10.5005/jp-journals-10052-0073

ORIGINAL ARTICLE

Effect of Tobacco Extract, Cigarette Smoke, and Carbonated Beverage on Surface Roughness and Color Stability of Three different Restorative Materials: An *in vitro* Study

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ABSTRACT

Introduction: Porcelain has color-rendering and optical properties that simulate natural teeth; though these restorations are considered to be color stable, discoloration is one of the primary factors for failure of esthetic restorations.

Aims and objectives: To evaluate the surface roughness and color stability of three different restorative materials when exposed to tobacco extract, cigarette smoke, and carbonated beverage.

Materials and methods: A total of 99 samples were fabricated, 33 samples in each restorative material. A total of 33 samples were subdivided such that 11 samples of the above-mentioned restorative materials were subjected to tobacco extract, the other 11 were exposed to cigarette smoke in an artificial chamber, and the remaining 11 were immersed in carbonated beverage for a period of 90 days with variant exposure times. The pretreatment values of 99 samples for color stability were recorded using spectrophotometer and those of degree of surface roughness were recorded using profilometer. Posttreatment values were recorded using the same instruments.

Results: The IPS e.max, zirconia disks when subjected to tobacco extract and cigarette smoke ($p > 0.05$) had no significant differences found for color stability and surface roughness. All three materials when exposed to carbonated beverages, statistically significant values were obtained ($p < 0.001$). Among the three different restorative materials used, Vita VMK Master exhibited the maximum change in value of surface roughness (0.035818 μm).

Conclusion: Among the three irritants used, smoke and tobacco extract did not affect color or degree of surface roughness for three restorative materials.

Carbonated beverages, on the contrary, exhibited significant differences in color stability as well as surface roughness when measured pre- and postexposure for all the three restorative materials.

However, among the three materials, feldspathic porcelain exhibited superior change in color and surface roughness when measured postexposure to irritants.

Keywords: Carbonated beverages, Cigarette smoke, Color stability, Porcelain, Surface roughness, Tobacco extracts.

How to cite this article: Prajapati AM, Sanyal PK, Guru R, Vaswani P, Tewary S, Sushma R. Effect of Tobacco Extract, Cigarette Smoke, and Carbonated Beverage on Surface Roughness and Color Stability of Three different Restorative Materials: An *in vitro* Study. Int J Prev Clin Dent Res 2017;4(1):9-18.

Source of support: Nil

Conflict of interest: None

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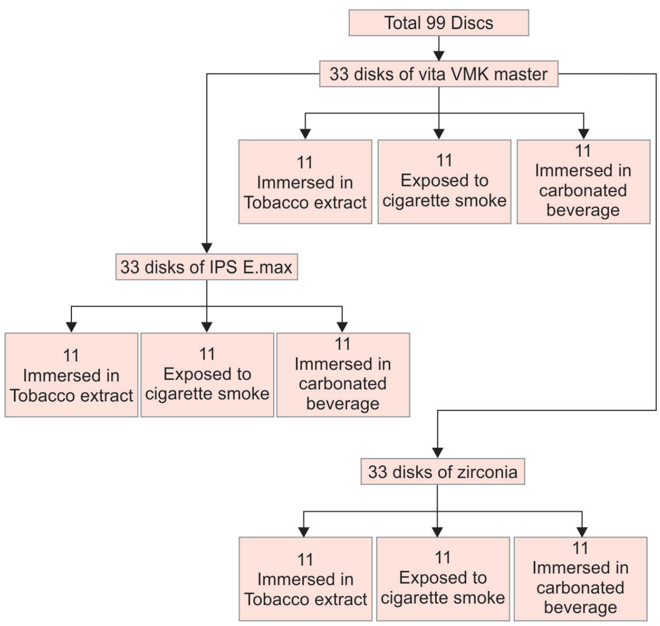
INTRODUCTION

