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Original article "effects of temperature of beverages on ardness, surface roughness and color stabilty of resin composite –an in vitro study"

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Abstract
Background And Objectives: *Effects of temperature of beverages on microhardness surface roughness and color stabilty of resin composite.*
Methodology: *A total of 105 specimens of the Tetric N-Ceram (Ivoclar Vivadent, Switzerland)were prepared and initial roughness, microhardness, and color were measured. Then the specimens were randomly divided into seven groups of 15 specimens each: artificial saliva (control) Coffee at 70°C, Cola at 10°C, Coffee 70°C+Cola 10°C, Cola10°+ Coffee 70°C, Coffee 70°C+Artificial saliva 37°C+Cola 10°C and Cola 10°C+Artificial saliva 37°C+Coffee70°C. After the samples were subjected to 15 min × 3 cycles per day of exposure to the solutions for 28 days, the final measurements were recorded.The surface roughness was measured using profilometer, microhardness was measured with Vickers microhardness and colour stability was measured using a spectrophotometer.*
Results: *Highest effect of temperature change on surface roughness was seen in Group4 i.e Coffee70°C +Cola10°C. In a variation of temperature change, maximum change in microhardness was seen in Group 2 i.e.Coffee70°C and the highest discoloration was seen in the group coffee70°C (Group2).*
Interpretation And Conclusion: *Beverages, independant of colour caused a difference in the colour stability of the composites used in this study. Coffee, showed the highest staining ability and maximum change in microhardness whereas maximum change in surface roughness can be seen in a variation of temperature change i.e Coffee70°C+Cola10°C.*

Keyword: *Composite resin, soft drink, coffee, surface roughness, microhardness color stability, spectrophotometer, profilometer,* vickers hardness testing device .

I. Introduction

The search for optimal esthetic smile is increasingly present in dental office. This increased demand for cosmetic procedure may be slightly influenced by media.[1] Resin composites are one of the most popular material in esthetic dentistry because of their excellent esthetic properties, adequate strength and their ability to be bonded to dentin or enamel[2] allowing their use in both anterior and posterior restorations[3,4].

Restorative materials are constantly subjected to thermal challenges in oral environment[5]. Such challenges if significant, can have unfavourable effects on the material such as on the margins of the restoration and the tooth structure[6].

Consumption of certain beverages and a wide range of physical and chemical conditions in the mouth, including temperature variation, masticatory forces, and chemicals from food may effect the esthetic and physical properties such as microhardness, surface roughness and color stability of the resin composite, thereby, undermining the quality of restorations.[6]Currently the behaviour of nanohybrid composite material over temperature change of beverages is relatively unknown.[6] However, in support of this current study, a number of studies have shown that coffee, tea, grape juice and black cola had a significant staining effect on optical properties of resin-based restorative materials.[7,8-13] The temperature change of oral cavity and dietary substrates are also associated with discolouration to resin based materials.[14] Long-term immersion of resin composite in a high temperature solution can induce changes in the material properties, which ultimately may lead to discolouration.[7,14] This prolonged exposure to heat may degrade organic matrices to promote pigmentation.[8]

Roughness is an important property of the restoration surface, as a rough surface enhances accumulation of dental plaque and resides, which causes gingival irritation and secondary caries. It also diminishes the gloss of the restoration and causes more discoloration or surface degradation.[15] Studies have shown that the surface roughness of composite resins have a direct influence on susceptibility to staining,[16,17] others have reported no correlation between surface roughness and staining susceptibility.[15,16] It has been demonstrated in several studies that the erosive activity of acids as ingredients of beverages affects the microhardness and wear of the composite resin and durability of the restoration in the long term.[16-19] Various studies have been conducted to determine the effects of different solutions on the surface characterstics of composite resins[20-22] but to the best of our knowledge very few studies has evaluated the effect of beverages' temperature on the surface roughness,hardness,and color stability of a nanohybrid composite resin.

