Original Research

Effect of brushing on the color stability of nanohybrid composite after immersion in brewed beverages – an *in vitro* study

Jayeeta Verma[1], Leena Padhye[2], Sidharth Verma[3]

1) Department of Endodontics, MGM Dental college and hospital, Navi Mumbai, India

2) Department of Endodontics, DY Patil University School of Dentistry, Navi Mumbai, India

3) Incharge Pain Clinic, Department Of Pain Medicine, DY Patil University School of Medicine, Navi Mumbai, India

Abstract

Background and aims. In today's world, everyone is mindful of one's appearance and appreciates aesthetics. Of the various restorative materials available, composites are considered as the most aesthetic with good color stability. This study aims at finding the effect of brushing on the color stability of nanohybrid composite after being immersed in various beverages.

Methods. Thirty disk specimens were prepared for each staining solution (N=30), with a total of 90 specimens. The disk specimens for each staining solution were then sub divided into 2 groups (N=15): brushing and non-brushing. After preparation, the specimens were soaked in distilled water for 24 hours in separate containers. Baseline color of the samples was evaluated using spectrophotometer. The samples were then immersed in tea, coffee or water. The groups of samples to be brushed were held in the mold and 20 strokes of brushing using an electronically powered toothbrush were done on each side of the disk sample. The color was re-evaluated after a period of 14 days.

Results. When comparing among the three beverages, tea showed the highest ΔE*ab indicating greatest discoloration when compared to coffee and water. This can be graded as tea > coffee > water. However, statistically there was no significant difference between tea and coffee. When compared within tea, coffee, or water specimens the non-brushed specimens showed greater discoloration compared to the brushed specimens both clinically and statistically.

Conclusion. When immersing the specimens in the solutions, tea showed more color change compared to coffee, making the specimens clinically unacceptable. However, brushing the specimens reduced the discoloration when compared to non-brushing, making the coffee specimens clinically acceptable.

Keywords: nanohybrid composite, spectrophotometer, tea, coffee, brushing, non-brushing

Introduction

Aesthetics has emerged as the most important part of dentistry in recent times. A desire to look attractive and appealing is no longer taken as a sign of vainglory. In today's economically and socially competitive world, an attractive appearance has become a necessity. Since the face is the most exposed part of the human body, and the mouth an eminent feature, teeth are getting a greater share of attention. Successful color matching of the restoration is one of the critical clinical requirements to increase the acceptance of any dental restoration.

During the first half of 20th century, silicates were the only tooth – colored aesthetic materials available. However, they are no longer used as they are strong irritants to the pulp and show severe erosion within a few years [1]. Resin composites have a gained a wide popularity worldwide since their introduction in 1970's because of their excellent aesthetic properties. However, when compared to ceramics they suffer from discoloration

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Address for correspondence:
jayeetaverma@gmail.com

after prolonged exposure to oral environment. Thus, newer universal composite systems combining the properties of the earlier hybrid and microfilled composites, have been introduced. One of the most significant modifications in the recent years has been the application of nanotechnology to resin composites, which has increased its color stability and gloss retention [2].

The use of nanotechnology has seen the incorporation of nano – sized fillers into the composite resins. Resin nanocomposites have many advantages such as increased mechanical properties, improved optical properties and overall diminished wear [3]. The nanohybrid resin composite has particles sizes ranging from 40 to 3000 nm, whereas the nanofilled resin composite has particles of 5 to 20 nm in size, but they are agglomerated into particle sizes that reach 600 to 1400 nm, which exceeds the sizes of the smaller particles in the nanohybrid resin composite [4].

However, success or failure of any aesthetic restoration depends first on the color match and then on the color stability of the material. The failures may include discoloration of the material, which may then require its replacement. This failure concerns the patient and the dentist since it consumes both time and money [5].

Discoloration of tooth colored resin based materials may be caused by either intrinsic or extrinsic factors. Intrinsic discoloration involves physical and chemical changes within the material. However, improved matrix properties, better filler matrix coupling and various light cure materials have decreased intrinsically mediated discoloration [6]. On the other hand, extrinsic factors such as absorption or adsorption of the stains pose another problem. According to the demographic and topographic distribution of India, tea is more commonly consumed in North India while coffee in South India. Also, personal oral hygiene plays an important role in the uptake of stains. However, brushing and polishing might remove material from the composite; they tend to remove the superficial staining partially or even completely. Thus, it enhances the color stability of dental resin composite restorations [7,8].

Color perception of any individual by visual analysis of any object is a subjective, physiologic and psychological process that can vary. Perceptibility and acceptability thresholds have been found to be significantly different [9]. A spectrophotometer is a scientific standardized equipment which measures color in three dimensional space attributes. It matches colors that numerically specify the perceived color of any object [10].

