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DIFFUSION DYNAMICS OF THREE COMPOSITE RESIN EXPOSED TO VARIOUS MEANS PRESENT IN DAILY LIFE OF PATIENTS

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ABSTRACT

The aim of this study was to evaluate the effect of exposed to differents means on water sorption and solubility of three composite resin. Specimens of each composite were andomly divided in 12 groups (n=10 per group): G1 (Control): no agents; G2: cigarette smoke; G3: coffee beverage; G4: wine beverage; G5: essential oils mouthrinse; G6: smoke/coffee; G7: smoke/wine; G8 smoke/mouthrinse; G9: smoke/coffee/mouthrinse; G10: smoke/wine/mouthrinse; G11: coffee/mouthrinse; G12 wine/mouthrinse, during 28 days. For evaluation of sorption and solubility, the specimens were stored in a laboratory desiccator until the attainment of constant initial mass (M-1). After exposition to the differents means, all specimens were placed in distilled water and reweighed (M-2) and stored again in the desiccator for constant mass evaluation (M-3). The results showed higher values of water sorption for Filtek Z350 XT (3M/ESPE) brand, whereas the solubility was most significant for IPS Empress Direct (IvoclarVivadent) when exposed to the association of smoke, coffee and mouthrinse (G9). Exposure to coffee and mouthrinse (G11) increased significantly sorption; however the exposure to coffee and its associations showed less solubility for all tested composite resins. It can be concluded that differents agents commonly used by patients can interfere in the diffusion process.

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INTRODUCTION

The use of composite resins is widely spread out in restorative dentistry due to its excellent aesthetic properties and conservative approach for its application (Ardu *et al.* 2010, Kim *et al.*2007). However, the humidity of oral environment is very challenging to composite resin restorations. Absorption of water and other substances by resin restorations can lead to failure and restoration replacement (Ertas *et al.*2006, Topcu*et al.*2009). Composite resins suffer hygroscopic expansion by absorbing the water present in saliva, beverages and certain solid food. This volumetric challenge promotes physical and chemical modifications i.e. plasticization, oxidation and hydrolysis that may compromise the longevity of composite resin restorations (Anfe *et al*. 2011, Berguer *et al.* 2009, Silva *et al.* 2008, Qahtani *et al.* 2012).

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Two mechanisms may occur: (1) the sorption of water that leads to volume increase, and (2) the solubility or leach of resin components (i.e. loading particles and residual monomers) (Almeida *et al.* 2010) that lead to a subsequent reduction in the mass of composite resins. Insofar, these deleterious effects of resin structure impact its clinical performance and consequently the durability of aesthetic restorations (Anfe *et al*. 2011, Silva *et al.* 2008, Ferracane *et al.* 2006). As a matter of fact, the direct contact of restorative materials with colored agents such as cigarettes, beverages, and mouthrinse can disrupt its aesthetic and physical properties (i.e. micro-hardness, surface roughness, translucence, among others) (Festucia *et al.* 2012, Barutcigil *et al.* 2012, Alandia-Roman *et al.* 2013). The consequences of such damages in the restorative materials depend on the intrinsic characteristics of each composite, chemical composition, capacity to absorb liquids, the degree of conversion of monomers in polymers, and extrinsic factors such as the restoration surface quality and pigment retention from diet (Tantanuch *et al.* 2016). In dentistry, most of the studies on smoking are related to their systemic effects (Johnson *et al.* 2007, Winn *et al.*2001), such as cancer, periodontal diseases, delay in healing process, lower rates of osseointegration related to dental implants, (Banoczy *et al.*2004, Nogueira-Filho *et al.* 2007, Sreedevi *et al.* 2012, Ponnaiyan *et al.,* 2017). However, the consequences of smoking in dental treatment can go beyond its systemic action, it is related to patient's aging [21] and interaction with composite resins (Mathias *et al*. 2010, Mathias *et al.* 2011, Mathias *et al.* 2014). The results of these surveys can work as an important strategy in anti-smoking campaigns (Sood *et al.* 2014, Nazir *et al.* 2017). Thus, this study aimed to evaluate the diffusion dynamics of three commercial composite resin brands exposed to differents means and its effects on the physical properties. The null hypothesis is that colored agents alone or combination does not interfere with the sorption of water and solubility of all tested composite resins.

