Journal of Dental Biomaterials
Shiraz University of Medical Sciences, Shiraz, Iran

Journal of Dental Biomaterials. 2014;**1**(1)

The Effect of Drinks and Temperature on the Staining of Resin Composites Coated with Surface Sealants

Hui R, Choi IH, Hussein I, Hockey J, Hetrelezis D, Wong RHK

Melbourne Dental School, Faculty of Medicine, Dentistry and Health Sciences, University of Melbourne, Victoria, Australia

ARTICLE INFO

Article History
Received 15 Feb 2014
Accepted 21 May 2014

Keywords:
Resin composite
Staining
Surface sealants
Temperature
Drinks

Corresponding Author:
Wong RHK.
Melbourne Dental School, The University of Melbourne, 720 Swanston Street, Victoria 3010, Australia
Tel: +61 393411517
Fax: +61 393411595
Email: rhkwong@unimelb.edu.au

Abstract

Statement of problem: Surface staining of resin composite by dietary factors may be modified by the placement of a low-viscosity surface sealant aimed at reducing surface voids and defects occurring after light-curing and polishing.
Objectives: The aim of this study was to investigate the staining effect of various drinks and temperatures on the surface sealant (Fortify Plus™) sealed on a nano-filled resin composite (Supreme XTE™) after artificial aging at different temperatures.
Materials and Methods: Surface sealant was applied on one surface of forty resin composite discs (10×2 mm). Five discs each were immersed in test solutions of black cola, commercial dark grape juice, coffee and distilled water (negative control). Discs were either placed at 4°C (20 discs) or 37°C (20 discs) and the colour difference (ΔE) was calculated based on the colour coordinates at 0 (baseline), 7, 14 and 28 days of staining treatment. Two-factor with replication analysis was carried out with ANOVA.
Results: The results showed significant discolouration after 28 days immersion in coffee ($P<0.001$) and grape juice group ($P<0.001$). Surface sealant significantly affected colour changes in coffee and grape juice group ($P=0.002$). Higher temperatures in coffee and grape juice also significantly increased the effect of staining ($P<0.001$).
Conclusions: Surface sealant was able to reduce discolouration in the grape juice group only. A lower temperature of 4°C caused less staining in coffee and grape juice groups as compared to the 37°C corresponding test groups. Prolonged immersion time significantly increased discolouration in coffee and grape juice groups.

Cite this article as: Hui R, Choi IH, Hussein I, Hockey J, Hetrelezis D, Wong RHK. The effect of drinks and temperature on the staining of resin composites coated with surface sealants. J Dent Biomater, 2014;1(1):16-22.

Introduction

Aesthetic requirements contribute a major aspect in determining the success of dental restorations. In most cases, aesthetics was considered more important than the functional aspects of restorations [1]. Poor aesthetics may result in patient dissatisfaction, treatment complications and even added expenses for replacement [2,3]. To preserve these aesthetic properties in resin composite restorations, surface sealants can be used [4].

Dental surface sealants, also known as *Glazes*, were first introduced some 30 years ago, and were mainly used for covering resin composite restorations [4]. Its composition consists of an unfilled, self-curing Bis-GMA (bisphenol- A- glycidyldimethacrylate) resin matrix, which has less polymerisation shrinkage, linear expansion coefficient and water sorption than resin composite restorative materials [4,5]. Depending on the type of resin matrix, size of filler particles, manual mixing skills and the lack of accuracy in finishing instruments, resin composite restorations often results in various surface defects [4]. These include microstructural cracks and surface irregularities due to the removal of surface particles. Micro-fractures can also occur along the enamel-adhesive interface due to light curing induced shrinkage [7]. This often results in poor aesthetics, discolourations, staining and potential plaque retentive sites in resin composite restorations [4,8]. Thus, surface sealants are placed to penetrate and fill in these voids, cracks and marginal openings to improve the surface texture, staining resistance and optical properties of resin composite restorations [4,6-10].

