficulty



FIGURE 1. A four-hole metal mold was used to prepare porcelain disks.

in bonding laboratory-made fully cured composite resins to acid-etched tooth structure, and the color unpredictability.³

Light-cured GRADIA is an indirect restoration system for crown and bridge, inlays, onlays, and veneers. The chemistry of GRADIA couples a micro-fine ceramic/pre-polymer filler with a urethane dimethacrylate matrix to produce a superior ceramic composite, thus the system has improved mechanical properties, has the advantage of more strength, better translucency, and smoother surface finish, thus providing an ideal material for some prosthetic purposes.⁴ Still, one of the properties these composites have to pass the test of time is their color stability.

Composites are susceptible to discoloration that may be intrinsic or extrinsic.⁵ Intrinsic factors involve discoloration because of alteration of the resin matrix itself or the interface of matrix and fillers, oxidation, or hydrolysis in resin matrix.⁶ The resin matrix, a major component of composite materials, has been reported to play a critical role in color stability and is affected by different pH solutions and alcohol concentration.⁷ Studies of Ferracane et al. have shown that alcohol can plasticize the resin matrix, making it soft and prone to degradation.^{8,9} In addition, a study by Dietschi et al. showed that the intrinsic staining may be related to high resin content and water absorption.¹⁰

Extrinsic factors for discoloration include staining by adsorption or absorption of colorants as a result of

TABLE 1

Recommended Firing Cycle Used for VITA VMK 95 as Instructed by the Manufacturer

Firing	Preheat temp °C	→	↗	Temp. approx °C	→	VAC
Glaze firing with fluid	600	4.00	4.00	900	1.00	0.00

contamination from various exogenous sources.¹¹⁻¹³ Thus, dietary habits such as large consumption of soft drinks and beverages can contribute to the external staining of the laminates.¹⁴⁻¹⁷

Ertaş in 2006 showed that there are noticeable color changes of resin composites after immersion in different drinks.¹⁸ In 2005, Gupta manifested that the color match of esthetic restorations in the oral cavity is affected by dietary habits.¹⁹ However, because of the inconsistencies inherent in color perception and specification among observers, only visual comparison is not reliable. Colorimetry, based on comparison with a known standard is the most scientific and practical method to assess color stability.²⁰

The CIELAB (Commission Internationale de l'Eclairage) color coordinates system is a very useful mode that provides information about location of object color in a uniform 3-D color space. It quantifies the color in terms of three coordinate values L*, a*, and b*. Here, L* represents brightness or lightness (value) and a* and b* serve as numeric correlates both for hue and chroma.²¹ The a* and b* values represent position on a red/green and yellow/blue axis, respectively: + a* = red, - a* = green, + b* = yellow, and - b* = blue. The magnitude of the color difference perceived between two objects is calculated by formula $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$.

Color stability is decisive for the success of any anterior veneering material. Color mismatch is a major cause for the replacement of conventional anterior composites. Discoloration of restorative materials may result in patient dissatisfaction and additional

time and expense for replacement. However, in this regard, the color stability of microceramic-reinforced composites has not been evaluated and clarified. These composite materials designed for anterior fixed prosthodontic applications must possess color stability at least comparable to that of dental porcelain.

This study was conducted to evaluate the effect of three commonly consumed beverages: orange juice, tea, and cola, on color stability of an indirect microceramic-reinforced composite and a porcelain.

Materials and Method

A microceramic-reinforced composite, i.e., GC Gradia, (GC America Inc.) and a dental porcelain, i.e., Vita VMK 95 (Vita 3D-Master) were selected for this study.

Specimens were prepared in the form of discs. The shade used for test material was Vita VMK 95 EN 1 and GC Gradia El 1. Twenty discs of each material were prepared with a diameter of 20±2 mm and thickness of 2±0.2 mm.