II. Material And Method Preparation Of Specimen

- A total of 105 cylindrical samples of nanohybrid composite (Tetric-N-Ceram,shad voclar,Vivadent,Switzerland) will be packed into a Teflon ring mold (12 mm in diameter and 2 mm in thickness).The composite specimens ill be cured with a Light Emitting Diode (LED) device. The LED curing light must be calibrated before and after g to ensure that all sample will be cured with approximately the same intensity of light cm2).The specimens will be stored in 37°C distilled water for 24 h before finishing and polishing in order to replicate the oral conditions following polymerization.The specimens will be polished starting with coarse and ending with extra fine. lishing procedures must be kept to a minimum time, 10 s for each step, to avoid micro‑crack formation.
- Subsequently, baseline color, surface roughness and microhardness values will be measured.The composite specimens will be randomly subdivided into seven groups of 15 specimens each. One will be control group and six experimental groups.[Table1]
- Procedure duration i.e 28 days and time i.e 15 mins three times a day(morning, afternoon, night) will be same for all groups.
- The specimens will be kept immersed in 1.2 ml of artificial saliva at 37°C in an incubator in the intervals between cycles.All specimens will be stored in light‑proof containers and the solutions were changed for each test period.The temperatures will be measured with a digital thermometer.After 28 days of immersion in the solutions, the specimens will be rinsed with distilled water for 5 min and blotted dry with absorbent paper before the final measurements.

GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6	GROUP 7
n =15 CONTROL	n =15 EXPERI-MENTAL	n =15 EXPERI-MENTAL	n =15 EXPERI-MENTAL	n =15 EXPERI-MENTAL	n =15 EXPERI-MENTAL	n =15 EXPERI-MENTAL
	HOT	COLD	HOT+COLD	COLD+HOT	HOT+ ARTIFICIAL SALIVA+ COLD	COLD+ ARTFICIAL SALIVA+ HOT
ARTIFICIAL SALIVA 37°C	COFFEE 70°C	COLA 10° C	COFFEE 70°C + COLA 10°C	COLA 10°C +COFFEE 70°C	COFFEE 70°C +ARTIFICIAL SALIVA 37°C +COLA 10°C	COLA 10°C +ARTIFICIAL SALIVA 37°C + COFFEE 70°C

Color Measurements

The color of specimens was measured at baseline and after 30 days immersion using a VITA Easyshade (Vident, Brea, CA, USA) Spectrophotometer (AIMIL Ltd., India),with the CIELAB scale L^*,a^*, and b^*. ΔE^* was calculated by the following equation:

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

All color measurements were performed three times for each specimen.The device was calibrated before the measurement of each specimen.

Surface Roughness Measurements

All the specimens were subjected to roughness testing using a contact Profilometer (Mitutoyo, Japan) equipped with a 5 mm radius diamond tipped stylus that was attached to a pickup head. The stylus traversed the

surface of the specimen at a constant speed of 0.5 mm/s with a force of 5 mN and automatic return. Each specimen was traced in four parallel locations near the center across the finished and/or polished surface with an evaluation length of 4 mm. Five measurements in different directions were recorded for each specimen. Leveling of all parts of the apparatus was achieved by adjusting the pickup head knob.
A calibration block was used periodically to check the performance of the device

Vickers Hardness Measurements

A Vickers surface microhardness device (Mitutoyo, Japan) was used for specimen indentation. For each microhardness test, five indentations with 100 g load for 15 s (100 μm of distance) were performed for each specimen. All color, surface roughness, and microhardness measurements were performed by the same operator, and the mean values were used for the subsequent statistical analysis.

Statistical Analysis

The data among groups and the changes over time were evaluated by using analysis of variance (ANOVA) for repeated measures for the parameters of microhardness, roughness, and color (*L*, *a*, *b*) and processed with SPSS (version 15.0.1; SPSS,Chicago, IL, USA). A P value of < 0.05 was considered statistically significant. Multiple comparisons were evaluated by Bonferroni test. Welch ANOVA test was used to evaluate the differences in ΔE measurements among the groups. A P value of <0.05 was considered statistically significant.

III. Result

Microhardness Change

In Table 2, mean differences and statistically significant differences in microhardness change of the tested composite resin for each beverage are presented. There were no statistically significant differences among the baseline hardness values of the tested composite resin ($P < 0.001$). After immersion in beverages, the artificial saliva group showed hardness values higher than those of the other groups ($P < 0.001$). The 70°C coffee group showed the greatest microhardness alteration and minimum change seen is in a variation of temperature change i.e.10^{o}cola+37^{o}C artificial saliva+70^{o}cola.

