RESEARCH ARTICLE

Evaluation of the color stability of two different posterior tooth colored restorative materials [version 1; peer review: 2 approved with reservations]

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Abstract

Background: The aim of this *in vitro* study was to evaluate the color stability of esthetic restorative materials (Cention N, Solare Sculpt) after exposure to different staining solutions (coffee, green tea and Diet Coke).

Methods: Cylindrical specimens of both materials (n=40/material) were prepared using 4x8 mm metal molds. They were further divided (n=10) based on the beverages in which they are immersed. The color of each sample was recorded immediately after sample preparation and at 60 days after the staining procedure. Color changes were then analyzed statistically.

Results: Color differences (ΔE) were statistically significant between Cention N and Solare sculpt in all beverages with Cention N showing highest staining after 60 days. Among all the beverages, coffee showed the highest level of staining.

Conclusions: Staining beverages caused significant discolorations for both test materials. Cention N showed greater color variations with all beverages compared to Solare Sculpt. Coffee showed the highest staining with both materials, followed by Diet Coke then green tea.

Keywords

Beverages, color stability, staining susceptibility, spectrophotometer

Open Peer Review

Approval Status ? ?

	1	2
version 1		
16 Oct 2020	view	view

1. **Rubens Nisie Tango** , São Paulo State University, São José dos Campos, Brazil
2. **Neda Eslami**, Mashhad University of Medical Sciences, Mashhad, Iran

Any reports and responses or comments on the article can be found at the end of the article.

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Introduction

The use of tooth-colored restorative materials has been on the rise in the recent times. Patient awareness and improvement in the properties of composite materials have led the clinicians to use these materials, even in the posterior regions. But strength and other properties like staining have remained as a challenge with the newer materials that are being introduced¹.

Recently developed esthetic materials like Cention N and Solare Sculpt have been reported to have improved properties for use as posterior restorative material. One important aspect of esthetic restorative materials is color. Interactions between the components of a restorative material play a key role in their color stability. Composite resin materials are mainly discolored due to the intrinsic or extrinsic factors. The intrinsic discoloration of the composites can be determined by the photo initiator, quality of resin matrix and by the inorganic filler, in the same way the extrinsic discoloration is caused especially by the colorants present in beverages and foods through adsorption and absorption². In the present contemporary society there is a high prevalence of consumption of coffee, green tea and soft drinks, causing discoloration of the tooth-colored restorations³.

Many studies⁴⁻⁶ have focused on comparing the physical properties of Cention N with composite materials and others. To our knowledge, no study has compared the staining ability of Cention N with Solare Sculpt.

Thus, the present study aimed to evaluate the staining susceptibility of a recently developed nanohybrid composite (Solare Sculpt) and Cention N after immersion in artificial saliva, coffee, green tea and Diet Coke using a spectrophotometer. The null hypothesis tested in this study was that there would be no difference in staining susceptibility among the materials tested and no difference in staining ability of all the beverages used.

Methods

Solare Sculpt and Cention N (Shade A2) were the materials used in the study. Detailed descriptions of the products used are presented in Table 1. A total of 80 metal molds 4 mm thick and 8 mm in diameter were prepared for each specimen. Each restorative material was prepared as per manufacturer instructions and placed in the metal rings to prepare the 80 samples (n=40 for each material). The ring was then placed between glass slabs to remove the excess and to obtain a flat surface. All the samples were light-cured with a blue phase light-curing unit (Ivoclar Vivadent, Schaan, Liechtenstein, UK) for 20 seconds on both sides. Cured specimens were then removed from the mould and were finished and polished.

Finishing was done with fine-grit Sof-Lex flexible disks (3M ESPE, MN, USA), and then polished using rubber cups (Shofu dental products, San Marcos, USA) at low speed. All samples were stored in distilled water for 24 h after curing. All the samples of both materials were then divided according to the beverage in which they are immersed (n=10):

1. Artificial saliva (Yash Pharma Laboratories, Uttarakhand, India) (control group)

2. Coffee (Bru coffee, Hindustan Unilever Limited Mumbai, Maharashtra)
3. Green tea (Lipton Green tea, Hindustan Unilever Ltd., Mumbai, India)
4. Coke (Hindustan Coca-Cola Beverages Pvt. Ltd., Pune, India)

After finishing and polishing and before immersion, color measurements were conducted as baseline values using a spectrophotometer (Easy shade compact spectrophotometer, VITA, Zahnfabrik H, Bad Sackingen, Germany. Model no; DEASYCS22). After taking the baseline values, the individual samples were transferred into small bottles and labeled according to the type of restorative material and the staining solution (as described below).