VITA VMK Disk Preparation

A four-piece metal mold with specified dimensions was machined and used for making the VITA VMK 95 discs. The metal mold consisted of three parts. The upper and lower parts were two simple flat metal plates, whereas the middle part consisted of four holes (FIGURE 1). A disc of condensation silicone; Speedex (Colten, Whaledent, USA) was prepared by injecting the material between the two halves of a metal mold; both halves of the metal mold were then pressed together uniformly. The silicone disc thus obtained was

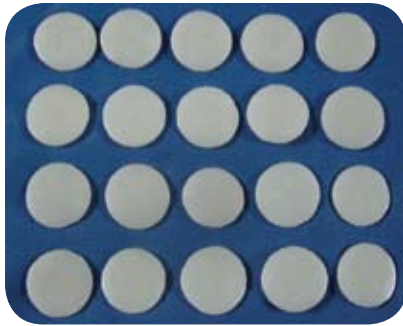


FIGURE 2. The prepared porcelain disks.

then placed inside a wax mold and the wax mold was filled with a refractory investment material to prepare a mold. VITA VMK 95 was applied on this mold, condensed, and trimmed flush with the upper part of the metal mold and fired. The purpose of this procedure was to have standardized porcelain disks.

Before firing the disks, thorough testing of the ceramic furnace was performed. Damaged fireclay bases as well as contaminated furnace linings were exchanged before firing. Furnaces featuring large temperature fluctuations were not used in this study.

Corrections on the disks were made using diamond-coated burs. The entire surface was ground with one abrasive instrument as different abrasive materials result in different degrees of roughness, and hence different degrees of surface gloss. The disks were cleaned again. Then, the glaze was applied to the entire surface. Excess glaze was removed with a dry brush until only a film of glaze remained. Final glazing was done according to **TABLE 1** as instructed by the manufacturer:

Afterward, the discs were removed from refractory mold taking care not to damage the glazed surface (**FIGURE 2**).

GC Gradia Disk Preparation

A five-piece glass mold was used for making the composite disks. Like the metal mold described, it consisted of three parts (**FIGURE 3**). A cellophane



FIGURE 3. A five-hole glass mold was used for the preparation of GC Gradia disks. It consisted of three parts: upper, lower, and a middle hole part.

sheet was placed at the base of the mold and then the material was placed in the mold and pressed uniformly. Extra flash was removed and the material was made flush with the top of the mold surface. Discs were light-cured 20 seconds from both sides, as instructed by the manufacturer using a visible light cure unit, GC Steplight SL-I (GC America Inc.). Final curing was performed by GC Labolight LV-III (GC America Inc.) for three minutes as instructed by the manufacturer, but they were cured two minutes more to ensure sufficient polymerization.

The cured specimens were finished with six brush strokes in the same direction using Moore's disks (E.C. Moore Co., Dearborn, Mich.) to produce a standard rough surface. The specimens were then polished with the use of the Sof-Lex (3M ESPE, St. Paul, Minn.) system.⁴ The system the authors used consisted of three steps:

1. Application of a medium aluminum oxide disc (40 μm)
2. Application of a fine aluminum oxide disc (24 μm)
3. Application of an ultrafine aluminum oxide disc (8 μm)

The same slow-speed handpiece was used for all procedures. The polishing procedure consisted of repetitive strokes for 30 seconds, 10 seconds per step of the system, to prevent heat buildup. An intentional effort was made to standardize the strokes, downward force, and the

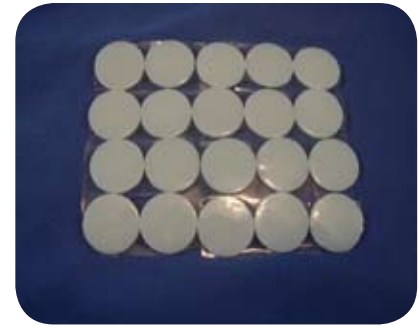


FIGURE 4. The prepared composite disks.

number of strokes for each polishing procedure. According to the manufacturer's instructions, Sof-Lex system was used dry. Specimens were labeled on one side using a fine, round bur.

All the disks (GC Gradia and VITA VMK 95) were stored in Saliva Substitute (Roxane Laboratories Inc., Columbus, Ohio) in plastic bags at 36 degrees Celsius 24 hours prior to their placement in the staining solutions (**FIGURE 4**).

Test Solutions

Tea (Lipton's black tea), orange juice (Tropicana), cola (Coke), and distilled water were used in this study. A solution of 250 ml each was taken and specimens were immersed in solutions. For tea preparation, a black tea bag was immersed in 300 ml boiling distilled water and simmered for two minutes. All solutions were kept at a constant temperature of 50 ± 1 degree Celsius in an incubator. Test solutions were changed every seventh day.

