Original Article

pISSN, eISSN 0125-5614
M Dent J 2023; 43 (Suppl) : S89-S96

Effects of coffee immersion on translucency of high-strength flowable composites under simulated toothbrushing condition: an *in vitro* study

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Objectives: This study aims to evaluate the effects of consuming coffee on the translucency of high-strength flowable composites under simulated toothbrushing conditions.

Materials and Methods: Ninety cylindrical specimens were prepared using three types of resin composites: (1) Filtek™ Z350XT (Z); (2) Filtek™ Supreme Flowable (F); (3) G-ænial™ Universal Injectable (G) (diameter 6 mm, thickness 2 mm). 30 specimens of each type were prepared, which then were divided into three subgroups of ten based on testing conditions: artificial saliva (S), coffee (C), and simulated toothbrushing before immersion in coffee (BC). All groups were immersed in their respective solutions at 37°C for 28 days. Translucency parameter (TP) measurements were performed before and after immersion for 7 days and 28 days (triplicate). Three-way repeated ANOVA and Bonferroni statistical tests were applied to the observation data set.

Results: The mean TP of ZC, ZBC, FC, and FBC groups significantly changed after immersion for 7 days, whereas the other groups showed that the TP did not significantly differ from that before immersion. The mean TP difference of groups ZC and FBC was greater than the perceptibility translucency thresholds at day 7. All subgroups of G had TP within the perceptibility translucency thresholds at 7 and 28 days.

Conclusions: Immersion in coffee had no effect on the translucency of G-ænial™ Universal Injectable after 7 or 28 days. G-ænial™ Universal Injectable were found to have suffered the least change in their translucency compared to Filtek™ Z350XT and Filtek™ Supreme Flowable.

Keywords: high-strength flowable resin composites, simulated toothbrushing condition, translucency stability

How to cite: Tiptimaphan K, Chiaraputt S, Ritthiti A. Effects of coffee immersion on translucency of high-strength flowable composites under simulated toothbrushing condition: an *in vitro* study . M Dent J 2023; 43(Suppl):S89-S96.

Introduction

Resin composites have been developed with both desirable mechanical and physical properties. They are widely used in both anterior and posterior teeth because they can reproduce the natural color of teeth. They can also reduce tooth preparation because they can adhere to the tooth structure through an adhesive system [1]. Resin composites can be classified into 3 types according to their consistency: conventional resin composites, condensable resin composites, and flowable resin composites [2].

Flowable resin composites are conventional resin composites that reduce the filler loading from 50-70% to 37-53% by volume, resulting in a lower viscosity and higher flowability[1, 3], which allows for better adaptability to cavities [4]. However, first-generation flowable resin composites had a relatively low-filler load, resulting in poor mechanical properties [3]. Recently, flowable resin composites have been further developed by increasing their filler load to compensate for this. G-ænial™

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Received: 18 August 2023 **Revised:** 11 September 2023 **Accepted:** 14 September 2023

Universal Injectable is a high-strength flowable resin composite [5], which contains 69% filler load by weight (150 nm barium glass fillers). This material can be used for anterior restorations using injection molding [6].

For anterior restorations, the translucency of restorative materials is an important property because it needs to mimic the optical properties of natural teeth, allowing the underlying tooth structure to be visible and the surrounding tooth structure to reflect light. The translucency of dental materials is normally evaluated using a translucency parameter (TP). The translucency of various resin composites varies according to their shade, thickness, matrix composition, filler particle size and content, and the presence of opacifiers. Translucency stability appears to be correlated with staining, higher staining resulting in less translucency [7].

The translucency stability of resin composites has been investigated in several studies [7, 8]. Translucency can be measured instrumentally [9], allowing for higher validity [10]. The instruments used can include colorimeters, spectrophotometers, and other digital image analysis tools. SpectroShade is a spectrophotometer that analyzes color from digital images combined with an LED spectrophotometer, which offers a reliable way to measure the color properties of dental materials [11].

The CIEL*a*b* color system is used in many research projects because it is based on the human eye's perception of color [12]. L*, a*, and b* values are calculated as TP values. The perceptibility translucency thresholds (TPTab) and the acceptability translucency thresholds (TATab) are at 1.33 and 4.43, respectively [13].