Preparation of the staining solutions

Control group. An artificial saliva bottle (Entod Pharmaceuticals, Yash Pharma Laboratories, Uttarakhand, India) was used for dispensing into the containers, at 10 ml per container that were labeled as artificial saliva group.

Coffee. The coffee was prepared by dissolving 10 grams of coffee powder (Bru coffee, Hindustan Unilever Limited Mumbai, Maharashtra) in 500 ml of boiling distilled water. After 10 min of stirring, the solution was filtered through a filter paper. The filtered solution was then dispensed into the containers, at 10 ml per container that were labeled as coffee group.

Green tea. The green tea was prepared by using two tea bags (Lipton Green Tea, Hindustan Unilever Ltd., Mumbai, India) according to the manufacturer's instructions. First, 500 ml of water was boiled then allowed to cool down to 80°C as measured by the Lab Thermometer (Ludwig Schneider, Wertheim, Germany). The green tea bags were then steeped in the 80°C water for 1 minute, and the bags were then removed from the water. This prepared green tea was then dispensed into the containers, at 10 ml per container that were labeled as green tea group.

Diet Coke. A 300 ml Diet Coke can (Hindustan Coca-Cola Beverages Pvt. Ltd., Pune, India) was used for dispensing into the containers, at 10 ml per container that were labeled as the Diet Coke group.

Staining procedure

After the baseline analysis, the test group specimens were placed in bottles with their respective staining solutions for one hour every day up to 60 days, while the control group specimens were placed in the artificial saliva for 24 hours every day up to 60 days. After each day's one-hour staining period, the stained test specimens were removed from their respective staining solution, rinsed in distilled water and transferred back to the bottles with artificial saliva (E SALIVA, Yash Pharma Laboratories, Uttarakhand, India) for the remaining time.

After the 60 days of immersion period the specimens were rinsed with distilled water for five minutes and blotted dry

Table 1. Composition of the restorative materials used in the study.

CENTION- N		
Composition	Weight, %	Function
Powder		
Calcium fluorosilicate glass	25 – 35	Ion release
Ba-Al silicate glass	20 – 30	Strength
Ca-Ba-Al fluorosilicate glass	10 – 20	Strength, Fluoride release
Ytterbium trifluoride	5 – 10	Radiopacity
Isofiller (Copolymer)	15 – 25	Shrinkage stress reliever
Initiator (a copper salt & thiocarbamide- self cure) (Ivocerin and acyl phosphine oxide photo initiator)	< 1	Initiator
Pigment	< 0.1	Pigment
Liquid		
UDMA (Urethane dimethacrylate)	95–97	Monomer
DCP (Tricyclodecandimethanoldimethacrylate)		
Aromatic aliphatic UDMA (Tetramethylxylylendiurethane dimethacrylate)		
PEG-400 DMA (Polyethylene glycol 400 dimethacrylate)		
Additives		
Initiator (hydroperoxide – self cure)	2–3	
Stabilizer	<1	
Solare Sculpt		
Bis-GMA		
Bis-MEPP		
UDMA		
TEGDMA		
Barium glass		
Fine silica particles		
Pigments and photoinitiator		
High density pre-polymerised nano-fillers		
300-nm strontium glass fillers		

with absorbent paper and the final color of all specimens were measured as described above. The CIE 1976 L*a*b* color system⁴ was used to calculate the color differences. The following formula was used to calculate the color differences (ΔE) at various time intervals:

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

Where ΔE represents the mean color change, ΔL the mean of baseline L values, Δa the mean of baseline a values and Δb the mean of baseline b values.

Statistical analysis

Unpaired t-test was used to compare the color change values between the two main groups and analysis of variance

(ANOVA) was used to compare the color change values between their sub-groups. Data was analyzed using SPSS version 20 software. All statistical analysis was performed at 95% level of confidence, with the significance level established at $P < .05$.