MATERIAL AND METHODS

Confection of the specimens

For this work, specimens were confectioned from three commercial composite resins (A3 enamel) were used: (1) Filtek Z350XT (3M/ESPE; nanoparticles resin), (2) Opallis (FGM; nanohybrid resin) and (3) IPS Empress Direct (Ivoclar Vivadent; nanohybrid resin). The composition and technical specifications of all tested composite resins are described in Table 1.

weight of 500mg on top to promote 30 sec of material excess draining. After the removal of the weight, the composite was photo activated through the strip for 40 seconds (LED, Radii Cal SDI), with an intensity of light of 1,200 mW/cm. The colored agents selected for this study were: red wine (Mioranza, Flores da Cunha, Brazil), coffee (Marata, Itaporanga D'Ajuda, Brazil), mouthrinse (Listerine®, São José dos Campos, Brazil), and cigarette (Hollywood®, São Paulo, Brazil) (Table 2). Prepared specimens of each resin brand were divided into 12 groups (n=10) and exposed to selected colored agents, during 4 weeks:

G1. Control (no colored agents)
G2. Smoke simulation
G3. Immersion in coffee
G4. Immersion in red wine
G5. Immersion in mouthrinse (Listerine®)
G6. Simulation of smoke and immersion in coffee
G7. Simulation of smoke and immersion in red wine
G8. Simulation of smoke and immersion in mouthrinse (Listerine®)
G9. Simulation of smoke, immersion in coffee and mouthrinse (Listerine®)
G10. Simulation of smoke, immersion in red wine and mouthrinse (Listerine®)
G 11. Immersion in coffee and mouthrinse (Listerine®)
G12. Immersion in red wine and mouthrinse (Listerine®)

Table 1. Characteristics of tested commercial composite resins

MATERIAL	CLASSIFICATION	COMPOSITION
Filtek Z350 XT (3M Espe, Lot 1226800371)	Nanoparticle	Matrix: bis-GMA, UDMA, TEGDMA, bis-EMA. Combination of non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated /non-aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler: 20 nm silica and 4 to 11 nm zirconia particles 63.3% by volume 78.5% by weight
IPS Empress Direct (IvoclarVivadent AG, Lot R49396)	Microhybrid	Matrix: bis-GMA, UDMA, Barium dimethacrylate glass filler, mixed oxides. Combination of glass barium, ytterbium trifluoride, highly dispersed silicon dioxide, copolymer. 40 nm and 3000 nm (average of 500 nm) 52 to 59% by volume 75 to 79% by weight
Opallis (FGM, Lot 070312)	Microhybrid	Matrix: bis-GMA; bis-EMA; TEGDMA, UDMA. Combination of barium-aluminum glass, silicon silicate and silicon dioxide nanoparticles. 0 nm to 3 microns (average of 0.5 microns) 57 to 58% by volume 78.5 to 79.8% by weight

Abbreviations: Bis-GMA, iso-propyliden-bis (2(3)-hydroxy-3(2)-4(phenoxy)propyl)-bis (methacrylate) or bisphenol A diglycidyl methacrylate; UDMA, diurethanedimethacrylate; TEGDMA, triethylene glycol dimethacrylate.; Bis-EMA, bisphenol A diglycidyl methacrylate ethoxylated.

Table 2. Composition of tested agents

MATERIAL	COMPOSITION
Mioranza Red wine (BebidasMioranza Ltda., Lot 734)	Fermented from Isabel and Bordo grapes, sugar and conservative. Alcoholic graduation 10.4% Vol, pH 3.3
Coffee (MARATÁ Tradicional, IndustriasAlimentíciasMaratá Ltda., Lot S1014M)	100% coffee 5g/ 150ml water
Listerine® Mouthrinse (Jonhson&Jonhson, Lot. N 0850WL13/ N 1610B07)	Thymol, Eucalyptol, Methyl Salicylate, Menthol, Water, Alcohol (21.6%), Sorbitol, Flavoring Agent, Poloxamer 407, Benzoic Acid, Saccharin Sodium, Sodium Benzoate, FD & C: Blue
Hollywood® Cigarettes (Souza Cruz BAT, Lot 31OUT13CI)	10mg Tar, 0.8mg Nicotine, 10mg Carbon monoxide