Restoration of smile is one of the most challenging and esthetically satisfying services a prosthodontist can render to a patient.[1] The need to restore and rehabilitate the patient's dentition, so as to improve the function, comfort, and esthetics of the stomatognathic system is one of the main objectives of the dental profession. The biomaterials that are used for the fabrication of fixed restorations are the mainstay for the success and longevity of such prostheses. Of all the esthetic restorative materials known to mankind, ceramics have proven themselves to be the most natural in appearance, texture, color, reflectance, and translucency, so much so that distinguishing them from the natural teeth at times may be impossible. Feldspathic porcelain, glass ceramic, and now zirconia are the various contemporary materials used for the fabrication of crowns and bridges. Porcelain has color-rendering and optical properties that simulate natural teeth; though these restorations are considered to be color stable, discoloration is one of the primary factors for failure of esthetic restorations. Discoloration of porcelain may be due to intrinsic or extrinsic factors. Intrinsic factors involve changes within the material itself. The extrinsic factors that may cause discoloration of porcelain restorations include adsorption or absorption of stains in the oral cavity. Extrinsic staining, very likely, depends upon the smoothness of the surface of the restoration.[2] Several studies have been undertaken to evaluate the color stability of composite restorations, and it has been concluded that composite resins are unable to retain the color they had possessed at the time of insertion.[3] Substances that cause extrinsic stains are cola, tea, coffee, orange juice, acidic beverages, etc.[1] There have been several studies done on color changes and surface roughness of ceramics due to extrinsic factors, but very few studies focus on the effect of three different ceramics with three different parameters. Hence, the present study was undertaken and conducted using three contemporary esthetic materials covering the most commonly used ceramic systems viz., metal ceramics (feldspathic porcelain, Vita VMK), pressable metal-free ceramic (IPS e.max), and computer-aided design–computer-aided manufacturing (CAD–CAM) fabricated zirconia (Zenostar). These materials were exposed to coloring agents as well as agents that alter the surface roughness like tobacco extracts, cigarette smoke, and carbonated beverages (Flow Chart 1).

Flow Chart 1: Study design



MATERIALS AND METHODS

Materials Used

- Zirconia blank (Zenostar, Ivoclar Vivadent, USA)
- Pressable glass ceramics – IPS e.max ingots (Ivoclar Vivadent, USA)
- Feldspathic porcelain (Vita VMK Master)
- Tobacco extract (Pandharpuri)
- Carbonated beverage (Thums Up, Coca-Cola, India)
- Cigarette smoke (Bristol, Kolkata, India)

Instruments and Equipment Used

- Ceramic kit for mixing and condensing VITA Master
- Reflectance spectrophotometer (Shimadzu Corp., Kyoto, Japan)
- Profilometer (Model SJ 210 Mitutoyo, Japan)
- Ceramic finishing and polishing burs (DFS, Germany)
- Sintering furnace (Ivoclar Vivadent EP600) for e.max press ingots
- Sintering furnace for Vita VMK Master (VITA VACUMAT 6000M)
- Customized smoke chamber
- Milling machine (Wieland, Ivoclar Vivadent)
- CAD scanner software (Ceramill mind CAD software)
- Sintering furnace (Ceramill Therm furnace, Germany)

A hollow custom, spherical mold made up of stainless steel (80 mm × 2 mm) was fabricated for condensing and packing feldspathic porcelain. Thickness of the disk specimen was 2 mm. Diameter of the disk was 12 mm (Fig. 1). This aids in easy retrieval of the condensed material for sintering.

Fabrication of Feldspathic Porcelain (Vita Master)

Disks are fabricated by condensing the Vita VMK material (Fig. 2) in the mold space and firing in the

Fig. 1: Stainless steel mold for condensing ceramic material

Fig. 2: Vita VMK Master ceramic powder

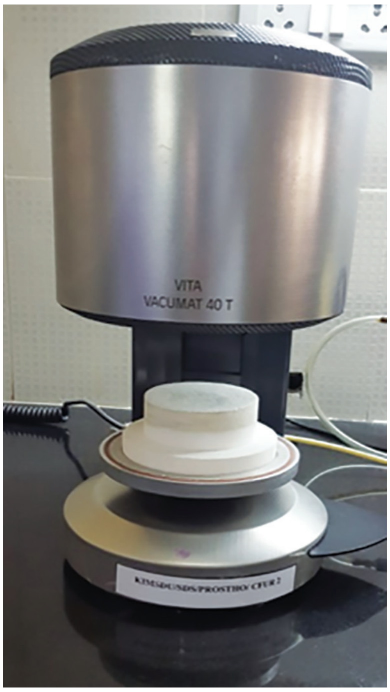


Fig. 3: Sintering furnace for Vita VMK Master (VITA VACUMAT 6000M)