Table 2 Bonferroni test comparing the surface microhardness of composite resin(TETRIC N CERAM, Ivoclar vivadent India) within the groups at specific temperature

(I) group	(J) Group	Mean Difference (I-J)	'p' Value*
1	2	3.47	0.001
	3	-0.68	1.000
	4	-1.15	1.000
	5	-1.65	0.950
	6	2.29	0.124
	7	-2.05	0.281
2	3	-4.15	<0.001
	4	-4.61	<0.001
	5	-5.12	<0.001
	6	-1.17	1.000
	7	-5.52	<0.001
3	4	-0.47	1.000
	5	-0.97	1.000
	6	2.97	0.009
	7	-1.37	1.000
4	5	-0.51	1.000
	6	3.44000*	0.001
	7	-0.91	1.000
5	6	3.95	<0.001
	7	-0.40	1.000
6	7	-4.35	<0.001

Surface Roughness Change

The mean differences and statistically significant differences in surface roughness change of the tested composite resin in different beverages are shown in Table 3. In this study the highest effect of temperature change on surface roughness was seen when composite resin was subjected to two different temperatures immediately one after another i.e.70^{o} coffee and 10^{o}cola (Group4) however both cola and coffee had low pH.

Table 3 Bonferroni test comparing the surface roughness of composite resin(TETRIC N CERAM, Ivoclar vivadent India) within the groups at specific temperature.

(I) group	(J) Group	Mean Difference (I-J)	'p' Value*
1	2	-4.52	<0.001
	3	-2.75	<0.001
	4	-4.99	<0.001
	5	-3.86	<0.001
	6	-3.82	<0.001
	7	-2.98	<0.001
2	3	1.77	<0.001
	4	-0.47	0.047
	5	0.66	0.001
	6	0.69	<0.001
	7	1.54	<0.001
3	4	-2.24	<0.001
	5	-1.11	<0.001
	6	-1.07	<0.001
	7	-0.23	1.000
4	5	1.13	<0.001
	6	1.17	<0.001
	7	2.02	<0.001
5	6	0.04	1.000
	7	0.89	<0.001
6	7	0.85	<0.001

Color change

Table 4 shows the mean differences and statistically significant differences in color change in the tested composite resin after immersion in different beverages. No significant differences were observed in the baseline color measurements (*L*, *a*, *b*) of the tested composite resin among the test groups ($P > 0.001$). After immersion in beverages,the highest discoloration was seen in the group coffee70^{o}C **(Group2)** and minimum color change was seen in artificial saliva37^{o}C**(Group1).**

Table 4 Bonferroni test comparing the color change of composite resin(TETRIC N CERAM, Ivoclar vivadent India) within the groups at specific temperature.

(I) group	(J) Group	Mean Difference (I-J)	'p' Value*
1	2	10.18	<0.001
	3	4.71	<0.001
	4	8.03	<0.001
	5	6.08	<0.001
	6	5.81	<0.001
	7	7.39	<0.001
2	3	-5.48	<0.001
	4	-2.16	<0.001
	5	-4.10	<0.001
	6	-4.38	<0.001
	7	-2.79	<0.001
3	4	3.32	<0.001
	5	1.38	<0.001
	6	1.10	0.006
	7	2.69	<0.001
4	5	-1.94	<0.001
	6	-2.22	<0.001
	7	-0.63	0.685
5	6	-0.28	1.000
	7	1.31	<0.001
6	7	1.59	<0.001

IV. Discussion

Esthetics of the teeth is of great importance to many patients. Public demand for esthetic dentistry has increased in the recent years. Studies confirm the importance of attractiveness on perceived success and self-esteem.[23,24] Introduction of composite restorative materials in 1960s marked the beginning of the modern cosmetic dentistry by combining the principles of esthetics and tooth conservation.[25]

Due to improvement in both physical & mechanical properties, composite resins are presently among the most popular esthetic restorative material in dental clinical practice. Manufacturers have introduced different shades for restorative materials, capable of fulfilling all the requirements for the environment light sensitivity, depth of cure, color match and stability.[26]

