Color Stability Of Different Restoratives After Exposure To Coloring Agents

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Abstract: ***Objectives:*** To evaluate color stability of three different restoratives and efficacy of sonic-brushing in preventing color changes of these restoratives when subjected to coloring agent. ***Methods:*** 70 discs (5mm diameter x 2mm thick) made of each tested restorative [Ketak N100 (KN), 3M/ESPE, Beautifil II (BII), Shofu and Filtek Supreme Ultra (FS), 3M/ESPE]. Ten specimens were used as control while other 60 specimens were subdivided into six subgroups (n=10); First, second and third subgroups immersed in cola, coffee and tea respectively for 10 min. 3-times daily. Fourth, fifth and sixth subgroups immersed in cola, coffee and tea respectively for 10 min. 3-times daily and brushed with sonic-brush for 1min. after each exposure. Specimens were immersed in artificial saliva between staining and brushing challenges. After a month, all specimens tested for quantitative color changes using Quanta-Environmental Scanning Electron Microscope. Data statistically analyzed using Three-way ANOVA and Tukey's post-hoc test ($P \leq 0.05$). ***Results:*** The mean color change of non-brush-cycled subgroups (124.1pixel) showed statistically significantly higher values than brush-cycled subgroups (118pixel). BII showed the highest mean color change values (126.4pixel), whereas, no significant difference found between FS (117.4pixel) and KN (120.7pixel). ***Conclusions:*** The tested nanoionomer and nanocomposite performed similarly under the test conditions. Brushing specimens after staining improved the color changes of the tested materials.

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1. Introduction:

Esthetics is ranked at the top priority in modern restorative dentistry, and with the rapid development in dental materials and techniques. The creation of a magnificent smile is no longer a fantasy.

Resin composites gained a wide popularity since their introduction in 1970 because of their excellent esthetic properties, Craig et al.,(2000). However, when compared to ceramics they suffer from discoloration after prolonged exposure to oral environment, Mjör et al.,(2000); Stober et al.,(2001); Hickel et al.,(2004) . For this reason, there is a continuous and fairly rapid turnover in resin composites to improve their optical, physical, as well as, mechanical properties resulting in the introduction of nano-composites in which filler sizes ranging within 0.1 to 100 nanometers.

The basic idea was to combine the excellent aesthetics of Micro-fills with high-strength properties of Hybrid Composites. Nanofill technology has improved properties of composite to be similar to ceramics in shade selection and color stability and better gloss retention, Celik et al.,(2008) .

Glass ionomer cements (GICs) were introduced in about 1972 as a direct restorative material offering two unique advantages; release fluoride and adhere to both enamel and Dentine, Wilson and Kent (1972). However, they were found to be unable to maintain adequate color stability. Therefore, resin-modified glass ionomers followed by compomers or polyacid modified resin composites. Craig et al.,(2000) were developed in order to overcome some of the disadvantages of conventional glass-ionomers, as well as, offering improved esthetic properties, Wilson(1989). Lately, Giomer which contains "prereacted glass" has been introduced with claims of good color matching and stability.

However, dentists are still asking for a better-looking glass ionomer product. Therefore, recently, nanoionomer is introduced to the market. It is the first paste/paste resin-modified glass ionomer restorative based on bonded nanofiller technology in which nanotechnology brings us wear resistance, aesthetics and polish, all while offering fluoride release similar to conventional and resin-modified glass ionomer restoratives.

To ensure excellent aesthetics, it is necessary for tooth-colored materials to maintain intrinsic color stability and a resistance to surface staining, Diab et al.,.(2007). Since, one of the main factors that affect the clinical longevity of esthetic fillings is the discoloration. Extrinsic factors, such as adsorption or absorption of stains, may cause discoloration of esthetic materials. In an *in-vivo* situation, it is reported that saliva and exogenous sources such as coffee, tea, nicotine and beverages may affect resinous restorations, Asmussen and Hansen (1986);Dietschi et al.,(1994); Noie et al.,(1995); Lee et al.,(1998). The resin matrix has been reported as being critical to color stability, and staining may be related to high resin content and water absorption, Dietschi et al.,(1994). However, this unacceptable color change may lead to replacement of the restorations, Kroeze et al.,(1990); Wilson et al.,(1997); Mjör et al.,(2000).