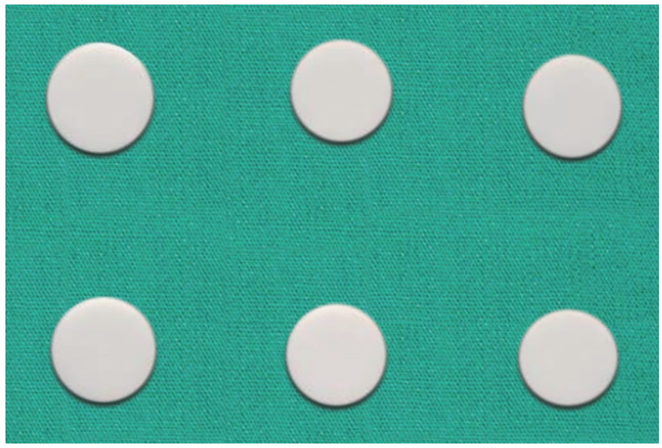


Fig. 4: Vita VMK Master disk specimen

Fig. 5: Pressable IPS e.max ingot

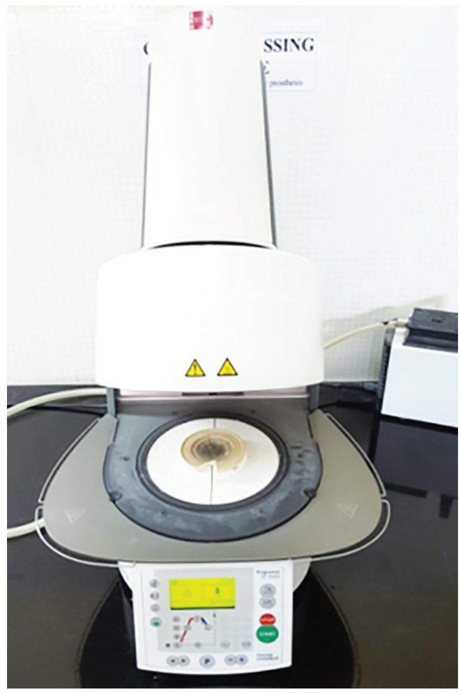


Fig. 6: Sintering furnace for e.max press ingots (IVOCLAR VIVADENT EP600)

sintering furnace VITA VACUMAT 6000M (930°C, 7.49 min) (Figs 3 and 4).

Fabrication of Pressable Glass Ceramics (IPS e.max Disks)

In the present study, the wax blanks were fabricated by using stainless steel mold. The sintering furnace IVOCLAR VIVADENT EP600 furnace was used for the sintering the e.max press ingot (Fig. 5). The wax blanks were invested and dewaxing procedure was done. On completion of dewaxing procedure, pressable ceramic ingots were casted. Following this, the e.max press ingots were sintered in the sintering furnace IVOCLAR VIVADENT EP600 furnace (Figs 6 and 7).

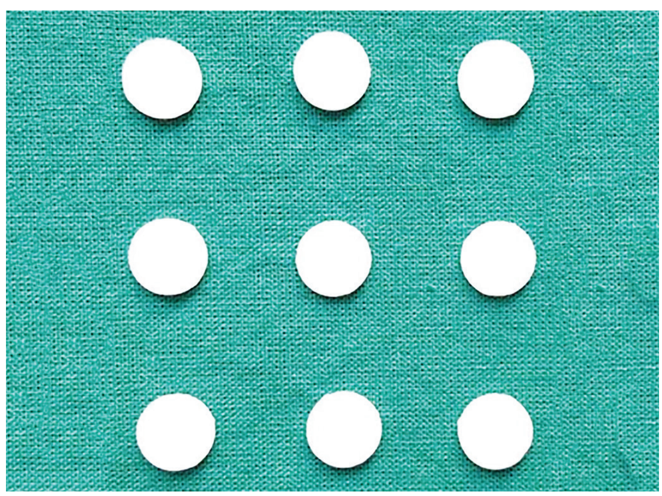


Fig. 7: IPS e.max glass ceramic disk specimen

Fig. 8: Sintering furnace (Ceramill Therm furnace, Germany)

Fig. 9: Zenostar (Ivoclar Vivadent Zirconia block)