For each brand, 120 bodies were confectioned, using stainless steel matrix in the dimensions of 6mm of diameter and 1.5mm of thickness. The matrix was filled with a single increment of each composite that was covered with a polyester strip and a

Cigarette exposure

The cigarette smoking simulation was modified from Le Mesurier *et al.* (1981) (Le Mesurier *et al.* 1981). Briefly, an acrylic box with two linked chambers was used. The first chamber stored lighted cigarettes with the aid of a blowpipe. Air is pumped towards chamber 2 through an orifice that takes smokes through the filter of cigarettes for the second chamber, in which the specimens are placed. In the second chamber there is has another orifice for air outflow. Specimens were exposed to the smoke of 20 cigarettes per day (10 cigarettes per 8 minutes, 2 times per day) for a period of 28 days (Nociti *et al*., 2002). During the exposure breaks, all specimens were kept in distilled water 37^{o}C.

Liquids exposure

The individual exposure to coffee, red wine and mouthrinse were accomplished with the immersion of each specimen in 2ml of each respective solution. For the groups exposed to coffee and red wine, the period of immersion was 3 min, and for the groups exposed to mouthrinse, the period of immersion was 1 min. The exposures were performed twice a day, during the period of 4 consecutive weeks. For the groups that represent associations of the studied colored agents, the exposure was done as follows: G6/G7/G8- smokes exposure followed by immersion in one of the solutions (coffee, red wine or Listerine®) respectively; G9/G10- smoke exposure followed by immersion in coffee or red wine followed by immersion in Listerine®; and G11/G12- immersion in coffee or red wine followed by immersion in Listerine®. Specimens were washed in distilled water and stored in containers filled with distilled water at 37^{o}C. Control group specimens of each composite resin were stored per 4 weeks in distilled water. The solution was changed daily.

Sorption of water and Solubility

All specimens were stored in a laboratory desiccator until the attainment of constant initial mass (M-1) determined by a precision analytical scale (Shimadzu, mod. AUW220D). After exposition to the colored agents, all specimens were placed in distilled water and reweighed. After the 4 weeks, the saturated mass of each specimen was measured (M-2). A new cycle at the desiccator was performed to determine the values of constant mass in each specimen for all groups (M-3). The solubility of each specimen was represented by the difference between initial dry mass (M-1) and final dry mass (M-3) divided by its volume (m1-m3/volume). Sorption was measured by the difference between saturated mass (M-2) and the final dry mass (M-3) divided by its volume (m2-m3/volume). The respective values (µg/mm3) were analyzed statistically (ANOVA and Tukey tests) with a level of significance of 5%.

RESULTS

Sorption: Specimens prepared with Filtek Z350 XT resin showed significant differences on sorption when exposed to some of the differents means (Table 3). Exposure to mouthrinse increased the values of sorption only for the control group, however, mouthrinse and cigarette smoke exposure did not affect sorption in the Filtek Z350 XT specimens ($p>0.05$). The group immersed in coffee presented higher values of sorption when compared to control ($p>0.05$), while the group immersed in red wine presented intermediate values but without significant difference ($p>0.05$). IPS Empress Direct specimens presented significant differences in sorption only when smoke and mouthrinse where present simultaneously (Table 4). Coffee exposure presented higher values of sorption followed by the red wine group and to control ($p<0.05$).

Table 3. Means and standard deviation (SD) from Filtek Z350 sorption (µg/mm^3)

SORPTION		Mean/SD	Mean/SD
		No Smoke	Smoke
No Listerine®	No Colored agents	30.94 (1.81) Ba	32.11 (1.58) Ba
	Wine	32.01 (2.61)ABa	33.24 (2.13) Aba
	Coffee	33.92 (1.22) Aa	33.28 (1.26) Aa
Listerine®	No Colored agents	33.57 (1.64) Aa*	33.81 (0.94) Aa
	Wine	32.28 (1.07) Aa	33.94 (1.28) Aa
	Coffee	33.96 (0.53) Aa	34.56 (1.94) Aa

*Statistical significance: interaction colored agents x Listerine® ($p = 0.03$)
Means followed by distinct letters / symbols represent statistical significance (3-way ANOVA / Tukey, alpha = 5%). Uppercase compare levels of colored agents within the smoke / Listerine® factors; lowercase compare levels of smoke within the colored agents / Listerine® factors; asterisks compare Listerine® levels within the colored agents / smoke factors.