Aesthetic colour stability and discoloration properties of a novel nanoionomer and new version of giomer glass ionomer are severely lacking and limited in dental literature which may provide guidance for selection of nano-composite and other novel aesthetic restoration for clinical usage. Thus, it was found of value to study the influence of exposure to different coloring agents and the use of sonic brushing on the color stability of three different restorative materials.

2. Materials and Methods:

2.1. Materials:

2.1.1. Sample of the study:

Ten specimens were used as control while other 60 specimens subdivided into six subgroups (n=10):

1) Immersed in cola for 10 min. 3 times daily for one month

2) Immersed in cola for 10 min. 3 times daily for one month then brushed with the sonic brush for one min. after each exposure.

3) Immersed in coffee for 10 min. 3 times daily for one month,

4) Immersed in coffee for 10 min. 3 times daily for one month then brushed with the sonic brush for one min. after each exposure

5) Immersed in tea for 10 min. 3 times daily for one month ; and

6) Immersed in tea for 10 min 3 times daily for one month then brushed with the sonic brush for one min. after each exposure.

2.1.3. Restoratives:

Three different restoratives [KetakN100 (KN) by 3M/ESPE, Beautifil II (BII) by Shofu and FiltekSupreme Ultra (FS) by 3M/ESPE] were tested in this study (Table 1). 70 discs (5mm diameter x 2mm thick) of each tested material were made. The discs were fabricated by carefully inserting composite resins into a circumferential Teflon mold with 5mm of internal diameter and 2mm of height positioned onto a 0.051 mm thick transparent polyester film strip (Mylar, DuPont, Wilmington, Del.) over a glass slide. Another 0.051 mm thick transparent polyester film strip was applied on top of the metal matrix filled with the tested material. An additional glass slide was placed over the previously positioned polyester film strip, and 1 kg weight applied during 1 min. Afterward, the weight was removed and the tested restorative material light cured for 20 seconds each side (Optilux 501, Kerr Corp, Orange, CA) through the polyester film strip. The output light intensity was continuously monitored with a radiometer (SDS Demetron, Orange, CA) to ensure a constant value of 600 mW/cm^2.

2.1.3. The staining agents:

The staining agents were:

-*Coffee* was prepared by mixing 12 g of natural coffee powder (Nescafe®) and 10 g of white sugar with 200 ml of boiling water.

- *Cola* used was Coca Cola® brand.

-*Lipton*® tea sachet. Tea was prepared by placing the tea sachet together with 10 g of white sugar in boiling water for 5 minutes and then the sachet was removed.

All specimens were placed in staining solutions at room temperature.

2.2. Methods:

2.2.1. Procedure:

Between staining and brushing challenges, specimens were immersed in artificial saliva. The sonic toothbrush used was the Dentasonic (Rowenta Corporation, Germany). This sonic power toothbrush uses an electromagnetic driving system to produce high frequency (500 strokes per second) with low amplitude bristle movement at the tooth surface. This examination for color changes was done by using quanta environmental scanning electron microscope (QESEM) and specific computer software. By using XT Document program, the scanning photomicrograph taken by the QESEM (Figure 1, a) is converted to have Quantitative computerized image analysis using digital scanner with a special computer program. This program divides the surface of all specimens image on computer monitor into points (Figure 1, b). Each point has a pixel value at the two coordinates (x, y) as shown in the excel sheet. From the data of the two coordinates, the gray value for each point was calculated. The statistics sheet containing the mean of the gray value for these points are calculated (range between 0 and 255, with greater value meaning the brighter the surface). The gray value was measured as a linear measurement to get three readings (count, maximum, minimum values of these points). To ensure proper and accurate data, the mean of three readings was calculated as the mean gray value of each specimen.