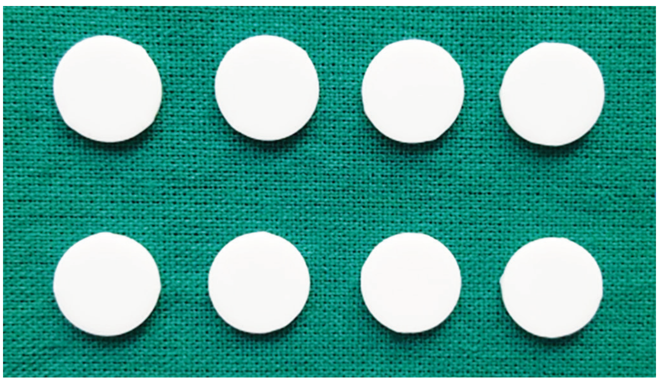


Fig. 10: Zenostar zirconia disk specimen

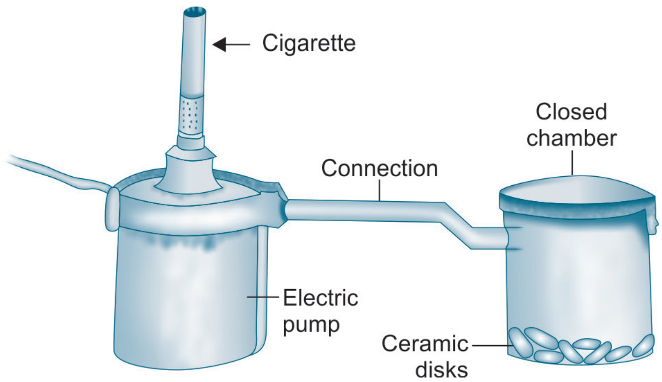


Fig. 11: Schematic diagram of artificial smoke chamber

Fabrication of Zirconia Disks using Ceramill CAD/CAM Machine

In the present study, the zirconia disks were fabricated using the Ceramill system (Amann Girrbach, Ceramill motion 2). It consists of a scanning system (Ceramill map 300 work station), a CAD software (Ceramill mind CAD), a CAM machining system (Ceramill CAM), and a sintering furnace (sintering furnace Ceramill Therm furnace) (Fig. 8). The material used in the present study was partially sintered zirconia (zenostar), which has high strength and rigidity (Figs 9 and 10).

Description of Artificial Smoke Chamber

An electric pump machine (side winder) consisting of a chamber having a capacity of 250 cc is obtained to prepare a smoke chamber (Fig. 11). The chamber has a suction device installed that draws the smoke from the cigarette into the chamber through the inlet present at the top of the chamber. The smoke in the chamber then passes through the outlet present at the side. This outlet connects to a second chamber via a plastic pipe. Samples from each group were placed in the second chamber for exposure to smoke for a specified period of time.

Immersion of Ceramic Disks in various Beverages

Immersion of the Disk Specimen in Tobacco Extract Solution

A total of 11 samples of ceramic disks from each group are randomly selected (namely Zirconia, e.max press, and Vita Master) and immersed in tobacco extract solution for 2 hours a day for 90 days. The solution is made using 100 mL water in which 20 gm of crushed tobacco leaves are dissolved (Fig. 12).

Exposure of the Disk Specimen to Cigarette Smoke

A total of 11 samples of ceramic disks from each group were selected (namely zirconia, e.max press, Vita Master) and kept in a customized smoke chamber. Three cigarettes were used to produce smoke in the chamber for 1 hour a day for 90 days (Fig. 13).

Immersion of the Disk Specimen in Carbonated Beverages

A total of 11 samples of ceramic disks from each group (Zirconia, e.max press, Vita Master) are immersed in

Fig. 12: Disk specimens immersed in tobacco extract solution

Fig. 13: Customized smoke chamber

Fig. 14: Disk specimens immersed in carbonated beverage

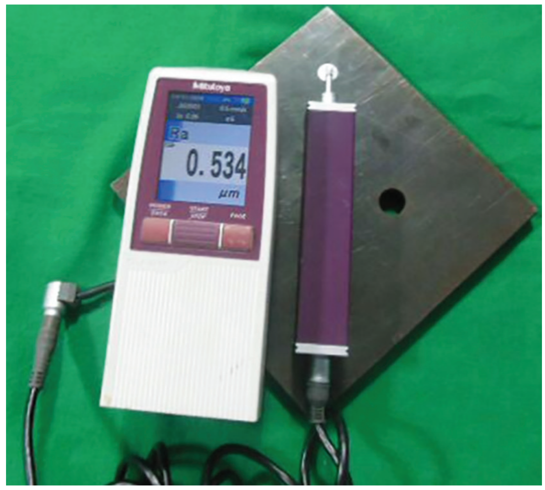


Fig. 15: Profilometer (model SJ 210 Mitutoyo, Japan)

carbonated beverage (Thums Up, Coca-Cola, India) 30 minutes a day for 90 days (Fig. 14).

Evaluation of Surface Roughness through Profilometer

Roughness measurements were performed on each disk using a profilometer (model SJ 210 Mitutoyo, Japan) with a cut-off value of 0.25 mm (Fig. 15). Three random, different regions were evaluated in each specimen to determine three Ra and Ry values (surface roughness values), and the final value to characterize that each sample was the arithmetic mean. These comparisons were done before treatment and after treatment with various parameters. These readings were noted and subjected to statistical analysis. The mean and standard deviations of the surface roughness (Ra) were calculated, and results subjected to analysis of variance (ANOVA) test, *post hoc* Tukey's test, and Student's *t*-test.