Intra-oral exposure to food dye, black cola, coffee, tea, chlorhexidine and even artificial saliva has a profound effect on staining susceptibility and physical properties in resin materials due to water sorption [8,11-12]. Staining of dental resin materials due to the patient's dietary intake is often attributed to multiple factors. It is difficult to generalize the effect of diet as a whole on the staining susceptibility of dental resin materials. 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 [11,12,13-17]. The temperature of oral cavity and dietary substrates are also associated with discolouration to resin based materials [18]. Long-term immersion of resin composite in a high temperature solution can induce changes in the material properties, which ultimately may lead to discolouration [11,18]. This prolonged exposure to heat may degrade organic matrices to promote pigmentation [12]. Nevertheless; the effects of temperature on the staining susceptibility of surface sealants have never been explored. Therefore, in this current study, the role of temperature on the staining susceptibility of surface sealants will be investigated.

The aim of the current study is to investigate: (1) The effect of an unfilled low viscosity resin surface sealant (Fortify Plus™) on the staining susceptibility of nano-filled restorative resin composite restorative material when immersed in black cola, coffee and grape juice. (2) The effect of temperature on the staining susceptibility of the resin composite coated with surface sealants when immersed in black cola, coffee and grape juice.

The null hypothesis: (1) Presence of surface sealant significantly reduces the discolouration of resin composite restorative material when immersed in black cola, coffee and grape juice. (2) Increased temperature significantly increased the discolouration when immersed in black cola, coffee and grape juice.

Materials and Methods

Stainless steel washers 10 mm Ǿ×2mm height were placed on celluloid sheets and used as moulds. Filtek™ Supreme XTE (3M™ ESPE, St. Paul, Mn, USA) universal restorative resin composite (A2 shade) was dispensed into these washers carefully in order to avoid voids. A second celluloid sheet was placed over the washers and packed flat down using a 5 kg weight. Discs were then light cured by a 450 nm blue light (LE Demetron II, Sybron/Kerr; Middleton, USA. Output: 1200 mW/cm^2) for 30 seconds on both sides. On one side of each specimen, an unfilled low viscosity resin based surface sealant (Fortify™ Plus, Bisco, Inc., Schaumburg, Illinois, USA) was applied with a micro-brush and light-cured for 10 seconds. The other side of each disc was left as the unsealed surface. All discs were then stored for 24 hours in a humidified incubator at 37.5°C and 95±5 % relative humidity.

The forty resin composite discs were randomly allocated to 6 test groups and 2 control groups, groups were black Cola®, (20 ml, pH 2.36, Coca Cola™, Amatil, Australia) stored in either 4°C (n=5) or 37°C (n=5), coffee (20 ml, pH 4.77, Nescafé Gold Dark 100% Arabica Beans, Nestlé Professional, Australia) at 4°C (n=5) or and 37°C (n=5), grape juice (20 ml, pH 3.24, Ariel Rouge® Premium De-alcoholised Wine, Organic Wine Pty Ltd, Australia), 4°C (n=5) or 37°C (n=5), control (20 ml, pH 6.62, distilled water) 4°C (n=5) or 37°C (n=5). All specimens were stored in their respective solutions and temperatures in an environment where all sources of light were excluded for the length of the experiment. The resin composite discs were removed briefly from their respective staining solutions at days 7, 14 and 28, rinsed with deionized water (Milli-Q, Merck Millipore, Darmstadt, Germany) and pat dried with a cotton pad. Digital images of both the sealed and unsealed surfaces of each disc were obtained at days 0 (baseline), 7, 14 and 28 using a Nikon® D3000 camera under the same ambient controlled light environment (Figure 1). All photographs were analysed in Adobe Photoshop® 5.0 (Adobe Systems, Mountain View, CA) using a standardised internal feature of CIE L*a*b profile conversion and any colour difference (ΔE) was generated using the formulae:

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

Results were then analysed by 2-way ANOVA using GenStat® (14th Edition, VSN Int. Ltd., Hemel Hempstead, UK) and presented as mean±SD. An alpha value of 0.05 was considered to be statistically significant.