Table 4. Means and standard deviation (SD) from IPS Empress Direct sorption (µg/mm^3)

SORPTION		Mean/SD	Mean/SD
		No Smoke	Smoke
No Listerine®	No Colored agents	16.53 (0.94) Aa	16.84 (0.80) Aa
	Wine	17.13 (1.13) Aa	17.47 (0.97) Aa
	Coffee	16.95 (1.74) Aa	17.21 (1.61) Aa
Listerine®	No Colored agents	16.01 (0.70) Aa	16.37 (1.21) Ba
	Wine	16.87 (0.92) Aa	17.03 (0.93) Ba
	Coffee	16.68 (1.53) Ab	19.54 (0.98) Aa*

*Statistical significance: interaction colored agents x smoke x Listerine® ($p = 0.001$)
Means followed by distinct letters / symbols represent statistical significance (3-way ANOVA / Tukey, alpha = 5%). Uppercase compare levels of pigment within the smoke / Listerine® factors; lowercase compare levels of smoke within the colored agents / Listerine® factors; asterisks compare Listerine® levels within the colored agents / smoke factors.

The sorption of water in specimens prepared with Opallis composite resin was not affected by smoke and mouthrinse exposure ($p>0.05$). Coffee and red wine groups presented similar values for sorption when compared to control group (Table 5).

Table 5. Means and standard deviation (SD) from Opallis sorption (µg/mm^3)

SORPTION		Mean/SD	Mean/SD
		No Smoke	Smoke
No Listerine®	No Colored agents	18.45 (1.39) Ba	18.78 (1.53) Ba
	Wine	21.05 (1.52) Aa	21.17 (1.12) Aa
	Coffee	20.54 (1.28) Aa	20.16 (1.04) Aa
Listerine®	No Colored agents	18.70 (1.73) Ba	18.95 (1.11) Ba
	Wine	19.31 (1.69) Aa	21.47 (1.54) Aa
	Coffee	19.59 (1.53) Aa	20.02 (1.08) Aa

*Statistical significance: colored agents (p = 0.0001)
Means followed by distinct letters / symbols represent statistical significance (3-way ANOVA / Tukey, alpha = 5%). Uppercase compare levels of colored agents within the smoke / Listerine® factors; lowercase compare levels of smoke within the colored agents / Listerine® factors; Asterisks compare levels of Listerine® within the colored agents / smoke factors.

Table 6. Means and standard deviation (SD) from Filtek Z350 XT solubility (µg/mm^3)

SOLUBILITY		Mean/SD	Mean/SD
		No Smoke	Smoke
No Listerine®	No Colored agents	2.72 (0.50) Aa	2.40 (0.32) Aa
	Wine	2.64 (0.63) Aa	2.51 (1.44) Aa
	Coffee	1.51 (0.59) Ba	1.84 (1.25) Ba
Listerine®	No Colored agents	2.36 (0.74) Aa	2.40 (0.75) Aa
	Wine	2.91 (1.01) Aa	2.74 (1.03) Aa
	Coffee	1.72 (1.10) Ba	2.01 (0.58) Ba

*Statistical significance: colored agents factor (p = 0.0001)
Means followed by distinct letters / symbols represent statistical significance (3-way ANOVA / Tukey, alpha = 5%). Uppercase compare levels of colored agents within the smoke / Listerine® factors; lowercase compare levels of smoke within the colored agents / Listerine® factors; asterisks compare Listerine® levels within the colored agents / smoke factors.

Table 7. Means and standard deviation (SD) from IPS Empress Direct solubility (µg/mm^3)

SOLUBILITY		Mean/SD	Mean/SD
		No Smoke	Smoke
No Listerine®	No Colored agents	0.75 (0.61) Ba	1.32 (0.86) Ba
	Wine	1.81 (0.52) Ab	2.74 (0.42) Aa
	Coffee	1.07 (1.75) Ba	1.59 (0.59) Ba
Listerine®	No Colored agents	1.39 (0.64) Ba	1.79 (0.95) Ba
	Wine	2.88 (1.06) Aa*	2.24 (1.00) Ba
	Coffee	2.01 (0.31) Bb*	3.10 (0,66) Aa*

*Statistical significance: interaction colored agents x smoke x Listerine® (p = 0.007)
Means followed by distinct letters / symbols represent statistical significance (3-way ANOVA / Tukey, alpha = 5%). Uppercase compare levels of colored agents within the smoke / Listerine® factors; lowercase compare levels of smoke within the colored agents / Listerine® factors; Asterisks compare levels of Listerine within the colored agents / smoke factors.