Evaluation of Color Stability through Spectrophotometer

The quality of color was measured by Commission Internationale de I'Eclairage (CIELAB) coordinates. The spectrophotometer measures the amount of light reflected by a surface as a function of wavelength to produce a reflectance spectrum. The reflectance spectrum of a sample can be used in conjunction with the CIE standards. The CIE system provides information about the location of object color in a uniform three-dimensional color space. It quantifies the color in terms of three coordinate values, i.e., L*, a*, and b*. Color change (ΔE) mathematically expresses the amount of difference between the CIE L*a*b* coordinates of different specimens or the same specimen at different instances.

In this study, the difference in color or the change was analyzed using a spectrophotometer (Shimadzu Corp., Kyoto, Japan) (Fig. 16) against a standard white background (standard for 45/0°; Paul N. Gardner Co, Inc, Pompano Beach, FL). The spectrophotometer has 30 light-emitting diode component lights arranged in a circle, with 10 different colors, which light up and produce a light beam at 45° to the surface of the specimen, and results were obtained.

RESULTS

A total of 99 samples were fabricated, 33 samples in each restorative material. A total of 33 samples were subdivided such that 11 samples of above-mentioned

Fig. 16: Measurement of color values by reflectance spectrophotometer

restorative materials were subjected to tobacco extract, the other 11 were exposed to cigarette smoke in an artificial chamber, and the remaining 11 were immersed in carbonated beverage for a period of 90 days with variant exposure times. The pretreatment values of the 99 samples for color stability were recorded using a spectrophotometer and that of degree of surface roughness were recorded using a profilometer. Posttreatment values were recorded using the same instruments.

The values obtained were subjected to statistical analysis using ANOVA test followed by *post hoc* Tukey's test for multiple group comparison and paired t test for intragroup comparisons. In the above tests, $p<0.05$ was taken to be statistically significant. The data entry was done in Microsoft Excel 2007. All analysis was performed using Statistical Package for the Social Sciences software version 17.

DISCUSSION

Porcelain was among the initial materials discovered to be used as a definitive anterior esthetic restorative material. In fact, its selection was mainly because of its natural appearance, good wear resistance, and color stability. Dental porcelain has color and optical properties that simulate natural teeth.[4-6] Although porcelain restorations are considered to be color stable, discoloration is one of the major factors for failure of esthetic restorations.[7-11] Literature search has shown the range of variations and alterations in color and surface luster of ceramics when artificially exposed to commonly consumed foodstuffs.[10-14]

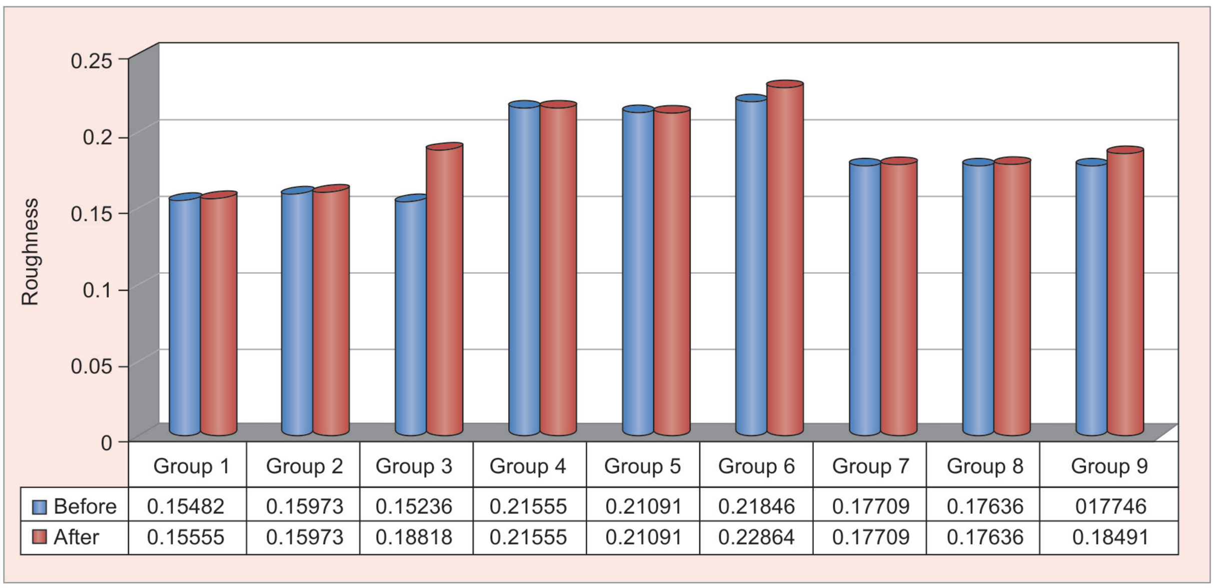
In this study undertaken to evaluate the degree of surface roughness and color stability when exposed to various chemicals at varied time intervals, 33 disk samples (n = 11 Vita VMK Master, n = 11 IPS e.max, n = 11 Zirconia) were immersed in tobacco extract solution for 2 hours a day for 90 days, 33 disk samples (n = 11 Vita VMK Master, n = 11 IPS e.max, n = 11 Zirconia) were exposed to three cigarette smoke a day for 1 hour for 90 days, and for carbonated beverage, 33 disk samples (n = 11 Vita VMK Master, n = 11 IPS e.max, n = 11 Zirconia) were immersed in Thums Up for 30 minutes a day for 90 days. The surface roughness values of nine different groups (n = 11) for which minimum, maximum, mean value, and standard deviation before treatment (0 days) pre- and posttreatment (90 days) are shown in Table 1 and it is also depicted in Graph 1. It is revealed that no statistical significance was seen in Vita VMK Master, IPS e.max, zirconia disks when subjected to tobacco extract and cigarette smoke ($p>0.05$); however, when the disks fabricated in the above-mentioned materials were exposed to carbonated beverages, statistically significant values were obtained ($p<0.001$) showed in Table 2 and Table 3. Among the three different restorative materials used, Vita VMK Master exhibited maximum change in value of surface roughness (0.035818 µm). These results are in accordance with the study carried out by Shuchi et al,[15] who reported that ceramic disks, when exposed to carbonated drink, have comparatively higher percentage of changes in surface roughness followed by coffee, milk, and tea on glazed ceramic surfaces, and milk, coffee, and tea on polished ceramic surfaces respectively.