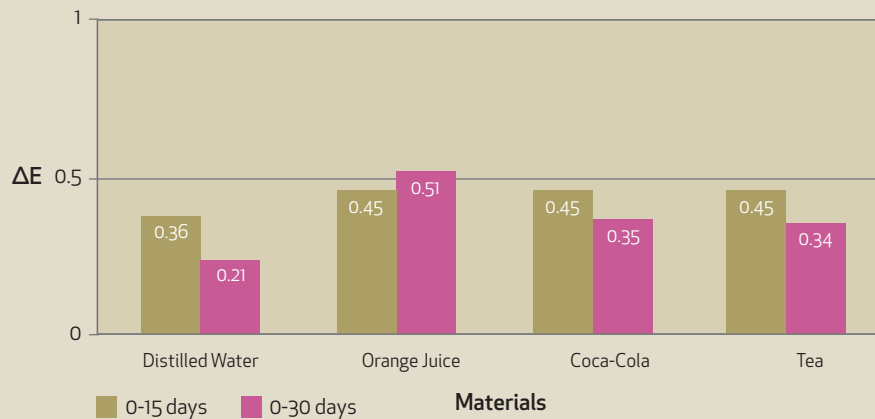
Color Evaluation

Color changes were measured at an interval of one day, 15 days, and 30 days for all the solutions.

Following removal from the staining solutions, the samples were dipped in distilled water and moved up and down 10 times. The samples were then wiped dry with tissue paper with light pressure and then placed in viewing port for color measurement. Each specimen

TABLE 2

Total Discoloration of VITA VMK 95 in Different Beverages at Different Time Periods



cance of 95 percent was satisfied during the entire statistical analysis.

Results

All three factors studied, i.e., type of material, solution, and time factors had a significant effect on each of the three measured color parameters. VITA VMK 95 after immersion in the test solutions showed a small amount of color change after one month that was clinically non-perceptible in all the solutions, including distilled water. The color change ranged from 0.21 ΔE units in water to 0.51 ΔE units in orange juice after one month (TABLE 2). GC Gradia showed increased discoloration over the observation period of one month. The color change ranged from 3.12 ΔE units in water to 6.09 ΔE units in tea after one month (TABLE 3).

The difference in total discoloration was significant between VITA VMK 95 and GC Gradia ($p < 0.001$), with the latter showing more discoloration than porcelain in all the solutions. The maximum mean difference between VITA VMK 95 and GC Gradia was: 2.91 in water; -5.75 in tea; -3.67 in orange juice; and -3.86 in cola. Considering the mean staining intensity of all the solutions, tea was found to cause more discoloration than orange juice, cola, and water.

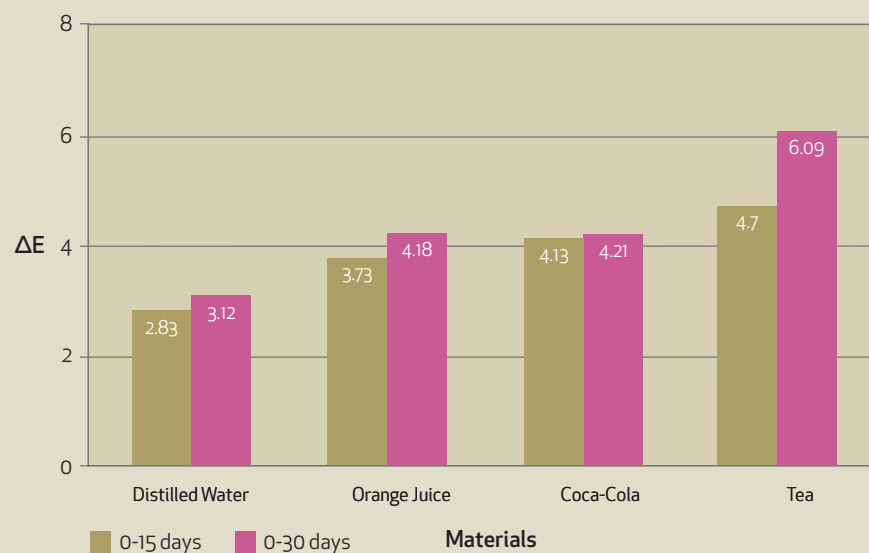
There was a significant change in ΔL (brightness) after a period of one month in both groups. Both groups showed a decrease in L value, i.e., became darker and less bright with time. However, the amount of ΔL changes after one month for VITA VMK 95 was clinically non-perceptible. This change ranged from 0.04 units in tea to 0.32 units in cola.