Results

A total of forty specimens were evaluated for colour alteration (ΔE). After 28 days of immersion, the maximum ΔE was observed in the sealed grape juice

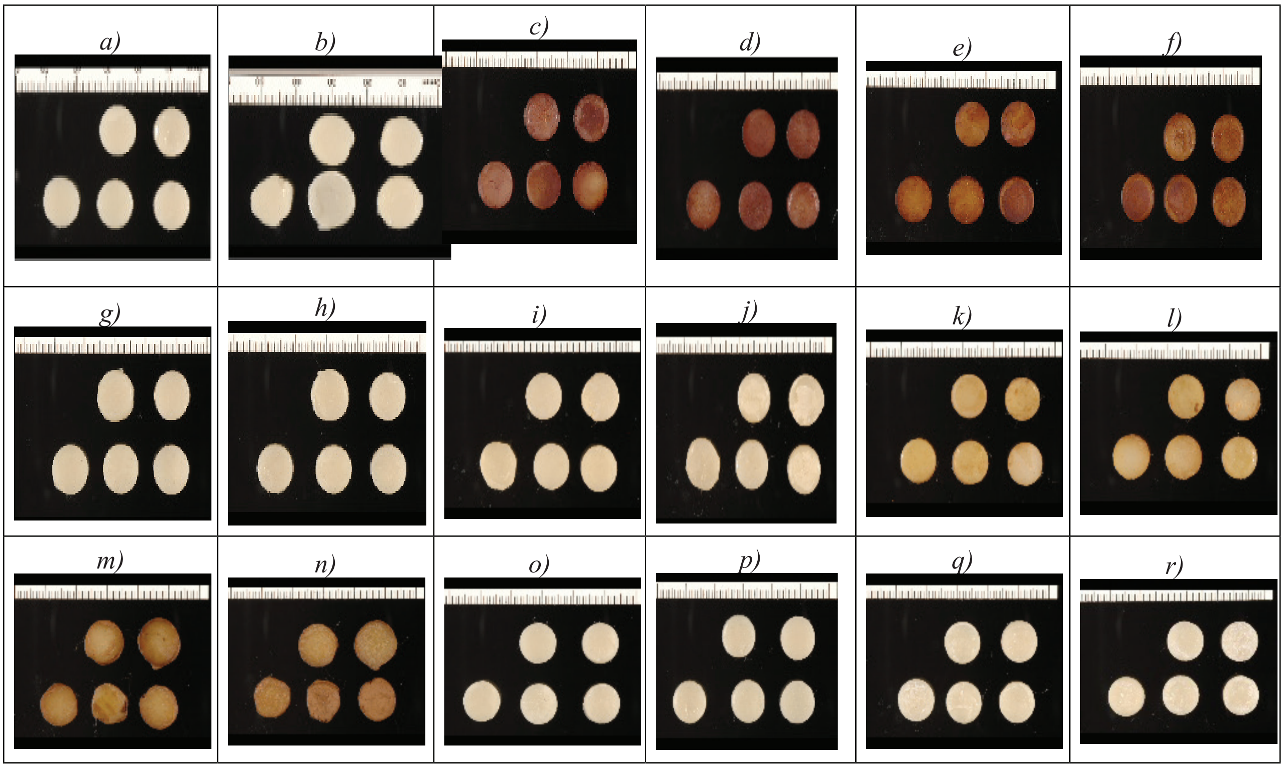

Figure 1: Day 0 and day 28 of resin composite discs, sealed and non-sealed.
a) Day 0, 4°C sealed b) Day 0, 37°C non-sealed, c) Day 28 Grape juice 4°C sealed, d) Day 28 Grape juice 4°C non-sealed, e) Day 28 Grape juice 37°C sealed, f) Day 28 Grape Juice 37°C non-sealed, g) Day 28 Black Cola 4°C sealed, h) Day 28 Black Cola 4°C non-sealed, i) Day 28 Black Cola 37°C sealed, j) Day 28 Black Cola 37°C non-sealed, k) Day 28 Coffee 4°C sealed, l) Day 28 Coffee 4°C non-sealed, m) Day 28 Coffee 37°C sealed, n) Day 28 Coffee 37°C non-sealed, o) Day 28 Control 4°C sealed, p) Day 28 Control 4°C non-sealed, q) Day 28 Control 37°C sealed, r) Day 28 Control 37°C non-sealed.

group at 37°C (ΔE=58.42±3.97, Table 1 & Figure 1), and the minimum ΔE in the non-sealed black cola test group at 4°C (ΔE=0.9±0.9, Table 1 & Figure 1).

Effect of Surface Sealant

Two-way ANOVA showed significant interactions between the solution and the presence of surface sealant (P=0.002). The presence of surface sealants promoted a significantly higher discolouration in the sealed coffee group compared with the non-sealed coffee group (mean ΔE=3.02, 95% CI: 0.13–5.90). On the contrary, the surface sealant produced a lower ΔE observed in the sealed