According to previous studies, coffee caused resin composites to suffer the most discoloration [14]. Furthermore, the effect of tooth brushing also affects the quality of the restoration as it significantly increases the surface roughness of the composite material [15], which then affects the color of the resin composite material [16]. Therefore, this study aims to determine the effect of coffee on the translucency of a new type of high-strength flowable resin composite, G-ænial™ Universal Injectable, after simulated brushing.

Materials and Methods

The compositions of resin composite materials used in this study are listed in Table 1. Ninety disc-shaped specimens were prepared using three different resin composite materials (Filtek™ Z350XT (Z), Filtek™ Supreme Flowable (F), and G-ænial™ Universal Injectable (G)). Materials were inserted into a stainless steel mold (6 mm diameter and 2 mm thickness), pressed with a glass slide, and light-activated (Bluephase N, Ivoclar Vivadent, Schaan, Liechtenstein) with a 1,200 mW/cm^2 output irradiance for a total of 40s (20s x 2). The cured specimens were stored for 24 hours in distilled water in a lightproof container at 37 °C. All specimens were polished using a polishing machine with #1,200, #1,500, #2,000, #3,000, #5,000, and #7,000 grit silicon carbide paper. The thickness of the specimens was standardized (2±0.01 mm) using digital calipers. Finally, the specimens were cleaned in an ultrasonic cleaner for 10 minutes.

Specimens were divided into three groups (Z, F, and G) based on material and then subdivided into three subgroups of ten specimens each according to the immersion solution and brushing simulation (artificial saliva (S), coffee (C) and simulated toothbrushing before immersion in coffee (BC)). The translucency parameters were evaluated using a spectrophotometer (SpectroShade Micro II, MHT Optic Research, Niederhasli, Switzerland) under white and black backgrounds. The data was obtained as L*, a*, and b* values in order to calculate the translucency parameter using the equation $TP_{ab} = [(L_b - L_w)^2+(a_b - a_w)^2+(b_b - b_w)^2]^{½}$. The subscripts "b" and "w" refer to color coordinates over the black and the white backgrounds, respectively [13].

Table 1 Products, manufacturers, types of materials and compositions of the materials used in this study.

Product	Manufacturers	Types of Materials	Compositions		Shade	Lot No.
Filtek™ Z350XT	3M ESPE, St. Paul, MN, USA	Nanofill	Bis-GMA, UDMA, Bis-EMA, PEGDMA, TEGDMA	Silica 20 nm, Zirconia 4-11 nm, Zirconia/silica nanocluster 0.6-10 µm (comprised of 20 nm silica and 4 to 11 nm zirconia particles)	78.5%wt 63.3%vol	A2E	NE02935
Filtek™ Supreme Flowable	3M ESPE, St. Paul, MN, USA	Nanofill	Bis-EMA, TEGDMA, Procylat	Ytterbium trifluoride 0.1–5.0 µm, Silica 20,75 nm, Zirconia 5-10 nm, Zirconia/silica nanocluster 0.6-10 µm (comprised of 20 nm silica and 4 to 11 nm zirconia particles)	65%wt 46%vol	A2	NE83495
G-ænial™ Universal Injectable	GC Corp., Tokyo, Japan	Nanohybrid	Bis-EMA, bismethacrylate, UDMA, TEGDMA.	Silica, Ultra-fine barium particles 150 nm	69%wt 50%vol	A2	2112061

For the S and C groups, the specimens were immersed in artificial saliva and ready-to-drink black coffee (Nescafe Black Ice, Nestle, Thailand) respectively. The solution was 10±5 mm above the specimen at 37 °C for 28 days. Solutions were changed and pH was evaluated daily. The average pH of coffee is 6.23. The solutions were put in closed containers to prevent evaporation. TP analyses were performed at Day 7 & Day 28. Before measurement, the specimens were gently rinsed with distilled water, cleaned with an ultrasonic cleaner for 5 minutes then dried with absorbent paper. For the BC groups, a brushing simulation was performed on the top of the specimens by a custom-made toothbrush simulator (Oral-B Vitality, BRAUN, Shanghai, China). The electric toothbrush was fixed into a constructed apparatus that allowed the head of the toothbrush to be aligned parallel to the surface of the specimen. Conditions for simulating brushing have been standardized: the distance between the toothbrush and the surface of the specimens was consistently standardized and the rotation rate was set to 7,600 strokes/mins.