Results

The color change values (ΔE) observed between the two groups and subgroups can be seen in Table 2 and Table 3. The p-value obtained between the groups shows statistically significant difference between the two materials and between the sub-groups of each group.

Both the groups stained in artificial saliva showed the least color change after 60 days, while those stained in the coffee showed the highest color change, followed by Diet Coke and green tea. Among the two materials, Cention N had exhibited more staining than Solare Sculpt in all immersions (Table 2 and Table 3).

Discussion

Success or failure of an esthetic restoration primarily depends on the color stability of the material⁷. The extent of discoloration *in vitro* depends on various factors, including the

Table 2. Inter-group comparison of mean color changes of the tested materials.

Liquid	Group	Mean ΔE	SD	Mean difference in ΔE	p-value
Saliva	Cention N	0.81	0.09	0.05	0.553
	Solare sculpt	0.75	0.29		
Coffee	Cention N	5.74	0.48	0.57	0.025
	Solare sculpt	5.17	0.55		
Diet coke	Cention N	3.87	0.11	0.56	0.001
	Solare sculpt	3.30	0.16		
Tea	Cention N	2.26	0.15	0.20	0.003
	Solare sculpt	2.06	0.09		

Table 3. Intra-group comparison of mean color changes of the tested materials.

Restorative material	Group		Mean difference, ΔE	p-value
Cention N	Saliva	Coffee	-4.93	0.001
		Diet Coke	-3.05	0.001
		Tea	-1.45	0.001
	Coffee	Diet Coke	1.87	0.001
		Tea	3.48	0.001
	Diet Coke	Tea	1.60	0.001
Solare Sculpt	Saliva	Coffee	-4.41	0.001
		Diet Coke	-2.55	0.001
		Tea	-1.30	0.001
	Coffee	Diet Coke	1.86	0.001
		Tea	3.11	0.001
	Diet Coke	Tea	1.24	0.001

composition of the material itself, test method, curing time and device, aging conditions, etc.

Incomplete polymerization of the resin composites leaves unreacted monomers, which leads to discoloration of composites by aging and subsequent reactions with other substances^{3,4}. To avoid this, all samples were stored in distilled water for 24 h after curing⁸.

Discoloration can also occur through water sorption and food intake. Since the foods and beverages consumed contain a variety of coloring agents, they can alter the color of the resin composites through absorption and/or adsorption of colorants during the long period of exposure. The staining solutions used in this study are common in the diet, and some have the known potential to stain tooth-colored restorative materials. According to Guler and others, storage of samples for 15 days in coffee solution simulates the coffee consumption of an individual for at least 1 year⁸. Thus, in the present study 60 days of storage was done, equating to about 48 months of beverage consumption. The staining protocol (quality and quantity and concentration of solutions prepared, and also daily changing of staining solutions) were strictly followed to mimic the *in vivo* conditions. The surface roughness of the restorative surfaces can also affect the discoloration potential because the more the rougher the surface, the greater the surface area for contact with the coloring agents⁷.

That is the reason all the samples were finished and polished with fine-grit Sof-Lex flexible disks and rubber cups.

There are two categories for color evaluation, one is visual and other is through the use of instruments. Instrumental assessment can potentially eliminate subjective errors in color assessments which may be observed visually. Therefore, in the present study a digital spectrophotometer was used for assessing the color change⁹.

In the present study following immersion in the test beverages, all restorative materials exhibited a color change of $\Delta E > 1.5$, and those immersed in tea and diet coke exhibited a color change of $\Delta E > 3.3$ ^{10–12}. The results indicated that both the groups stained in artificial saliva had shown the least color change ($\Delta E < 1$) while those stained with coffee showed the highest color change ($\Delta E > 5$).

Of the two materials tested, Centon-N had exhibited greater staining than Solare Sculpt after 60 days. The final matrix of Centon N comprises of 12–40% monomers that may leach out; alternatively, fluoride release from the material may be the reason for color change over a period of time.