The staining of traditional polymeric materials by different staining solutions such as coffee, tea, beverages, and other coloring agents have been reported in many studies done in the past. However, for nanohybrid composites materials very few long-term clinical studies have been done to check their color stability and clinical performance. Thus, the aim of this study was to evaluate the effect of brushing on the color stability of nanohybrid composites after exposure to commonly consumed beverages (tea and coffee) using a spectrophotometric analysis.

The null hypothesis tested in this study is that there are no differences among the different solutions on color stability of the nanohybrid composite; and that tooth brushing does not affect the staining ability of the restorative materials.

Methods

Specimens of nanohybrid composite were prepared and then stained by immersion in the staining solution. Using spectrophotometry the degree of color change (ΔE^*_{ab}) following staining was measured to compare the staining ability of the nanohybrid composite to various staining solutions. Also, effect of brushing was also taken into consideration.

Sample of the study

Thirty disk specimens were prepared for each staining solution (N=30), with a total of 90 specimens. The disk specimens for each staining solution were then sub divided into 2 groups (N=15): brushing and non-brushing.

The specimens were fabricated by carefully condensing the composite resin: Brilliant NG (I) composite resin – A2/B2 dentin shade (Coltene Whaledent) (Table I) in a single increment in the polytetraflouroethylene mold having a circular shaped hole, (10 x 2 mm) punched in it. The condensed composite was then covered with mylar strips and sandwiched between a glass slide on one side and glass slab on the other. Pressure was maintained to remove the excess material and thus reduce porosity [11].

This was followed by curing on both sides for 40 seconds using a LED light curing unit (Monitex: Ti –Lite GT – 1500) at 700mW/cm^2. This was done to achieve complete polymerization of the specimens. Also, polishing was not attempted for any specimen; as polishing may render different surface characteristics to the resin material [12].

Table I. Composition of composite.

Composite resins	Shade	Organic matrix	Filler content	Manufacturer
Brilliant New Generation	A2/B2	BisGMA, BisEMA, TEGDMA	Nanohybrid filler (0.02-2.5µm), 65 vol%, 80wt%, Dental glass, amorphous silica	Coltene Whaledent, Altstätten, Switzerland

BisGMA - bisphenol-A-glycidyl methacrylate; BisEMA - ethoxylated bisphenol-A dimethacrylate; TEGDMA - triethylene glycol

After preparation, the specimens were soaked in distilled water for 24 hours in separate containers. This was done for elution of the unreacted components from the resin and to allow post irradiation and post setting polymerisation to occur [13]. The baseline color of the samples was then evaluated.

Staining agents

The staining agents were:

- Tea was prepared by adding 5 grams of tea powder into a vessel containing 80 ml of boiling distilled water. After 5 minutes of stirring, the solution was filtered through a strainer.
- Coffee was prepared in a similar manner
- Distilled water

All the specimens were placed in staining solutions at room temperature.

Procedure

All the specimens were immersed in the test solutions for 2 hours; 3 times/ day for a period of 14 days. Following removal from the staining solutions, the samples were rinsed in distilled water. The groups of samples to be brushed were held in the mold and 20 strokes of brushing using an electronically powered tooth brush (Oral – B; cross – action power) were done on each side of the disk sample (simulating three brushing with 40 movements per day). Between staining and brushing challenges, the specimens were immersed in distilled water. The specimens were blotted with a blotting paper during transfers to and from the distilled water.

As water sorption and solubility of composites are 0.6 mg/cm2 and 0.05 mg/cm2 respectively, the samples required more than 14 days before equilibrium was reached at body temperature. Hence, the study period of 14 days was selected [14].

Commission internationale de l'éclairage LAB colorimetric system was used for color evaluation. Color evaluation and differences (ΔE^*_{ab}) for each specimen were measured using a spectrophotometer (KONICA MINOLTA CM - 3600d).

The readings were taken under the standard illuminant of D65 and standard observer of 10° under daylight conditions. The disks samples were mounted at 90° relative to the light source.

Color measurements were made just before immersion and after 14 days.