GC Gradia showed a significant change in L value ($p < 0.001$) ranging from 1.64 units in water to 3.88 units in tea.

When compared with porcelain there was significantly more change

TABLE 3

Total Discoloration of GC Gradia in Different Beverages at Different Time Periods



was placed on a neutral gray background (Munsell N-7, Macbeth, New Windsor, N.Y.). This background was used for all color measurements. Minolta CR-10 was used in the study. Color changes were calculated by using the formula: Change in color $\Delta E = (\Delta L^2 + \Delta b^2 + \Delta a^2)^{1/2}$.

Statistical Analysis

A one-way ANOVA with a multiple-range test (Tukey test) was applied to see significant difference among the groups. To see the trend or impact of different beverages, a two-way ANOVA test was applied. A level of signifi-

in GC Gradia ($p < 0.001$). Δa (change along red-green axis) was found to be significant for all the materials after one month ($p < 0.001$) in all the solutions. Both VITA VMK and GC Gradia showed positive Δa , therefore indicating a shift toward red color. A maximum change in the “a” coordinate was seen in GC Gradia after exposure to tea. When compared with VITA VMK, there was significantly more change in GC Gradia ($p < 0.001$).

Δb (change along yellow-blue axis) was found to be significant for all the materials after one month ($p < 0.001$) in all the solutions. GC Gradia showed positive Δb , therefore indicating a shift toward yellow. A maximum change in the “b” coordinate was seen in GC Gradia after exposure to tea. VITA VMK 95 showed a negative Δb just in distilled water, thus indicating a shift toward blue or became less yellow.

In the other solutions, VITA VMK 95 showed positive Δb . When compared with porcelain, there was significantly more change in GC Gradia ($p < 0.001$).

Color change along individual coordinates of the CIELAB system (TABLES 4-6).

Discussion

A number of factors are known to impact color stability of the composites. In this study, the researchers were very careful to reduce such factors to a minimum. Different factors that could precipitate the staining of samples during polymerization, finishing, and storage. Although a high-gloss surface generally is considered less susceptible to staining, other surface conditions, such as incomplete polymerization of the resin matrix, may lead to the surface staining of composites.⁷ Microcracks, microvoids, or interfacial gaps located at the interface between the filler and the matrix are the most likely penetration pathways for stains.²²

This study evaluated the extrinsic

TABLE 4

ANOVA for ΔL Changes in Different Beverages at Different Time Intervals

Material	Solutions	1 Day	15 Days	1 Month
GC GRADIA	Distilled water	64.24±0.32	62.72±0.08	62.60±0.07
	Orange juice	64.26±0.19	62.34±0.19	62.16±0.15
	Tea	64.34±0.30	61.60±0.24	60.46±0.59
	Cola	64.20±0.30	62.22±0.14	62.08±0.08
VITA VMK 95	Distilled water	60.06±0.55	60.40±0.54	60.18±0.50
	Orange juice	60.06±0.43	59.90±0.07	59.74±0.27
	Tea	60.12±0.20	60.22±0.43	60.08±0.27
	Cola	60.44±0.53	60.22±0.52	60.38±0.51

TABLE 5

ANOVA for ΔA Changes in Different Beverages at Different Time Intervals

Material	Solutions	1 Day	15 Days	1 Month
GC GRADIA	Distilled water	-2.56±0.15	-2.50±0.10	-2.34±0.11
	Orange juice	-2.52±0.13	-2.40±0.15	-2.24±0.15
	Tea	-2.56±0.16	-1.90±0.24	-1.26±0.41
	Cola	-2.54±0.11	-2.10±0.10	-1.92±0.08
VITA VMK 95	Distilled water	0.44±0.08	0.38±0.08	0.46±0.05
	Orange juice	0.48±0.08	0.44±0.08	0.64±0.15
	Tea	0.44±0.05	0.52±0.04	0.66±0.08
	Cola	0.50±0.07	0.58±0.04	0.76±0.08