Consumption of certain beverages such as coffee, soft drinks, alcoholic beverages, and even water may affect the esthetic and physical properties (micro hardness, surface roughness, and translucency) of the composites due to the degradation of the resin matrix thereby undermining the quality of restoration.[27] Different mechanisms of polymer degradation have been demonstrated, such as hydrolytic, chemical and chemico-mechanical. Different definitions for degradation have been given; however it has been described by **Gopferich** (1996) as a 'chain scission process during which polymer chains are cleaved to form oligomers and finally monomers'. Gopferich stated that the intrusion of water into the polymer bulk activates the chemical polymer degradation which leads to the creation of oligomers and monomers.[28]

The purpose of the present in vitro study is to evaluate the " Effects of temperature of beverages on microhardness, surface roughness and color stabilty of resin composite –an in vitro study". Coffee and cola were selected in this study because they are very frequently consumed beverages**.**In the present study, composite resin was immersed in beverages at different temperatures.[5,1] Dentists have been demanding improved and more easily achievable esthetics in anterior restorations than those offered by earlier traditional composites, without sacrificing the strength of the material. The modification of fillers in conventional resin based composites has improved their mechanical properties and esthetic performance.

Nano composites are a type of composite in which the primary filler size is in the nm range while the secondary filler clusters are in the µm range. Thus, this material has a better polishability and improved retention of the polish and gloss compared to microhybrid composites.[29] Salivary enzymes, pH changes, organic solvents, and the ionic composition of food, beverages, or saliva may influence the surface quality of composite resins.[30]

In this study the highest effect of temperature change on surface roughness was seen when composite resin was subjected to two different temperatures immediately one after another i.e.70^{o} coffee and 10^{o}cola (Group4) however both cola and coffee had low pH. This may have been a result of the presence of acids and sugars in the chemical composition of the cola,which promote surface erosion of the composite resin. This result is in agreement to the previous study by Kitchens and Owens(2007) who found that surface roughness increased when immersed in cola[31] and also in agreement to the study conducted by da Silva *et al*.(2011) detected significant degradation of the resin matrix with immersion in coffee.[22] They concluded that the consumption of coffee did not affect the composite resin's microhardness, but its surface roughness was altered in the analyzed period. Similarly, Dos Santos *et al*.(2010) detected significant degradation of resin matrix upon immersion in coffee at high temperature.[33]As it can be observed in the present study, the artificial saliva group (Group1) presented almost the highest level of microhardness, which is in consistent with the studies conducted by Yanikoglu N et al(2009) and kitchen and owen(2007).[31,33] Coffee (Group2) and cola (Group3) caused more reduction of surface microhardness of the tested composite resin than the artificial saliva(Group1) did. This result is not in consistent with the study by da Silva,et al(2011) who reported that the microhardness of their material (nanoparticulated composite resin) did not change to a significant degree when immersed in coffee.[22] But maximum change was seen when randomly selected composite disks were subjected to a temperature of 70^{o}C coffee (Group2) and minimum change is in a variation of temperature change i.e.(Group7) 10^{o}cola+37^{o}C artificial saliva+70^{o}cola.(Table 3 and 4).

The beverages used in the present study caused varying degrees of discoloration in the tested composite resin. The highest discoloration was seen in the group coffee70^{o}C (Group2) and minimum color change was seen in artificial saliva37^{o}C(Group1). In the present study, immersion in coffee caused unacceptable color changes in the composite resin tested.(Table 5 and 6) .Mundim, *et al*.(2010) which is in agreement with the present study reported an unacceptable discoloration of Filtek Z250 when stored in coffee for 15 days.[34] Discoloration by coffee can be attributed to both absorption and adsorption of polar colorants onto the surface of materials. This adsorption and penetration of colorants into the organic phase of the materials was explained by the authors as probably due to the compatibility of the polymer phase with the yellow colorants of coffee.[35] This may explain the discoloration of composite specimens observed after immersion in coffee. In addition, our results showed that although cola had the lowest pH and that it might damage the surface integrity of resin composite materials, cola did not cause as much discoloration as coffee did, possibly due to its lack of yellow colorants.[35] Further, the findings of previous studies i.e. Bagheri R el al(2005), Patel SB et al(2010) and Barutcigil C et al(2006) also lent support to the present study in that coffee caused more discoloration than cola.[34,36,37,38]

It is difficult to extrapolate the results of this study to *in vivo* conditions. However, the results of this study can give an insight into how nanohybrid resin composites may behave when exposed to different temperature of beverages, thus affecting the clinician's choice of material and the patient's control of dietary habits.

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