This study was conducted to determine the effects of daily consumed beverages such as tea and coffee on the color change of nanohybrid composite resins. The color change can be evaluated by different techniques and instruments. In this study, digital analysis of color change was done using spectrophotometer. The color difference is calculated as [10]:

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

whereby:

ΔE^*_{ab} = is the difference in color

ΔL^* = is the difference in brightness values ($L_2 - L_1$). "L_1" indicates the pre staining value, "L_2" indicates the post staining value and "L" = indicates the brightness (value of 100 corresponds to perfect white and that of zero to black)

Δa^* = is the difference in the red green scale ($a_2 - a_1$). a_1 is pre staining value, a_2 is post staining values

Δb^* = determines the difference in yellow blue scale ($b_2 - b_1$). B_1 is pre staining value, b_2 is post staining values. Thus, ΔE^*_{ab} is expressed as the relative color change between repeated color measurements [15].

The significance level was set at 5% i.e $p < 0.05$. Statistical analysis was performed with SPSS 20.0 (Statistical Package for Scientific Studies, SPSS, Inc., Chicago, IL, USA) for Windows.

Results

Pre-immersion and post-immersion values of color coordinates (L*a*b*) were recorded and the change in the color (ΔE^*_{ab}) was calculated for each specimen. Means and standard deviations of the change in color values (ΔE^*_{ab}) for the dental resin composite after being subjected to different beverages used in the study with/without brushing are presented in table II. After immersion in various beverages, all the specimens showed lower ΔL^* values which indicates decrease in lightness and higher Δa^* values which indicates increase in the yellowness.

Table II. Mean, SD of color change values ΔE^*_{ab} for nanohybrid composite after being subjected to different beverages used in the study with/without brushing regarding the effect of different beverages.

Material	Group	Beverages	Mean± SD	One way ANOVA	p-value	Significant at 5% level
Brilliant NG	Non-Brushing	Tea	3.08 ± 0.34	96.711**	<0.001	Yes
		Coffee	2.91 ± 0.11			
		Water	1.70 ± 0.48			
	Brushing	Tea	2.82 ± 0.11	55.772**	<0.001	Yes
		Coffee	2.67 ± 0.22			
		Water	1.68 ± 0.28			

** Statistically highly significant at p<0.001

Table III. Comparison within the beverage for groups of Brushing and Non–Brushing specimens.

Material	Beverage	Group	Paired T test	p-value	Significant at 5% level
Brilliant NG	Tea	Brushing	2.32*	0.04	Yes
		Non brushing			
	Coffee	Brushing	4.49*	0.00	Yes
		Non brushing			
	Water	Brushing	0.28	0.78	No
		Non brushing			

* Statistically highly significant at $p<0.05$

One-way ANOVA test was used to compare the effect of different beverages for each group, followed by Sidak post hoc test when ANOVA yielded a significant difference. ($p<0.05$) In the non-brushing group, the highest ΔE^*_{ab} mean value was recorded in subgroup using Tea (3.08), whereas the lowest mean value was recorded in water (1.70). In the brushing group, the highest ΔE^*_{ab} mean value was recorded in subgroups using Tea (2.82), whereas the lowest value was recorded in water (1.68). Sidak post hoc test showed that there was no significant difference between tea and coffee. However, significant difference was seen in comparison to water.

Paired t-test was used to compare the composite for each beverage with/without brushing. Within all beverages, the highest Δ E mean value was recorded in the non-brushing group with significant difference between brushing and non-brushing groups in all beverages except water (Table III).

Discussion

Aesthetic failure is one of the most common reasons for replacement of restorations. Shade matching of composite with the tooth before curing ensures a good clinical outcome. Nevertheless, this must also remain after the material is completely cured and throughout the life of the restoration in the oral environment.

Three types of discolorations are generally described in case of composite resin restorations namely external / extrinsic (discoloration due to accumulation of plaque and surface stains due to surface roughness of the material); surface or subsurface color alteration (superficial or slight penetration of the staining agents within the superficial layer of the resin composites- adsorption); and internal / intrinsic discoloration (diffusion of stains in the resin followed by physico–chemical reactions in the deeper layers of the restoration-absorption) [16].

The staining ability of a resin based composite is related to the resin matrix, content and dimensions of the filler particles, degree and depth of polymerization, curing unit and time, polymerization type, adsorption and absorption of satins, type of staining agent and chemical reactions between the resin composite and the stains. In this study, a nanohybrid composite material has been used. This is in accordance with studies by Leite et al. [17], Ceci et al. [18], which showed that nanohybrid composite showed greater color stability than nanofilled composite.

In our study, the specimens were unpolished, as polishing them may render different surface characteristics to the specimens and thus influence their stain uptake, similar to a study by Malhotra et al [19]. Also, the oral conditions have been mimicked by short immersion periods. This is in accordance with the oral environmental factors where restorations may be exposed intermittently to the beverages depending on a person's habit of consumption of beverages rather a continuous exposure. This is similar to studies done by Nasim et al. [20] and Bezgin et al. [8], where continuous immersion schedule was not observed.