grape juice group as compared to the non-sealed grape juice group at 4°C (mean ΔE=-3.71, 95% CI: -6.59–-0.83). In other words, the surface sealants increased staining of the resin composite when soaked in coffee solutions but reduced staining in grape juice.

No significant effects were observed in the black cola or control test group (Figures 2 & 3).

Table 1: Mean ΔE values (±SD) of sealed and non- sealed specimens of all groups.

Time (Days)		7	14	28	7	14	28
			Non-sealed				
Drink solutions	Temperature	4◦C			37◦C		
Coffee		10.6±4.2	22.5±7.9	22.5±5.4[a]	30.9±6.0	36.2±4.3	37.3±5.6[a,b]
Black Cola		2.0±0.6	1.2±0.6	0.9±0.9	5.0±2.4	3.8±1.6	2.8±1.4
Grape Juice		33.1±11.8	50.3±4.8	53.1±5.0[a]	40.9±5.5	57.4±3.9	57.0±5.9[a,b]
Distilled Water		2.6±1.7	3.5±1.4	2.3±1.4	2.4±0.7	3.4±1.0	4.1±2.3
			Sealed				
	Temperature	4◦C			37◦C		
Coffee		16.3±3.1	26.6±2.4	27.3±7.5**,***,a	29.7±8.8	38.4±6.1	39.8±5.5**,***,a,b
Black Cola		2.5±1.1	1.6±1.2	2.3±1.0	3.5±2.4	4.9±1.3	4.7±2.4
Grape Juice		28.3±7.5	41.9±8.6	52.0±6.3**,***,a	35.1±16.7	53.8±2.8	58.4±4.0**,***,a,b
Distilled Water		1.3±0.3	1.8±1.1	1.3±1.5	2.4±0.7	2.7±1.9	3.1±1.2

denotes P<0.01 when compared to its non-sealed counterpart, * denotes P<0.001 when compared to baseline (day 0) in sealed group, [a] denotes a significant increase in ΔE as compared to baseline (day 0) in non-sealed groups. [b] denotes a significant increase in discolouration as compared to 4◦C.