A similar study conducted by Vechiato-Filho et al[16] reported that acidic beverages affected the surface topography of lithium disilicate ceramics. Also, in the year 2014, Karaman et al[17] reported that cola and coffee altered, to some degree, the color, surface roughness, and/or microhardness of the tested resin composite, depending on the characteristics of the materials. Duymus et al[18] reported that no statistically significant difference was observed between acidic agents (coke, orange juice, lemonade, mineral water, and black carrot juice) on surface roughness of feldspathic porcelain ($p>0.05$).

To evaluate the color stability when exposed to various chemicals at varied time intervals, 33 disk samples (n = 11 Vita VMK Master, n = 11 IPS e.max, n = 11 zirconia) were immersed in tobacco extract solution for 2 hours a day for 90 days, 33 disk samples (n = 11 Vita VMK Master, n = 11 IPS e.max, n = 11 Zirconia) were exposed to three cigarettes for 1 hour a day for 90 days, and for carbonated beverage, 33 disk samples (n = 11 Vita VMK Master, n = 11 IPS e.max, n = 11 zirconia) were immersed in Thums Up for 30 minutes a day for 90 days. Color stability was expressed in standard CIELAB method. The L*, a*, and B* values were measured for each disk (Table 4). The color difference (ΔE) between two objects, or in the same object before and after it is subjected to particular conditions, can be determined by comparing the differences between the

Table 1: Master chart for surface roughness values of nine different groups (n = 11) in which minimum, maximum, mean value, and standard deviation before treatment (0 days) and after treatment (90 days) are shown

Descriptive statistics						
Group		*n*	*Minimum*	*Maximum*	*Mean*	*Standard deviation*
Vita VMK Master in tobacco extract	Before	11	0.1410	0.1700	0.1548	0.00975
	After	11	0.1420	0.1700	0.1555	0.00998
Vita VMK Master in cigarette smoke	Before	11	0.1460	0.1790	0.1597	0.01113
	After	11	0.1460	0.1790	0.1597	0.01113
Vita VMK Master in carbonated beverage	Before	11	0.1350	0.1750	0.1523	0.01297
	After	11	0.1690	0.2060	0.1881	0.01222
IPS e.max in tobacco extract	Before	11	0.1950	0.2300	0.2155	0.01146
	After	11	0.1950	0.2300	0.21554	0.01146
IPS e.max in cigarette smoke	Before	11	0.1940	0.2260	0.2109	0.01060
	After	11	0.1940	0.2260	0.2109	0.01060
IPS e.max in carbonated beverage	Before	11	0.2000	0.2350	0.2184	0.01365
	After	11	0.2100	0.2490	0.2286	0.01384
Zirconia in tobacco extract	Before	11	0.1690	0.1880	0.1770	0.00555
	After	11	0.1690	0.1880	0.1770	0.00555
Zirconia in cigarette smoke	Before	11	0.1670	0.1840	0.1763	0.00564
	After	11	0.1670	0.1840	0.1763	0.00564
Zirconia in carbonated beverage	Before	11	0.1690	0.1860	0.1774	0.00598
	After	11	0.1760	0.1930	0.1840	0.00552