The specimens were subjected to brushing on the top of each specimen for a total of 168 minutes and the toothbrush heads (Oral-B Sensitive Gum Care, BRAUN, Shanghai, China) were replaced for every 5 specimens. The specimens were immersed in ready-to-drink black coffee before being tested for TP as in the ZC, FC, and GC groups (Figure 1).

Statistical Analysis

A Shapiro-Wilk test demonstrated that the data was normally distributed. TP results were evaluated using Three-way repeated ANOVA analysis. Then a Bonferroni test was applied to verify the differences between groups. All analyses were performed at the 5% significance level.

Results

The translucency parameter (TP) of the resin composites before and after immersion for 7 and 28 days are summarized in Table 2. Three-way repeated ANOVA test results of TP are shown in Table 3. Analysis of the data revealed that TP results were affected by material type ($p<0.001$*, F=111.132), intervention ($p<0.001$*, F=26.612), and time ($p<0.001$*, F=95.862). Also, in the interaction of the factors, the material types, intervention and time demonstrated a statistically significant difference ($p=0.021$*, F=3.420). After immersion for 7 and 28 days, the TP of GS, GC, and GBC groups were significantly higher than those of Z and F groups in the same intervention and storage time ($p<0.05$*). The TP of ZC, ZBC, FC, and FBC groups were significantly lower than the ZS and FS groups in the same material and storage time ($p<0.05$*), while there were no significant differences between GS, GC, and GBC in the same material and storage time ($p<0.05$*). After immersion for 7 and 28 days, the mean TP of the ZC, ZBC, FC, and FBC groups changed significantly, whereas the other groups' translucency parameters were not significantly different from before immersion. After the experiment, there was no statistically significant difference in the surface roughness of any of the groups.

Discussion

This study aimed to determine the translucency of G, compared to Z and F. After immersion in coffee at 37 °C for 28 days, the results show that coffee aging did reduce TP values. The mean TP difference from Day 0 to Day 28 of the ZC and FBC groups was greater than 1.33, which is the perceptibility translucency threshold (TPTab) that refers to the smallest translucency difference that can be detected by an observer. In contrast, all G-ænial™ Universal Injectable groups had TP values within perceptibility translucency thresholds.

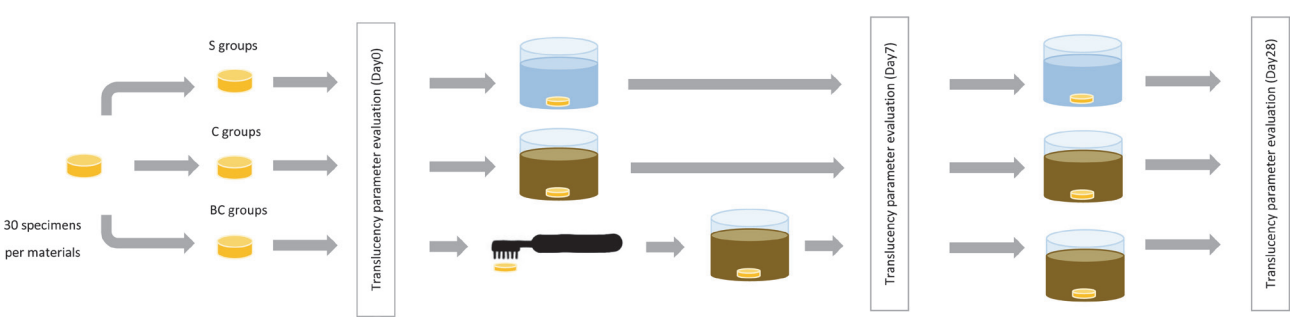


Figure 1 Schematic of the methodology

Table 2 The mean and standard deviation of the translucency parameter (TP) before and after the experiment.