TABLE 6

ANOVA for ΔB Changes in Different Beverages at Different Time Intervals

Material	Solutions	1 Day	15 Days	1 Month
GC GRADIA	Distilled water	0.24±0.28	2.62±0.19	2.88±0.22
	Orange juice	0.40±0.18	3.60±0.26	4.00±0.15
	Tea	0.46±0.18	4.22±0.26	4.96±0.29
	Cola	0.24±0.24	3.84±0.19	3.82±0.17
VITA VMK 95	Distilled water	3.24±0.15	3.26±0.16	3.14±0.13
	Orange juice	3.20±0.07	3.40±0.10	3.32±0.14
	Tea	3.18±0.16	3.44±0.15	3.32±0.19
	Cola	3.32±0.16	3.66±0.18	3.50±0.15

staining of the samples in different solutions. Extrinsic staining very likely depends upon the smoothness of the surface of the material. In this study, care was taken to have equal surface smoothness for the GC Gradia disks by performing standard procedures for all samples and the application of equal power during finishing and polishing procedures, the pressure used in this study was controlled by a conscious effort to standardize the stroke with a downward intermittent force, as well as the number of strokes for each polishing procedure. The amount of time to finish each sample with each abrasive material was also carefully controlled.

Careful following of the manufacturers guidelines regarding the glazing procedures of the VITA VMK 95 could possibly lead to an equal smoothness of surface for these samples. However, as porcelain samples were considered as controls in the study and since the two materials (GC Gradia and VITA VMK 95) are of totally different substances, no effort was made to equalize the surface smoothness of the composite groups to the porcelain disks.

To simulate the clinical discoloration potential of the samples, they were stored at 50 degrees Celsius in accordance with the accelerated lab test given by Asmusen in 1981 that stated color changes produced in composites by storing for one month at an increased temperature of 50-60 degree Celsius was well correlated with color change obtained after storing for 12 months at 37 degree Celsius.²¹

Color perception is a psychophysical phenomenon with variations, both between individuals and within an individual at different times, and instrumental measurement has the advantage of obviating the subjective errors of color assessment.¹⁹ The CIELAB color system is used almost exclusively for color research in dentistry around the world. It was

introduced in 1976 and recommended by the International Commission on Illumination. The strength of this system, unlike that of the Munsell system, is its ability for clinical interpretation, as equal distances across the CIELAB color space (color differences or ΔE) represent approximately uniform steps in human color perception, improving the interpretation of color measurements. This means that the magnitude of perceptible and/or

**TEA WAS FOUND
to cause
more discoloration
than orange juice,
cola, and water.**

acceptable color difference can be defined between for example, a porcelain crown and the adjacent natural dentition.²⁰ Thus, the application of this system helped the study have a rather precise method of color evaluation. As a result, observation bias in the collection of data by clinical observers has had little chance to occur.

Even porcelain (VITA VMK 95) after immersion in the test solutions showed a color change ranging from 0.21 to 0.51 ΔE units after one month though it was not in a visually perceptible range. The overall color changes were in a range similar to that reported in a study by Razzoog et al., in which two porcelain systems vs. Ceramco and Procera showed a color change in the range of 0.5- 1.5 ΔE units after an accelerated aging process for 900 hours in a weathering chamber.²³

Douglas evaluated the color stability of various indirect resins (Artglass, Zeta, Targis, Belleglass), one direct resin

(Herculite XRV), and a porcelain system (Omega 900) after accelerated aging for 300 hours.¹ Porcelain was reported to discolor the least and was not significantly different from Zeta and Artglass that showed a color change in the range of 0.62-3.4 ΔE units. But these studies differed from the present study since these studies evaluated only the change that occurred over time (effect of aging) and did not evaluate the resistance against external staining. Color changes of composite materials can happen through different mechanisms: the formation of colored degradation products, alterations in surface structure due to wear and by extrinsic staining. The last mechanism is not tested in accelerated aging.¹

Considering the mean staining intensity of all the solutions, tea was found to cause more discoloration than orange juice, cola, and water. The strong black tea used in the present study could have affected the results. This is in agreement with the results of some previous studies conducted to find effect of various staining agents on different resinous materials.^{15-24,25} Nonetheless, it has been reported that discoloration with tea is superficial and can be easily removed after cleaning with soap and toothbrush.¹⁹ As tea is a common drink in different countries, especially in Middle Eastern societies, clinicians should advise patients that drinking tea could intensify surface staining on composite restorations. It is highly recommended that a toothbrush be used to remove the stains after drinking tea.