Table 8. Means and standard deviation (SD) from Opallis solubility (µg/mm^3)

		No Smoke	Smoke
	Wine	2.82 (1.02) Aa	2.86 (0.86) Aa
	Coffee	3.06 (1.90) Aa	2.00 (0.48) Aa
	Wine	3.27 (1.39) Aa	3.60 (0.87) Aa*
	Coffee	2.93 (1.98) Aa	2.82 (0.63) Aa*
Listerine®	No Colored agents	2.00 (1.12) Ba	3.05 (0.45) Ba*
No Listerine®	No Colored agents	2.41 (0.95) Ba	1.89 (0.82) Ba
SOLUBILITY		Mean/SD	Mean/SD

*Statistical significance: smoke interaction x Listerine® (p = 0.02); colored agents factor (p = 0.009)
Means followed by distinct letters / symbols represent statistical significance (3-way ANOVA / Tukey, alpha = 5%). Uppercase compare levels of colored agents within the smoke / Listerine® factors; lowercase compare levels of smoke within the colored agents / Listerine® factors; asterisks compare Listerine® levels within the colored agents / smoke factors.

Solubility

Filtek Z350 XT specimens exposed to coffee and associations presented less mass loss followed by red wine and control groups (p<0.05). Smoke and mouthrinse exposure did not alter resin solubility (Table 6). For IPS Empress Direct specimens, solubility was increased (p<0.05) in the groups exposed to red wine followed by coffee groups and control group (Table 7). The solubility of Opallis specimens was less intense in the control group (p<0.05). The groups exposed to red wine and coffee increased equally mass loss.

Smoke exposure did not promote any changes in solubility of Opallis specimens. On the other hand, the immersion into mouthrinse resulted in an increase of the values of solubility in groups when associated with smoke exposure (Table 8).

DISCUSSION

Patients have satisfactory acceptance to composite resin restorations due to its esthetics and function features in the oral cavity. However, as the oral environment is constantly challenged by external factor some concern may rise on the longevity of these restorations. The present *in vitro* study demonstrated that agents commonly used by patients could alter negatively the diffusion dynamics of composite resin restorations. Interestingly, the agents presented different effects in the sorption of water and in the solubility depending on the brand of each composite resin tested. The International Organization for Standardization in accordance with ISO 4049-2009 (ISO 2009) have established that sorption of water of 40 µg/mm3 and solubility of 7.5 µg/mm3 are considered acceptable for polymer base restorative materials in a period of 7 days of storage in liquid. In the present study, although the specimens have been stored per 4 weeks in liquid, the average values of sorption and solubility for all the evaluated composite resins had not surpassed the refereed average values. Even though the increase of storage time of specimens can increase sorption (Oertengren *et al.* 2001 and Giannini *et al*. 2014). The physical and chemical properties of composite resins are dependent on its organic and inorganic matrices. Although hydrophobicity is a desirable feature, composite resins are able to absorb water in its molecular structure (Tantanuch *et al*. 2014). In the present study, the Filtek Z350 XT and the Opallis resins have similar monomeric composition i.e. Bis-GMA, Bis-EMA, TEGDMA, and UDMA, while the IPS Empress Direct resin has monomers with less hydrophilic characteristics in its matrix composition i.e. Bis-GMA, UDMA, cicloaliphalytic di-methacrylate and Bisphenol-A proxylate di-methacrylate. Sideridou *et al*. (2003) (32)have demonstrated that TEGDMA is the most hydrophilic monomer (70 µg/mm3) followed for the Bis-GMA (34 µg/mm3), UDMA (30 µg/mm3) and Bis-RHEA (20 µg/mm3).

In the present study, the nanoparticle resin Filtek Z350 XT presented the highest values of sorption regardless of the evaluated conditions, when compared to the microhybrid resins IPS Empress Direct and Opallis. Indeed, nanoparticle resins have a larger surface area in relation to its volume with higher silane particle loads and therefore more exposed surface to water. When water enters in contact with the silane, that has hydrophilic groups, it establishes hydrogen bridges increasing significantly sorption (Silva *et al*. 2009, Almeida*et al*. 2010, Karabela & 2008Sideridou, Silva *et al*. 2011). Our group has already shown that constant contact of composite resins to colored agents from diet or oral hygiene can promote resin staining but also diffusion dynamics changes as of water sorption and solubility.