Among the subgroups, the coffee solution caused the highest degree of staining followed by Diet Coke and green tea. The least staining was seen with the artificial saliva solution. The higher discoloration caused by the coffee solution to the composites

has been well established. Coffee contains yellow colorants with low polarity. The discoloration caused by coffee might be due to both adsorption and absorption of these colorants^{13,14}. The low polarity of these colorants results in slower discoloration. The absorption and penetration of the colorants into organic phase of materials may be due to the compatibility of the polymer phase with the yellow colorants in the coffee^{15,16}. Diet Coke did not produce as much as discoloration as coffee, potentially due to its lack of yellow colorants^{16–18}.

The specimens immersed in green tea gave ΔE values of between 2 and 2.5 for all the specimens tested. Green tea has a thin green color. In most of the specimens, the green colorant had no greening effect on the specimens, regardless of the composite. This trend suggests that the tested green tea solution did not contain tannins and the concentration of green colorant must be too low to be effective¹⁷.

Specimens immersed in artificial saliva showed no visible color change. For ΔE values, the slight change observed might be due to the adsorbed mucin of the artificial saliva on to the composite surfaces.

Composite resins that can take up water are also competent to take in other fluids containing pigments, leading to discoloration, with water mainly acting as a medium for stain penetration into the resin matrix^{17,18}. This is the reason discoloration is seen in both groups. To our knowledge this is the first study to compare Centon N with a composite (solare Sculpt) in terms of staining. As such, further studies are required for further substantiation.

Conclusion

Within the limitations of the present study, the null hypothesis, that there would be no difference in staining susceptibility among tested materials, was rejected. Staining beverages caused significant discoloration for both test materials. Centon N showed higher color variations with all beverages compared to Solare Sculpt. Coffee showed the highest degree of staining with both materials, followed by Diet Coke and then green tea.

Data availability

Underlying data

Figshare: Evaluation of color stability of two different posterior tooth colored restorative. <https://doi.org/10.6084/m9.figshare.12966680.v4>¹⁹.

This project contains the following underlying data:

- BOOK 2.xlsx. (Raw L, a and b colour values from each specimen.)
- study raw data values.docx. (Mean colour change values for each specimen.)

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

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Current Peer Review Status: ? ?

Version 1

Reviewer Report 08 March 2022

<https://doi.org/10.5256/f1000research.29004.r121099>

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Neda Eslami

Department of Orthodontics, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

This is a well and scientifically- written article. It compares color stability of two different types of composites when immersed in three routine drinks (coffee, Kola, green tea). They found that coffee induced more staining compared to other drinks, and difference between the two composites were statistically significant.

The authors did not explain if they refresh the staining medium every day.
There are many similar articles in literature. Please justify the importance of your research.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Orthodontics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 16 December 2021

<https://doi.org/10.5256/f1000research.29004.r115414>

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Rubens Nisie Tango

Department of Dental Materials and Prosthodontics, São Paulo State University, São José dos Campos, São Paulo, Brazil

The study design of the present manuscript on the color stability of esthetic restorative materials upon immersion in staining solutions is very simple. However, as presented it can not be accepted for indexing and neither can be reproduced. Please, see the comments as follows:

- Is the work clearly and accurately presented and does it cite the current literature? Partly. Many studies have shown a better correlation between DeltaE 00 and interpretation of color change. Additionally, important information about handheld spectrophotometers has already been published. Thus, please provide information on the limitations of Easyshade and on color change interpretation according to CIEDE 2000 (Paravina et. al^{1,3}). Which is the equivalence of 1h/60 days of immersion in real life?
- Is the study design appropriate and is the work technically sound? Are sufficient details of methods and analysis provided to allow replication by others? Are all the source data underlying the results available to ensure full reproducibility? No. Important information of sample preparation is lacking: the light intensity of LCU; polishing time, pressure and handpiece rpm per step - wet or dry; how was optimal polishing determined? How were specimens stored in the containers, individually? Were the measured surfaces in contact with the bottom of the container? How many measurements were obtained per specimen?
- If applicable, is the statistical analysis and its interpretation appropriate? No. It would be more accurate to use 2 way ANOVA (materials and staining solutions), because variability of the whole sample is not considered when performing isolated statistical tests. Please, also provide adequate post hoc test.
- Are the conclusions drawn adequately supported by the results? No, conclusions are based on statistical tests that should be changed.

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Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

No

Are sufficient details of methods and analysis provided to allow replication by others?

No

If applicable, is the statistical analysis and its interpretation appropriate?

No

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Dental materials, prosthodontics and dental education

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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