Graph 1: Master chart for surface roughness values of nine different groups (n = 11) in which minimum, maximum, mean value, and standard deviation before treatment (0 days) and after treatment (90 days)

Table 2: Intergroup comparison was done using unpaired t-test showing mean, standard deviation of difference before and after treatment, and statistically significant value

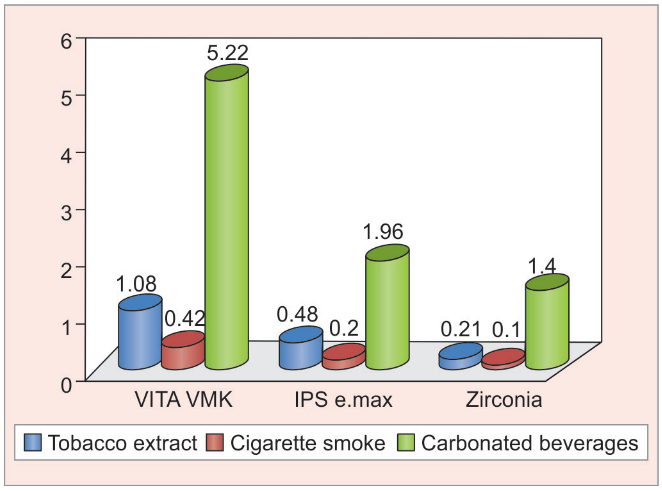
Paired samples test[a]						
		Paired differences				
Group		*Mean*	*Standard deviation*	*Standard error mean*	*t-value*	*Significance (2-tailed)*
Vita VMK Master in tobacco extract	After – before	0.0007273	0.0011909	0.0003591	2.025	0.070
Vita VMK Master in carbonated beverage	After – before	0.0358182	0.0050955	0.0015363	23.314	0
IPS e.max in carbonated beverage	After – before	0.0101818	0.0025226	0.0007606	13.387	0
Zirconia in carbonated beverage	After – before	0.0066364	0.0029757	0.0008972	7.397	0

Table 3: Combined statistically significant values for all materials and all three parameters. Chi-square test was used to know whether any statistically significant difference exists among the three groups

Parameters vs group	*Vita VMK Master*	*IPS e.max*	*Zirconia*	*p-value*
Tobacco	000727 ± 0.0011909	0	0	p < 0.001
Cigarette smoke	0	0	0	No effect on any groups so no difference
Beverage	0.035818 ± 0.0050955 p < 0.001	0.010182 ± 0.0025226 p < 0.001	0.006636 ± 0.0029757 p < 0.001	p < 0.001

respective coordinate values for each object or situation. It is observed that when all three materials are immersed in carbonated beverage and tobacco extract, there is a significant changes for L*, a*, and b* coordinates, resulting in a decrease in the L* value, creating darker specimens ($p < 0.01$), and an increase in a* and b* coordinate values, which resulted in specimens that were redder and more yellow ($p < 0.001$). Among the three different restorative materials used, Vita VMK Master exhibited the maximum color change in L*, a*, and b* values ($p < 0.001$). There is no statistically significance difference observed in all the materials when exposed to cigarette smoke ($p > 0.5$).

Table 5 shows the effect of different chemicals on three materials, observed by comparing ΔE means, before and after treatment. The clinical relevance of the present study depends on how much color change (ΔE) is considered perceptible. It is shown that a $\Delta E < 1$ is not considered perceptible to most subjects with normal color vision, and the restorations with a ΔE as high as 3.3 and 3.7 required replacements, as it is a clinically perceptible color change.[19,20] In this study, the maximum value for ΔE is with Vita VMK Master, when immersed in carbonated beverage (5.22). The minimum effect was observed when materials were exposed to cigarette smoke. When comparing three materials, the maximum color changes were observed with Vita VMK Master (Graph 2).



Graph 2: Summary of effect of tobacco extract, cigarette smoke, and carbonated beverages on color changes of Vita VMK Master, IPS e.max, and zirconia material. Values represent ΔE means between specimens before and after treatment

Ghahramanloo et al[21] conducted a similar study in which they compared color change of GC Gradia

Table 4: Master chart presents the means and standard deviations of L*, a*, and b* coordinates before treatment and 90 days after treatment with tobacco extract, cigarette smoke, and carbonated beverage