The staining and marginal leakage is also influenced by the ability of the material to become wet which is indicated by the contact angle a drop of water forms with the composite. The advancing contact angle of water on composites is about 65 and thus composite is classified as a hydrophilic solid (as (theta) is less than 90). With this contact angle and a contact angle for tooth structure of about 55, water/ saliva will spontaneously penetrate any crevice between the restorative material and the tooth. In addition, the hydrophilic surface readily absorbs hydrophilic precursors to plaque and stains [14]. Greater discoloration will occur with higher volume fraction of the resin while less discoloration with lower resin content in composition [21].

Resin composite should be adequately polymerized to achieve optimal mechanical and optical properties. An under-polymerized resin composite can produce undesirable effects such as water absorption and solubility of the unreacted monomers making it more susceptible to staining [22]. Also, inadequate polymerization can lead to easy dye and pigment diffusion through the resinous matrix [23]. Extra water sorption may decrease the life of resin composites by expanding and plasticizing the resin component, hydrolysing the silane and causing microcrack formation [24].

In dentistry, visual limits, perceptibility and acceptability representtools for controlling quality and

a guide for the evaluation and selection of restorative material. These define the visual match or incompatibility of color, translucency and luminosity [25]. The perceptibility limit refers to the smallest color difference (ΔE^*_{ab}) that can be detected by an observer. The acceptability threshold determines whether that color difference is acceptable or unacceptable and, therefore, whether or not a restoration color correction is involved. According with ISO / TR 28642, the ΔE^*_{ab} value for the perceptibility limit should ideally be less than or equal to 1.2; if it is greater than 1.2 the acceptability limit must be less than or equal to 2.7 [25,26]. Results of the present study showed that the specimens immersed in the tea and coffee showed color change which was visually perceptible and clinically unacceptable. However, after brushing the specimens immersed in coffee became clinically acceptable. Thus, the null hypotheses that there is no color change in specimens after immersion and that brushing had no impact on the color change was rejected.

In our study, there were significantly higher color changes for specimens which were not brushed. These results are in accordance with Bezgin et al. [8] and Mozzaquatro et al [24]. Brushing reduces the superficial staining [27]. This is due to the fact that the surface oxygen inhibited layer - which has a tendency to retain staining substances, was left un-removed [28]. Brushing the specimens reduces but does not prevent the staining caused by tea and coffee. Staining is surface phenomenon which can be mechanically removed by brushing [6]. This finding is not in accordance with Lepri et al. [29] which stated that brushing did not influence the color; or with Silva et al. [30], Alzayer et al. [31] who said that brushing would increase discoloration as surface become more rough and increases uptake of stains. The addition of a toothpaste may also increase surafce roughness and cause further discoloration [32].

Recently, a new color formula CIEDE2000 has been introduced which reflected the color differences perceived by the human eye better than the CIELab [33]. However, the key point is "nobody accepts or rejects color because of numbers—it is the way it looks that counts" [34]. Thus, accepting or rejecting an aesthetic restoration can be attributed to an individual's personal preference but clinically it may not be satisfactory. The importance of quality control in dentistry is reinforced by increased esthetic demands of patients and dental professionals.

However, in the mouth, the effect of the beverages may be diluted to some degree by the action of saliva, pH of the oral cavity. The exposure also depends on the number of times the beverage is consumed, concentration of the beverage, etc. So, to correlate the present findings clinically, more in-vivo studies are needed to evaluate the color stability in the oral cavity per se and for longer periods of time. Also, our study did not take into consideration the effect of sugars [35,36] which showed that drinks that contained sugars showed greater color change in contrast to unsweetened drinks. Also, another limitation is that the entire specimen was immersed in the solution, whereas in the oral cavity, only a certain amount may be in contact with the liquid. The frequency and duration of brushing may also affect the staining. Tooth brushing also brings negative effects over a period whether done or not done appropriately to maintain oral hygiene on the surface of composite restorations [37].

Conclusions

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

1. The specimens immersed in the tea and coffee immersion media showed discoloration which were visually perceptible and clinically unacceptable. The samples immersed in water did not show discoloration that was clinically visible.

2. Comparing among the test solutions, tea showed greatest discoloration. This can be graded as tea > coffee > water

3. Comparing among brushed and non- brushed specimens, the non-brushed specimens showed greater discoloration. Brushing made the coffee specimens clinically acceptable.

The clinical significance is that dietary habits play an important role in color stability of tooth colored restoratives and hence the patient must be aware of the likely potential of the daily consumed food stuffs to alter the color of the restorative resins.

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