Types of composite / Intervention	Mean TP ± SD		
	Day 0	Day 7	Day 28
Filtek™ Z350XT			
Artificial saliva	4.25 ± 0.31^{Ba}	4.37 ± 0.55^{Ba}	4.21 ± 0.31^{Ba}
Coffee	4.66 ± 0.67^{Aa}	$3.28 \pm 0.61^{Bb*}$	$3.18 \pm 0.47^{Bb*}$
Brushing + Coffee	4.11 ± 0.25^{Ba}	$3.29 \pm 0.46^{Bb*}$	$3.06 \pm 0.37^{Bb*}$
Filtek™ Supreme Flowable			
Artificial saliva	4.40 ± 0.52^{ABa}	3.89 ± 0.41^{Ba}	3.97 ± 0.27^{Ba}
Coffee	4.37 ± 0.66^{Aa}	$3.38 \pm 0.32^{Bb*}$	$3.33 \pm 0.41^{Bb*}$
Brushing + Coffee	4.73 ± 0.30^{Aa}	$3.33 \pm 0.43^{Bb*}$	$3.29 \pm 0.36^{Bb*}$
G-ænial™ Universal Injectable			
Artificial saliva	5.03 ± 0.41^{Aa}	5.09 ± 0.31^{Aa}	4.85 ± 0.32^{Aa}
Coffee	4.66 ± 0.43^{Aa}	4.48 ± 0.52^{Aa}	4.30 ± 0.38^{Aa}
Brushing + Coffee	5.22 ± 0.67^{Aa}	4.51 ± 0.34^{Aa}	4.44 ± 0.37^{Aa}

Different uppercase letters in column indicate statistically significant differences between types of resin composite in same intervention and same storage time (Bonferroni test, $p<0.05$).

Different lowercase letters in column indicate statistically significant differences between intervention groups in same material and same storage time (Bonferroni test, $p<0.05$).

* indicate statistically significant differences between measures of the same group in function of time (Bonferroni test, $p<0.05$)

Table 3 Three-way repeated ANOVA analysis for the translucency parameter (TP)

Source	Type III Sum of Squares	df	Mean Square	F	Significant
Corrected Model	110.706[a]	26	4.258	22.107	.000*
Intercept	4616.107	1	4616.107	23966.508	.000*
Material	47.871	1.471	32.534	111.132	<.001*
Intervention	13.475	1.480	9.105	26.612	<.001*
time	29.911	1.373	21.793	95.862	<.001*
Material * Intervention	2.958	1.947	1.519	1.962	.171
Material * time	4.197	4	1.049	5.447	.000*
Intervention * time	8.825	2.478	3.561	13.584	<.001*
Material * Intervention * time	3.469	3.723	.932	3.420	.021*
Error	46.803	243	.193		
Total	4773.617	270			
Corrected Total	157.510	269			

a. R Squared = .703 (Adjusted R Squared = .671)

Factors affecting the translucent stability would be the discoloration of the material. The discoloration of resin composite is affected by various factors, including chemical composition, depth of cure, finishing and polishing procedures, and the coloring agent [17]. Filler directly affects the resin's susceptibility to staining [12]. Also, of great significance is silanization, as improved mechanical properties can be achieved through silanization [18]. The amount of silane is affected by the shape and volume of the filler. With higher filler loadings and using smaller size fillers, the amount of silane will be close to the amount of monomer[19]. The filler of G-ænial™ Universal Injectable consists of 69% by weight of 150 nm barium glass. Bonding the resin matrix with silane by using full-coverage silane coating technology (FSC) reduces the area where the filler is uncoated with silane [20]. In addition, FSC-treated filler had significantly fewer hydroxy groups than FSC-untreated filler. As a result, water absorption through the surface area between the resin matrix and the filler is reduced considerably [21]. In contrast, the Filtek™ Z350XT and Filtek™ Supreme Flowable contain nanosized silica and zirconia filler combined with a nanocluster of zirconia and silica of various sizes. The fillers of both types of resin composites are the agglomerated fillers up to 90% of the total fillers. These are less resistant to staining than non-agglomerated fillers [22].