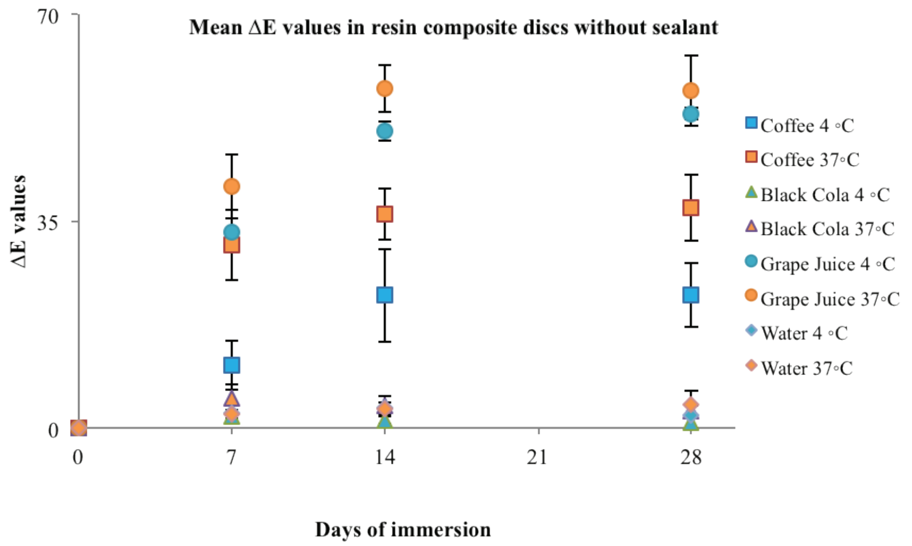

Figure 2: Mean ΔE in resin composite discs without surface sealant immersed in coffee, grape juice, black cola, and control group for 28 days. Data were recorded at days 0 (baseline), 7, 14 and 28. Data are presented as means±SD.

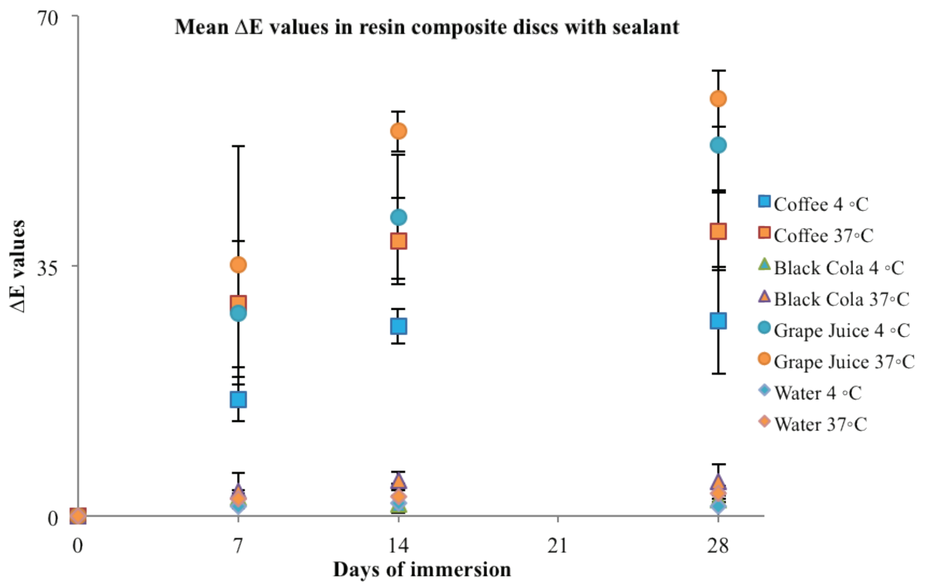

Figure 3: Mean ΔE in resin composite discs with surface sealant immersed in coffee, grape juice, black cola, and control group for 28 days. Data were recorded at days 0 (baseline), 7, 14 and 28. Data are presented as means±SD.

Effect of Temperature

There were significant interactions between the storage solution and temperature for ΔE values compared to baseline ($P<0.001$). A warmer storage temperature of 37°C compared with 4°C induced higher ΔE values for all test solutions. Significant differences were observed in both the sealed and non-sealed coffee groups (mean ΔE=14.42, 95% CI: 10.97–17.87) and grape juice groups (mean ΔE=7.36, 95% CI: 3.91–10.81) compared to their corresponding 4°C groups ($P<0.001$, Figures 2 & 3). There were no significant differences in ΔE for both black cola and control groups at both temperatures.