The coffee beverage was able to raise the values of sorption for Filtek Z350 XT and Opallis in the groups G3 and G6 and for IPS Empress Direct in the G9 group. Coffee exposure occurred with the solution in high-temperature (60^{o}C) as well as in prior studies (Domingos*et al*. 2011, Ren *et al*. 2012, Santos *et al*. 2010). High-temperature may have contributed to the increase in water incorporation in the polymeric structure of resins once high-temperature can lead to the expansion of the polymeric net of composite resins favoring the penetration of water. This finding is in accordance with the study of Kim *et al*. (2013) that had observed that high-temperatures (60^{o}C) raised the sorption of water in polymeric materials. Red wine in association with cigarette smoke exposure raised the values of sorption for Opallis resin probably due to the presence of alcohol in red wine. It has been reported that alcohol promotes plasticization on the polymeric matrix of resins leading to the increase of water sorption (Tantanuch *et al*. 2016). According as the exposure of Opallis specimens also to cigarette smoke mainly composed of carbon water, monoxide (CO), carbon dioxide (CO_2) and tar (39) could have increased the observed effect (Sarret *et al*. 2000, Vitória*et al*. 2013, Mathias *et al*. 2014). Cigarette smoke exposure in our study did not modify sorption of water in the evaluated composite resins probably because the specimens were kept in a dry environment during exposure with no contact with water that is essential for the sorption phenomenon. However, the temperature reached in the smoke chamber (38ºC) seems not to be high enough to degrade composite resins. This finding has disagreed to a previous study of our group (Mathias *et al*. 2014), as smoke exposure has shown an increase in the water sorption. In fact, resin specimens were kept in direct contact with water during the smoke exposures favoring changes in the dynamics of sorption.

Mouthrinse exposure in our study only increased sorption values for Filtek Z350 XT resin. As this a nanoparticle resin brand, this could be explained due to the reduced size of load particles (4- 20nm) and greater presence of the union agent silane in its composition. The silane can increase sorption as it creates hydrogen bridges with water that is trapped in the polymeric structure of resin (Silva *et al*. 2011). Moreover, silane also presents great affinity to ethanol that is present elevated amounts in this mouthrinse (Silva *et al*. 2011, Almeida *et al*. 2010, Silva *et al*. 2011). The diffusion dynamics of the studied resins have shown that all resins suffered solubility changes when exposed to the colored agents. The presence of phenolic compounds and the lower pH must have contributed to solubility of the composite resin tested materials (Silva *et al*. 2011). In fact, microhybrid resins have barium glass particles in its inorganic composition that promote greater propensity to the solubility as composite resins presented higher lixiviation of these barium particles (Mathias *et al*. 2014). The reduction in Filtek Z350 XT resin solubility was evident in coffee groups probably due to the decantation of coffee particles on the resin surface. Bagheri *et al*. (2005) have concluded that coffee promotes heavy staining in resins due to the affinity that the coffee stains to its polymeric phase. Maleikipour *et al*. (2012) have related resin color changes to sorption and absorption of yellow compounds of coffee to the composite resin. This evident may explain our results.

The increase in the solubility of composite resins exposed to the studied mouthrinse can be attributed to the deleterious effect of alcohol and its low pH attributed to this mouthrinse. The alcohol acts as solvent of resins by expanding its polymeric matrix making possible the diffusion of oligomers and monomers from resins (Almeida *et al*. 2010). The low pH acts in the polymeric matrices due catalyzes of esters groups of dimetacrylate monomers. The hydrolysis of ester groups leads to the formation of alcohol and carboxylic molecules that enhance polymeric matrix degradation probably due to the reduction of the pH (Almeida *et al*. 2010, Silva *et al*. 2011, Zhang *et al*. 2008). Finally, within the limitations of the present in vitro study, it can be concluded that liquid agents were able to disrupt negatively the diffusion dynamics of three composite resins by altering the sorption of water and resin matrix solubility. Clinical studies are deemed necessary to confirm such results.

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