When the trend for color change was observed over the observation period of one day to one month, it was noticed that GC Gradia showed a greater amount of discoloration in the first two weeks in general. The fact there is water solubility and leaches out after immersion in a solution might have affected

the early color changes in GC Gradia.

The results are in partial agreement with the study by Buchalla that was conducted to determine the color and translucency changes in a hybrid composite (Tetric) and a microfilled composite (Silux-plus) after exposure to an artificial light with and without water.²⁶ The samples were stored at room temperature (23 degrees Celsius) for one month. Both the materials in the study showed negative ΔL value (a decrease in L value), i.e., darkening with time. There was a blue shift (negative Δb) for both the materials. In the present study, changes along the “L” axis are in agreement with that by Buchalla, but changes along the “b” axis are different. The difference could be due to difference in the experimental conditions. In the authors’ study, samples were stored at an increased temperature of 50 degrees Celsius to simulate a long-term clinical exposure.

Secondly, the test solutions in the present study were tea, orange juice, and cola, along with water as a control. Tea was found to cause yellowing and reddening of the composites, in agreement with previous studies, and has been explained on basis of yellow component present in the solution.²⁵ The response to cola and orange juice varied among the test materials. The extremely low pH of cola (approximately 2) and orange juice can be a contributing factor to changes in the color characteristics of the materials.¹⁹ Cola gains its color through the addition of caramel color. Caramel exhibits colors ranging from palest yellow to deepest brown, and is made by heating sugar or glucose in the presence of alkali or mineral acid.²⁷ The positive b^* values for the specimens immersed in the cola solution indicate a shift toward yellow. The control, i.e., distilled water, was also found to cause small variations in color,

which may be due to increased temperature, causing increased water uptake by composites and leaching out of few soluble components of the materials.

The clinical relevance of the present study results depends on how much color change (represented by E values) is considered perceptible. It is shown that a $E < 1$ is not considered perceptible to most subjects with normal color vision. Studies state that observers do not believe that

THE RESPONSE to cola and orange juice varied among the test materials.

restorations with a E as high as 3.3 and 3.7 required replacement, although the color differences definitely were perceptible.^{28,29} Considering the fact that color perception can vary significantly among people, the latter results probably would represent the color perception reality of the general population, for whom the color difference probably would be visually detected, but it also may be clinically acceptable.^{30,31}

Conclusion

It has been claimed that under clinical conditions in the mouth, ΔE color differences have been reported as relevant only when the value is higher than 3.3 or 3.7. Thus, the changes in the GC Gradia are of relevance clinically as these changes would be apparent after prolonged and frequent exposure of the restorations to tea, orange juice, and cola. (Unlike some other studies, samples were stored at an increased temperature of 50 degrees Celsius to

simulate a long-term clinical exposure). GC Gradia tested in this study demonstrated color changes that could not be considered acceptable as this material did not possess color stability comparable to dental porcelain and because of its poor resistance against external staining.

Although the usage of GC Gradia as an anterior veneering material is not advocated by results acquired in this in vitro study, further in vivo and in vitro studies are needed to confirm this result. Nevertheless, VITA VMK 95 can be considered color stable and resistant to external staining.

Finally, the authors would like to emphasize that it is difficult to entirely correlate laboratory findings with the clinical behavior of any restoration since a number of factors are at play in oral environment that cannot be fully simulated in laboratory conditions. Therefore, to find a correlation between clinical studies and lab measurements, further in vivo clinical evaluation is suggested. ■■■■

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CONTACT Ahmad Ghahramanloo, assistant professor, via e-mail at ahmadghahramanloo@gmail.com or the Department of Prosthodontic, Dental Research Center and Dental School of Mashhad, Mashhad University of Medical Sciences.