2.2.2.Statistical Methods:

Data were presented as mean and standard deviation (SD) values. Regression model using Three-way Analysis of Variance (ANOVA) in testing significance for the effect of material, staining, brushing and their interactions on color changes.

Tukey's post-hoc test was used for pair-wise comparison between the means when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS 16.0 (Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA) for Windows.

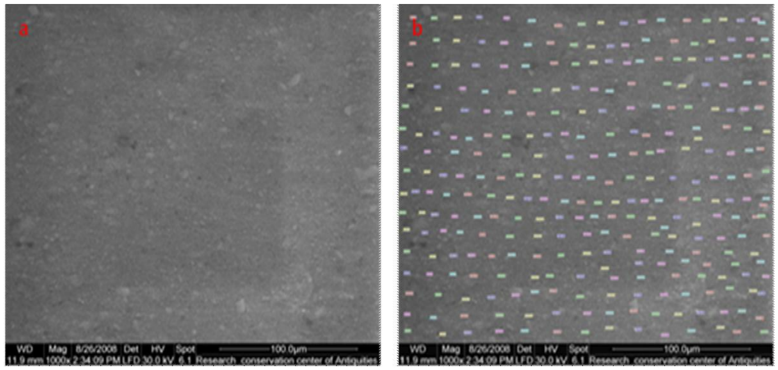


Figure (1):a. scanning photomicrograph of Beautifil II specimen after exposure to coffee, b. image analysis divided the scanning photomicrograph into points.

Table (1): Manufacturers, manufacturers' instructions and compositions of the used materials.

Material	Principal components	Manufacturer's Instructions	Manufacture
KetakN100 Nano-ionomer (Light-Curing Glass Ionomer Restorative)	De-ionized water, Blend including HEMA, methacrylate-modified polyalkenoic acid (Vitrebond Copolymer—VBCP) and acid-reactive fluoroaluminosilicate glass, Nano-particles and Nano-clusters (69% by Wt)..	1.Dispense Ketac Nano restorative into the Teflon mold 2. Allow Ketac Nano restorative to rest for approximately 60 seconds after placement in preparation permits the paste to become firmer and less tacky. Waiting time should not exceed the total working time (2.5 minutes). 3. After this waiting period the material is shaped and contoured with an appropriate placement instrument. 4. light cure the material for 20 sec.	3M/ESPE, St. Paul, U.S.A
Beautifil II (Nano-hybrid resin based giomer material)	**Matrix:** 16.7wt% of resin (Bis-GMA and TEGDMA). **Filler structure:** Surface Pre-Reacted Fluoroboroaluminosilicate Glass Filler, Nano Filler, Multi Fluoro-boroaluminosilicate Glass Filler (68.6 vol% and 83.3wt%)	1. Dispense the necessary amount of material from the syringe onto the mix pad. The dispensed material should be protected from light. 2. Pack the material into the teflon mold. 3. Light cure the material for 20 sec.	SHOFU INC., Kyoto, Japan
FiltekSupreme Ultra(Nano-filled resin composite)	Silane treated ceramic (60 - 80 % by Wt), silane treated silica, UDMA, Bis-GMA, TEGDMA, bisphenol a polyethylene glycol diether dimethacrylate, silane treated zirconia, polyethylene glycol di-methacrylate, 2,6-di-tert-butyl-p-cresol.	1.Dispense the necessary amount of restorative material from the syringe onto the mix pad, the dispensed material is protected from light. 2-Place the material into the Teflon mold. 3. Light cure the material for 20 sec.	3M/ESPE, St. Paul, U.S.A

3. Results:

The results of the three-way ANOVA showed that, the regression model is fit to describe the relationship between the studied variables. The results showed that, the tested materials, staining, brushing and the interaction between the three variables had a statistically significant effect on mean color change values ($P \leq 0.05$).