The resin matrix is one factor that affects the discoloration of resin composites. Bis-GMA is a monomer with a large molecular structure and high viscosity. Therefore, hydrophilic TEGDMA was added to the resin composites to decrease their viscosity. According to previous studies, adding TEGDMA to a Bis-GMA-based resin composite in order to increase the TEGDMA:Bis-GMA ratio from 0 to 1 increases the water absorption of the composite from 3% to 6%[23, 24]. Filtek™ Z350XT contains Bis-GMA (1-10%), UDMA, Bis-EMA (1-10%), PEGDMA, and TEGDMA (<1%). Whereas Filtek™ Supreme Flowable contains Bis-EMA (5-10%), TEGDMA (<10%), and Procylat (15-25%). While G-ænial™ Universal Injectable contains Bis-EMA (10-<25%) and (octahydro-4,7-methano-1H-indenediyl) bis(methylene) bismethacrylate (5-<10%), which are hydrophobic and have lower water absorption than Bis-GMA due to the absence of a hydroxyl group [25], it also contains 2,2-dimethyl-1,3-propanediyl bismethacrylate (2.5-<5%), which has lower water absorption than TEGDMA.

According to previous studies, coffee caused the most discoloration of resin composites [14]. Coffee contains chromogens, a yellow substance with a low polarity that can bind to polymers, causing adsorption and absorption into the material [26]. In previous studies, a cup of coffee was consumed in an average of 15 minutes, and coffee drinkers consumed an average of 3.2 cups of coffee per day [27]. This means that there are 48 minutes of exposure to coffee and the oral cavity in one day. Therefore, immersing the specimens in coffee for one day is equivalent to 30 days of coffee consumption [22]. In this study, immersing specimens in coffee for 7 and 28 days was equivalent to simulating 7 and 28 months in the oral cavity respectively. Awliya *et al.* investigated the effect of different types of coffee on the discoloration of resin composites. The dark colorant and concentration of coffee affect the material's discoloration. Coffee with more water content exhibited less color change [28].

In addition, toothbrushing also affects the quality of the restoration because it significantly increases the surface roughness of the resin composite material [15]. As a result, it affects the color stability of the resin composite [16]. Toothbrushing causes abrasive wear on the resin composite materials, which gradually removes the resin matrix, leaving the filler without the surrounding matrix. Consequently, there is a possibility that the filler will dislodge [29]. If the resin composite contains large fillers, when it is displaced, it will result in a rougher surface. Whereas if the resin composite has small fillers, the material is more wear-resistant. Additionally, the wear resistance of

resin composite is influenced not only by the size and amount of filler but also by the composition of the resin matrix and the silane coupling agent, which improves adhesion between the filler and the resin matrix as well [30].

Consistent with this study, Sulaiman *et al.* demonstrated that the nanofill composite and nanohybrid composite decreased translucency after coffee immersion for 14 days [7]. The translucency change of resin composite material is related to the aforementioned factors. In this study, G-ænial™ Universal Injectable had the highest translucency stability due to its monomer composition combined with full-coverage silane coating technology that could effectively cover the surface of the filler with silane. In contrast, Filtek™ Z350XT and Filtek™ Supreme Flowable have lower translucency stability due to their monomer composition and filler preparation.

Regarding the study's limitations, we did not use various beverages as an immersion medium. Additionally, the specimens were not similar to the restoration from a geometrical perspective. In fact, the resin composites may be exposed to other foods or beverages, depending on the individual patient's consumption behavior. There is also saliva that dilutes the beverage and buffers acid-base. It may have an effect on the coloration of the material. Therefore, further clinical studies should be conducted for the color stability of composite resin materials. Moreover, when planning treatment and selecting restorative materials, especially in esthetic areas, consideration should be given to the type and composition of the resin composite in order to ensure the quality of the restoration.

Conclusion

Resin composites are prone to translucency change after coffee aging, becoming less translucencent. Within the materials investigated in this study; G-ænial™ Universal Injectable suffered the least change in their translucency compared to Filtek™ Z350XT and Filtek™ Supreme Flowable.

Acknowledgements

This work was supported by the Dental Research Fund for Postgraduate Students, Faculty of Dentistry, Srinakharinwirot University, Bangkok, Thailand.

Conflict of interest

The authors have no financial interest in any of the companies whose products are used in this study.

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