Group	*L*0 (mean ± SD)*	*a*0 (mean ± SD)*	*b*0 (mean ± SD)*	*L*90 (mean ± SD)*	*a*90 (mean ± SD)*	*b*90 (mean ± SD)*
Vita VMK Master in tobacco extract	72.402727 ± 6.994915	1.180000 ± 0.228254	8.845455 ± 1.543686	71.508182 ± 8.7966162	1.694545 ± 1.155477	9.890909 ± 1.973689
Vita VMK Master in cigarette smoke	72.384545 ± 6.776753	1.221818 ± 0.3508794	8.750909 ± 1.801918	72.194545 ± 2.8982490	1.136364 ± 0.2241550	8.618182 ± 0.8163800
Vita VMK Master in carbonated beverage	75.700909 ± 8.1166587	1.253636 ± 0.3643699	8.472727 ± 1.709702	72.684545 ± 10.628348	2.530909 ± 1.102764	9.099091 ± 2.003449
IPS e.max in tobacco extract	91.269091 ± 7.5053587	1.120909 ± 0.8799256	3.280909 ± 1.7434016	90.834545 ± 10.8869421	1.280909 ± 0.6710060	4.190909 ± 2.112512
IPS e.max in cigarette smoke	91.577273 ± 6.7784719	1.000909 ± 0.8604238	2.190000 ± 1.7062239	91.30909 ± 3.7085211	1.187273 ± 0.1932403	2.005455 ± 0.6699457
IPS e.max in carbonated beverage	92.804545 ± 7.9071630	1.112727 ± 0.8247920	2.800000 ± 1.7728170	90.931818 ± 4.7349759	1.240909 ± 0.5953227	3.060000 ± 1.781083
Zirconia in tobacco extract	93.017273 ± 7.9553819	1.136364 ± 0.8433537	2.918182 ± 1.7498332	92.926364 ± 4.9558839	1.148182 ± 0.6819651	2.916364 ± 1.830848
Zirconia in cigarette smoke	94.055455 ± 7.3801387	1.018182 ± 0.4798295	3.434545 ± 2.0157845	94.054545 ± 2.0209966	1.018364 ± 0.2173142	3.431818 ± 1.557971
Zirconia in carbonated beverage	94.722727 ± 6.5674060	1.010909 ± 0.5163808	3.888182 ± 2.3750192	93.409091 ± 10.5262552	1.448182± 0.6188185	4.985455 ± 2.046833

Table 5: Descriptive statistics values for ΔE

Group	*ΔE*
Vita VMK Master in tobacco extract	1.08
Vita VMK Master in cigarette smoke	0.42
Vita VMK Master in carbonated beverage	5.22
IPS e.max in tobacco extract	0.48
IPS e.max in cigarette smoke	0.2
IPS e.max in carbonated beverage	1.96
Zirconia in tobacco extract	0.21
Zirconia in cigarette smoke	0.10
Zirconia in carbonated beverage	1.4

$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$; ΔL = L1 – L0 (final – initial record); Δa = a1 – a0 (final – initial record); Δb = b1 – b0 (final – initial record)

(composite) and Vita VMK 95 (porcelain) after immersion in tea, Coca-Cola, orange juice, and distilled water, and concluded that all the three factors studied, i.e., type of material, solution, and time factor, had a significant effect on each of the three parameters of color, i.e., (L*a*b*). Vita VMK 95, after immersion in the test solution, showed a small amount of color change ranging from 0.21 to 0.51 ΔE units; this value is quite low from that of our observations. The reason for this difference in our results could possibly be attributed to the extended time period of immersion (90 days).

In all groups, statistically significant differences showed a reduction in L* values after a period of 90 days, which is in accordance with the studies done by Gupta et al[22] and Ghahramanloo et al,[21] who also reported a decrease in L* values. In this study, the maximum color changes were observed when materials are immersed in carbonated beverages because surface degradation of the materials occur when they come in contact with the acidic beverage; hence, the staining potential is increased when compared with tobacco extract and cigarette smoke. Jensdottir et al[23] who had evaluated the immediate erosive potential of cola drinks and orange juice concluded that cola drinks had more than 10-fold higher erosive potential than orange juices within the first minute after exposure.

The results from the above study show that among the three selected materials, zirconia exhibited superior color stability and higher resistance to surface degradation. On the contrary, among the varied irritants used, carbonated beverages exhibited the maximum effect on the three restorative materials both in terms of color stability and surface roughness.

CONCLUSION

Within the limitations of the study, it can be concluded that:

- Among the three irritants used, smoke and tobacco extract did not affect the change in color or degree of surface roughness for the three restorative materials.
- Carbonated beverages, on the contrary, exhibited significant difference in color stability as well as surface roughness when measured pre- and postexposure for all the three restorative materials.
- However, among the three materials, feldspathic porcelain exhibited superior change in color and surface roughness when measured postexposure to irritants.

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