3.1.Effect of Material

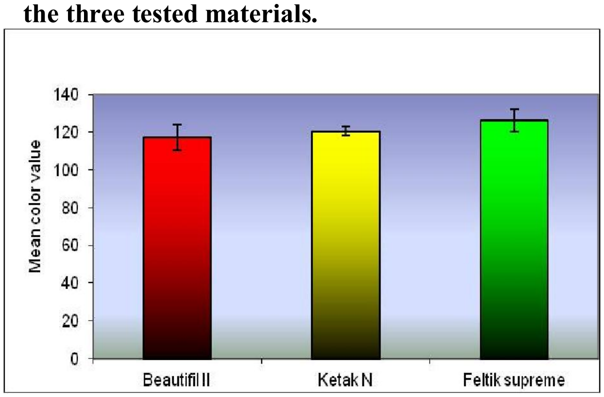
To compare the effect of the tested material on the color change values Tukey's test was used and the results were presented in Table (2) and Fig. (2) and showed that Beautifil had the statistically significantly highest mean color change values (*P ≤ 0.05*). Meanwhile, there was no statistically significant difference between Feltik and Ketak, both showed the statistically significantly lowest mean values of color change.

Table (2): Comparison between color change values of the three tested materials.

Feltik supreme		Ketak N		Beautifil II		*P*-value
Mean	SD	Mean	SD	Mean	SD	
117.4 [b]	7	120.7 [b]	2.5	126.4 [a]	5.9	**<0.001***

*: Significant at P ≤ 0.05, Means with different letters are statistically significantly different according to Tukey's test.

Figure (2): Bar graph representing means and SD for comparison between the color change values of the three tested materials.



3.2.Effect of staining

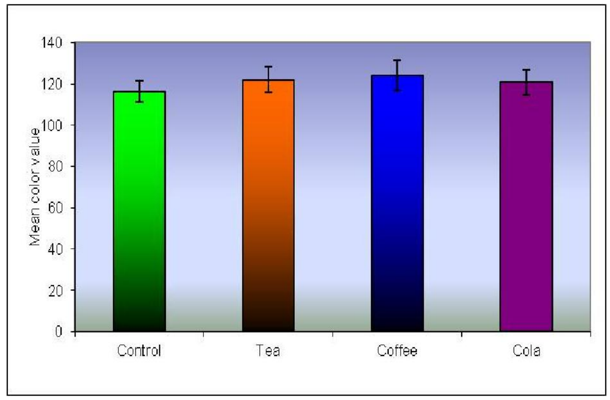
Tukey's test indicated that, there was no statistical significant difference between tea, coffee and cola subgroups which showed the statistical significant highest mean color change values compared with the control subgroup (Table 3 and Fig. 3).

Table (3): Comparison between color change values with and without staining.

Control		Tea		Coffee		Cola		*P*-value
Mean	SD	Mean	SD	Mean	SD	Mean	SD	
116.5 [b]	5.1	122 [a]	6.2	124.2 [a]	7.4	120.8 [a]	6.1	**0.003***

*: Significant at P ≤ 0.05, Means with different letters are statistically significantly different according to Tukey's test

Figure (3): Bar-graph representing means and SD for comparison between color change values with and without stains



3.3.Effect of brushing

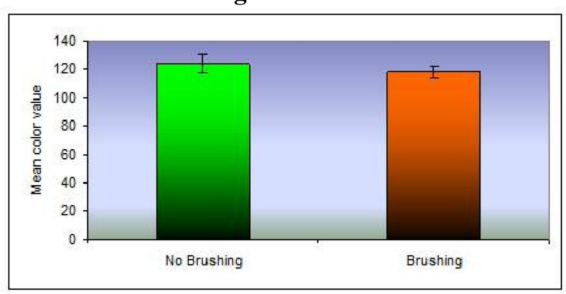
Tukey's test indicated that, the subgroups that were not subjected to brushing showed statistically significantly higher mean color change values than brushed subgroups (Table 4 and Fig. 4).

Table (4): Comparison between color change values with and without brushing.

No Brushing		Brushing		*P*-value
Mean	SD	Mean	SD	
124.1	6.7	118	4.3	**<0.001***

**: Significant at P ≤ 0.05*

Figure (4): Bar graph representing means and SD for comparison between color change values with and without brushing.