Effect of Time

An effect of time on ΔE was evident in both the sealed and non-sealed coffee and grape juice groups. At both temperatures, there was a significant increase in ΔE in both coffee groups (mean ΔE=9.86, 95% CI: 6.48–13.24) and both grape juice groups (mean ΔE=20.79, 95% CI: 17.41–24.17) at 28 days of immersion, compared to baseline ($P<0.001$, Figures 1 & 2). There was no difference in discolouration amongst both the black cola groups and control groups over time (Figures 2 & 3).

Discussion

A previous 5 year clinical study has shown that unfilled resins placed on the surface of restorations were able to increase abrasion resistance and improve the marginal integrity of restorations, thus potentially reducing staining in resin composite restorations [4,6]. In addition, it has been shown that surface sealants can improve the surface texture, staining resistance and optical properties of resin composites [4,6,9] . The surface sealants were thought to fill microstructural defects, decreasing the surface porosity and voids plus providing a more thoroughly cured surface [4,6,9,10].

The current study demonstrates that in both the 4°C and 37°C coffee test groups, resin composite discs sealed with a surface sealant showed higher levels of discolouration than its unsealed counterpart. The phenomenon was similar to those reported previously [1,2,19]. It may be due to the surface adsorption and absorption properties of surface sealant readily up-taking the astringent coffee pigments within the micro-pits and porosities present in the sealant material [19]. It is interesting to note that the greatest rate of discolouration for discs immersed in coffee was seen between baseline and day 7. Based on the results of this study, the discolouration in this test group appeared to plateau at approximately two weeks (Figure 1 & 2).

The greatest level of discolouration was observed in the grape juice test group at day 28 ($P<0.001$). This result is similar to findings in previous studies [18]. Dietschi *et al.* [21] showed that staining maybe associated with the water sorption process. Water particles have the potential to act as carriers for staining agents in the sorption process [22], hence contributing to the staining adsorption that usually occurs within the first week [21]. Furthermore, the staining effect of grape juice may also be due to a combined effect of dark pigments of the solution and the low pH (pH=4.2). Dark pigments have been shown to cause drastic discolouration in other studies [15,18]. The acids present in grape juice are mainly tartaric, malic and citric acid [23]. These acids are different to the ortho-phosphoric acid present in black cola, thus may elicit different effects on resin composite disc surfaces comparatively [24]. It is also interesting to note that till the current date, the staining effect of flavonoid pigments present in grape juice and red wine have not been thoroughly explored and warrant further research. Furthermore, previous studies have shown that solutions such as grape juice (pH=3.24) can cause greater staining than lower pH black cola solutions (pH=2.36) [18]. However, this effect was not observed in the higher pH coffee solution (pH=4.77). The acidic nature of grape juice when combined with the presence of microleakage, dark pigments and flavonoid induced staining may further result in chemical degradation of the organic matrix of the resin composite discs. This may also contribute to the discolouration effect observed in the grape juice test groups, which may be absent in the coffee solution [16,18]. Similarly, other studies [11,12,13-17] also had concluded that diet constituents (including grape juice) have a significant staining effect on resin composite material. Further research is required to explore the staining effect of each individual staining agent.

Within the grape juice group it was also observed that 37°C results in a more intense colour change compared to the 4°C discs ($P<0.001$). Catelan *et al.* and Domingos *et al.* [11,18] have also demonstrated that long term high temperature exposure of resin composite discs *in vitro* can increase staining. It is thought that higher temperatures can degrade the organic matrix, induce microleakage, create micro-cracks and collect voids in the composite material, hence increasing the effect of staining [8]. The degree of discolouration in the grape juice discs also intensified over each interval in the 28 day period at both 4°C and 37°C (See Table 1). A significant association ($P<0.001$) was found between ΔE at each interval (7 days, 14 days, 21 days, 28 days). The greatest change in ΔE was between 0 and day 7, with a plateau after day 14 (Figure 1 & 2). These observations suggest that time may be an important consideration in staining of resin composite materials and may need to be factored in with future studies investigating staining of dental materials. Clinically, this also reinforces patient review protocols on all existing composite restorations, particularly in grape juice drinkers, as over time gradual discolouration may compromise the aesthetic value of existing restorations.