The results of different interactions were presented in Table (5) and showed that there was no statistically significant difference between tea stained and not brushed Beautifil specimens, coffee stained and not brushed Beautifil specimens and cola stained and not brushed Beautifil specimens which showed the statistically significantly highest mean color change values.

On the other hand, no statistically significant difference were found between not stained and not brushed Feltik specimens, tea stained and brushed Feltik specimens, coffee stained and brushed Feltik specimens and cola stained and brushed Feltik specimens which showed the statistically significantly lowest mean color change values.

Table (5): Comparison between color change values of different interactions

Material	Staining	Brushing	Mean	SD	*P*-value
Feltik supreme	***Control (No staining)***	No Brushing	110.8^{e}	1.6	**<0.001***
	Tea	No Brushing	124.9^{c}	2.1	
		Brushing	112.9^{e}	1.5	
	Coffee	No Brushing	127.8^{b}	1.4	
		Brushing	113.6^{e}	2.1	
	Cola	No Brushing	120.6^{c}	2.7	
		Brushing	111.2^{e}	1.5	
Ketak N	***Control (No staining)***	No Brushing	117.8^{d}	1.9	
	Tea	No Brushing	122^{c}	2.1	
		Brushing	119^{c}	2.6	
	Coffee	No Brushing	125.3^{b}	1.7	
		Brushing	120^{c}	1.6	
	Cola	No Brushing	121.8^{c}	1.9	
		Brushing	119^{c}	2.3	
Beautifil II	***Control (No staining)***	No Brushing	120.8^{c}	1.8	
	Tea	No Brushing	131.7^{a}	2.1	
		Brushing	121.4^{c}	1.4	
	Coffee	No Brushing	135.4^{a}	1.7	
		Brushing	122.8^{c}	1.7	
	Cola	No Brushing	130.2^{a}	2.9	
		Brushing	122.2^{c}	1.7	

*: Significant at $P \leq 0.05$, Means with different letters are statistically significantly different according to Tukey's test

4. Discussion:

This study evaluated and compared the color stability of three different restorative materials, one of which is a new introduced material (Ketac N100). Staining and color stability of this material was compared with Filtek supreme and Beutifil II restorative materials.

This study was unique in three ways. The first is that, it is the first one to assess staining and color stability of Ketac N100. The second is that, the staining regimen used in our study tried to mimic real life situations. Many studies tested color stability and staining potential of different restorative materials but used unrealistic staining methodologies. For example, one study immersed the tested materials in common beverages (Cofee, Tea or Cola) for 24 hours over a period of 2 weeks, Ayad(2007); Soares et al., (2007) Another study immersed the restorative materials in coffee for seven days continuously, Ergücü et al., (2008) while another immersed the tested restoratives in 50 degrees Celsius for 30 days, Ghahramanloo et al., (2008). In our study, the staining solutions were at room temperature, and all tested restorative materials were immersed for 10 minutes three times daily for a period of one month. We also compared these staining solutions' effect on all restorations following sonic tooth brushing.

The third unique way about the study is the method of measuring color stability or staining. Many studies evaluated color difference using a colorimeter or a spectrophotometer to determine ΔE which basically is the color difference or shift, Mutlu-Sagesen et al., (2005); Ayad (2007); Soares et al., (2007); Ergücü et al., (2008); Ghahramanloo et al., (2008).This study was done by using QESEM with specific computer software. The QESEM compared the scanning photomicrograph taken for the surfaces of different specimens in each test group. This method has not been used before for color analysis. A future study needs to be carried out to compare the QESEM results to a colorimeter or spectrophotometer results. Since, significant differences in color change by different test groups could turn out to be clinically not relevant. However, determining color stability of different restorative materials after exposure to different staining agents can certainly be conducted with QESEM.