Interestingly, ΔE was significantly reduced on sealed discs compared with non-sealed discs within the grape juice test group, at both 4°C and 37°C. Although a reduction in grape juice discs were observed, there was little effect in black cola and the control groups. This phenomenon may be explained by the unique composition of grape juice, in contrast with black cola and coffee as previously mentioned. This may reveal that a certain component of the sealant is resistant to a unique discolouring agent present in the grape juice only. This serves as a basis for future investigations into grape juice constituents and their reduced affinity for unfilled, low viscosity surface sealants.

A decrease in ΔE was observed for the resin composite discs immersed in 4°C black cola in both the sealed and non-sealed groups (Table 1, Figure 1 & 2). This yellow to brown staining change is consistent with Catelan *et al.* [18] study which demonstrated that the caramel colour present in black cola was the primary cause, though when compared to other beverages such as coffee, had decreased levels of colourant resulting in decreased staining potential [15, 23]. Black cola has a low pH 2.36 due to the presence of orthophosphoric acid as well as the lime and lemon used in flavouring the beverage [24]. It has been shown that when enamel and dentine are exposed to a pH below 5.5 and 6.5 respectively, will result in mineral loss. This is also affected by the temperature of the solution and whether carbon dioxide is still present as carbonic acid is formed.

One of the limitations of this study revolves around the design of the resin composite discs. To improve the design, whole single resin composite discs should either have sealant placed or not placed so that specific sites can be examined for the effects of staining rather than one side of a same single disc. Another limitation is the clinical relevance of immersing resin composite discs in the same solution for 28 days. Although these laboratory test conditions assist in accelerating the staining effects of the solutions, clinical studies taking into account the presence of saliva and thermal cycling would provide further clinical information.

Conclusion

This current study demonstrates that surface sealants have a limited secondary role in preventing staining in certain beverages such as grape juice. A lower temperature reduces staining effect when resin composite discs were exposed to both coffee and grape juice for long periods of time. Solutions/drinks held in mouth for a longer period of time increases its temperature resulting in potentially higher staining than solutions/drinks that are consumed without holding in mouth. Time is also directly associated to increase in staining. Upon consumption of coloured beverages, it is advised to consume colder drinks in a shorter time frame to decrease the exposure of teeth and restorations with staining beverages. Clinically, in the mouth there will be saliva present, which may aid buffering of the acid and increase clearance of the fluids out of the oral cavity. The effects of saliva were not investigated in the current study; further research is required to explore these effects.

Acknowledgements

The authors would like to thank Associate Professor Graham Hepworth, for his help on statistical analysis.

Conflict of Interest: None declared.

References

1. Christensen GJ. Restoration longevity versus esthetics: a dilemma for dentists and patients. J Am Dent Assoc. 2011;142:1194-6.
2. Malhotra N, Shenoy RP, Acharya S, Shenoy R, Mayya S. Effect of three indigenous food stains on resin-based, microhybrid-, and nanocomposites. J Esthet Restor Dent. 2011;23:250-7.
3. Rutkunas V, Sabaliauskas V, Mizutani H. Effects of different food colorants and polishing techniques on color stability of provisional prosthetic materials. Dent Mater J. 2010;29:167-76.
4. Bertrand MF, Leforestier E, Muller M, Lupi-Pegurier L, Bolla M. Effect of surface penetrating sealant on surface texture and microhardness of composite resins. J Biomed Mater Res. 2000;53:658-63.
5. Zimmerli B, Strub M, Jeger F, Stadler O, Lussi A. Composite materials: composition, properties and clinical applications. A literature review. Schweiz Monatsschr Zahnmed. 2010;120:972-86.
6. Ferracane JL, Condon JR, Mitchem JC. Evaluation of subsurface defects created during the finishing of composites. J Dent Res. 1992;71:1628-32.
7. Lee YK, Powers JM. Combined effects of staining substances on resin composites before and after surface sealant application. J Mater Sci Mater Med. 2007;18:685-91.
8. Delfino CS, Duarte S, Jr. Effect of the composite surface sealant application moment on marginal sealing of compactable composite resin restoration. J Mater Sci Mater Med. 2007;18:2257-61.
9. Doray PG, Eldiwany MS, Powers JM. Effect of resin surface sealers on improvement of stain resistance for a composite provisional material. J Esthet Restor Dent. 2003;15:244-9; discussion 9-50.
10. Soelberg KB, Nicholson RJ, Kempler D, Leung R. Effects of abrasion on glaze coating materials. Dent Surv. 1977;53:60-4.
11. Domingos PA, Garcia PP, Oliveira AL, Palma-Dibb RG. Composite resin color stability: influence of light sources and immersion media. J Appl Oral Sci. 2011;19:204-11.
12. Garcia ER, Santos PAD, Campos JADB, Dibb RGP. Influence of Surface Sealant on the Translucency of Composite Resin: Effect of Immersion Time and Immersion Media. Mat Res. 2008;11:193-7.
13. Ertas E, Guler AU, Yucel AC, Koprulu H, Guler E. Color stability of resin composites after immersion in different drinks. Dent Mater J. 2006;25:371-6.
14. Fontes ST, Fernandez MR, de Moura CM, Meireles SS. Color stability of a nanofill composite: effect of different immersion media. J Appl Oral Sci. 2009;17:388-91.
15. Patel SB, Gordan VV, Barrett AA, Shen C. The effect of surface finishing and storage solutions on the color stability of resin-based composites. J Am Dent Assoc. 2004;135:587-94; quiz 654.
16. Tunc ES, Bayrak S, Guler AU, Tuloglu N. The effects of children's drinks on the color stability of various restorative materials. J Clin Pediatr Dent. 2009;34:147-50.
17. Yazici AR, Celik C, Dayangac B, Ozgunaltay G. The effect of curing units and staining solutions on the color stability of resin composites. Oper Dent. 2007;32:616-22.
18. Catelan A, Briso AL, Sundfeld RH, Goiato MC, dos Santos PH. Color stability of sealed composite

resin restorative materials after ultraviolet artificial aging and immersion in staining solutions. J Prosthet Dent. 2011;105:236-41.
19. Stober T, Gilde H, Lenz P. Color stability of highly filled composite resin materials for facings. Dent Mater. 2001;17:87-94.
20. Schulze KA, Marshall SJ, Gansky SA, Marshall GW. Color stability and hardness in dental composites after accelerated aging. Dent Mater. 2003;19:612-9.
21. Dietschi D, Campanile G, Holz J, Meyer JM. Comparison of the color stability of ten new-generation composites: an in vitro study. Dent Mater. 1994; 10:353-62.
22. Kupina SP, CA; Gannotti, JL. Determination of Tartaric, Malic, and Citric Acids in Grape Juice and Wine Using Gradient Ion Chromatography. Am J Enol Vitic. 1991;42:1-5.
23. Sajewicz E. Tribological behaviour of human enamel in red wine and apple juice environments. Wear. 2007;262:308-15.
24. Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent. 2005;33:389-98.
25. Walsh LJ. Lifestyle impacts on oral health. In Mount GJ, Hume WR. Preservation and restoration of tooth structure 2nd edition. Brisbane: Knowledge Books and Software; 2005.