Staining agents used in this study were tea, coffee, and cola, all of which resulted in significant color changes compared with the control no staining group. Amongst them, however, there were no significant differences in staining potential. These results were in accordance with Fontes et al who reported no difference between coffee and tea but significant ones compared to grape juice, Fontes et al.,(2009). Other studies however, found that coffee and tea caused more staining than cola or coffee more than cola Ayad(2007). Another study found that sugared tea and coffee caused more staining compared with no sugar beverages, Guler et al.,(2009). Obviously, these studies were performed on different restorative materials, some of which were experimental products Manabe et al.,(2009) and others were temporary restorative materials, Guler et al.,(2009); Rutkunas et al.,(2011). Different composition of these materials certainly plays in important role in their ability and potential to pick up stains. To further complicate the matter, stains can be adsorbed on the surface, or absorbed intrinsically by the material organic matrix. This is why many studies aimed to test staining agents with and without the effect of polishing agents to remove the surface layer of the material and compare color changes afterwards.

In our study, there were significantly higher color changes for specimens which were not brushed. This is due to the fact that the surface oxygen inhibited layer - which has a tendency to retain staining substances, Patel et al.,(2004)was left un-removed. The fact that color differences also existed amongst different materials (either brushed or not) means that color change in test specimens was due to intrinsic (stain absorption) and extrinsic staining (stain adsorption). Extrinsic staining was removed by sonic brushing while intrinsic staining caused the difference between different restorative materials.

The color change in the test specimens is due to the presence of monomers like diglycidyl methacrylate, urethane dimethacrylate**,** triethylene gylcol dimethacrylate. This makes the resin matrix hydrophilic in nature which greatly increases water and other fluids sorption leading to color changes within the material, Bagheri et al.,(2005). Other factors which may contribute to color changes are the photoinitiator systems and the distribution of filler particles, Janda et al.,(2004);Guler et al.,(2009); Patel et al.,(2004).

The introduction of nanofillers in composite restorations helped improve physical, mechanical, and optical properties of these restorations, Rodrigues et al.,(2008); Rodrigues et al.,(2008). Both KN100 and Filtek supreme materials contain non agglomerated nanofillers (5-25 nm in size) and nanoclusters (agglomerated with an average size of 1 to 1.6 microns). These fillers are derived from both silica and zirconia. The presence of these nanofillers enhances the gloss and polishability of the so called nanocomposites like the Filtek supereme, Yap,S, Yap (2004);Ergücü et al.,(2008); Mundim et al.,(2010).

Although we have not measured the gloss, polishability, or surface roughness in our study, but both materials containing nanofillers (KN100, and Filtek supreme) have performed similarly regarding color change. There were no significant differences between them, but Beautifill had significant color change when compared to either (Table 1). This is probably due to the fact that both nanofilled materials were heavily filled with fillers. Studies showed that the smaller the size of the filler particles, and the lower the organic matrix percentage -which is always the culprit in retaining or adsorping stains-, the lower the level of opacity and the less staining potential, Mitra et al.,(2003); Vichi et al.,(2004)

Beautifill is a giomer restorative material made up of glass ionomer and composite constituents, but no nanofillers. Glass ionomer is in the form of fluorosilicate glass particles of which the surface was pre reacted with polyacrylic acid prior to being incorporated into the resin matrix of the composite restoration. So, it is basically a composite restoration with incorporated surface pre-reacted fluorosilicate glass particles, which makes it similar to compomers in that they need a bonding agent and has to be light cured to polymerize them. It is probably the presence of nanofillers in KN100 and Filtek Supreme restoratives that made the significance difference in color staining compared with Beutifill II.

Our study did not account for two factors which may or may not have altered the results: the pH factor of the staining solution and the presence of sugar. Guler et al.,(2005) found that microhybird composite materials demonstrated higher color change when stained with coffee and tea with sugars compared with no sugar content beverages. Also, few studies have studied the association staining solution pH and color change, Abu-Bakr et al.,(2000); Imparato et al.,(2007).

Conclusions:

The tested nanoionomer and nanocomposite performed similarly under the test conditions, whereas, the tested giomer was affected severely by the staining agents. Brushing specimens after staining with coloring agents improved the color changes of the tested materials.

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