

THE EFFECT OF TEA AND COFFEE ON THE COLOR STABILITY OF BULK AND INCREMENTAL FILL RESIN COMPOSITE

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ABSTRACT

Objective: Two types of tea and coffee were selected to examine the color stability of bulk fill and incremental fill resin composite after storage for one and seven days.

Materials and methods: A total of 150 resin composite discs (Filtek™ Z350), bulk fill (Xtra-fil) and (Filtek bulk) were prepared using a cylindrical mold (2x4). Ten specimens of each restorative material were left in distilled water for one day to be used for baseline color assessment. Then each tested material where either placed in black coffee, black tea, lemon ice tea or coffee milk beverages for one day or seven days inside an incubator at 36±1 °C. The relative spectral reflectance of each specimen was assessed using a spectrophotometer after storage in these beverages.

Results: Kruskal-Wallis statistical test showed that there is a statistically significant difference between the three tested restorative materials after storage for one day and after 7 days in all the storage beverages where ($p < 0.05$). At the two aging periods, Z350 showed the statistically significant highest ΔE , X-tra fil showed the lowest statistically significant ΔE , while there was no statistically significant difference in the mean values of ΔE of Filtek bulk and these two materials. Regarding the effect of storage beverages on each restorative material at the two storage periods, black tea caused the highest statistically significant ΔE , while coffee milk caused the lowest statistically significant ΔE in the three tested resin composite.

KEYWORDS: Color stability- bulk fill- incremental fill- coffee- tea- lemon tea- coffee milk- spectrophotometer- storage time.

INTRODUCTION

The color stability of resin composite materials is crucial for esthetic restorations and it can be one of the most common reasons for restoration replacement⁽¹⁾. Several studies have shown that resin composite discoloration occur as a result of water sorption,

incomplete polymerization, chemical reactivity, oral hygiene, diet, and surface smoothness of the restoration^(2,3). Extrinsic discoloration occurs as a result of adsorption or absorption of staining agents from beverages, food, nicotine, drugs or dental plaque⁽⁴⁾. These adsorbed stains can be removed by at home brushing or professional teeth cleaning

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according to its severity^(5,6). In contrast endogenous discolorations are irreversible, they occur as a result of physicochemical reactions in the deeper portions of the restoration and the oxidation of the interface between the matrix and fillers⁽⁷⁾. Several studies showed that intrinsic discoloration depends on the composition of the resin composite as the organic matrix, the silane coupling agent, the photo-initiator, inhibitor, the filler type and loading⁽⁸⁻¹⁰⁾.

Bulk-fill resin-based composites have been introduced lately. The manufacturers claim that it can be cured at a depth of 5 mm for only 10-20 seconds allowing a much shorter time of application and providing high physical and mechanical properties. Many problems may be associated with bulk filled resin composite as the increase in shrinkage stresses, uncertain degree of conversion, increasing the chance of air entrapment and decreasing the adaptation to the cavity walls and margins^(11,12,13). That is why the success of bulk-fill resin-based composites in areas of high esthetic demand does not depend only on its accurate color match but also on its resistance to discoloration.

The most common beverages used worldwide are tea and coffee which are usually used hot or replaced by commercial cold tea and coffee in summer⁽¹⁴⁾. Consumption of beverages such as coffee and tea may affect the physical properties of resin composite and decrease its esthetic^(15,16,17,18,19). The effect of these beverages on the properties of resin composite is directly related to the amount and frequency of its intake⁽²⁰⁾.

The present study aimed to compare the color stability of two bulk and one incremental filled resin composites at day one and day seven after exposure to commonly consumed beverages

The null hypothesis proposed was that; there will be no significant difference in the color of all the tested resin composite materials after any of the following conditions; whether they were bulk or incrementally filled, stored hot or at room

temperature in tea, coffee, lemon tea or coffee milk for either one or seven days.

MATERIALS AND METHODS

Materials

Three resin composites were selected for this study:

- 1- Conventional incremental fill packable resin composite: Filtek Z350 XT (3M ESPE, USA)
- 2- Bulk fill packable resin composite: Filtek Bulk-fil (3M ESPE, USA)
- 3- Bulk fill packable resin composite: X-tra fil (Voco GmbH, Cuxhaven, Germany)

Four beverages were used for specimen storage:

- 1- Black tea (Lipton yellow label tea bag, Unilever, Alexandria, Egypt) pH= 6.8
- 2- Lipton lemon ice tea (PepsiCo Beverages Italia S.R.I, Italy) pH=4.1
- 3- Black coffee (Dalla Coffee, Middle East Sta Co., Cairo, Egypt) pH=6.8
- 4- Coffee milk Mochaccino, O.D. Gourmet-Coffee Latte - OU-Dean foods factory CO., LTD. pH=7.1

Methods

Specimen Preparation:

A total of one hundred and fifty resin composite discs were prepared using a split Teflon mold with an internal diameter of 2 mm and 4 mm height. This Teflon mold was held by a metallic ring to keep the two split halves in place. A small groove was made inside the internal diameter of the mold at 2 mm height to enable the application of incremental composite into 2 layers of 2 mm each. The Teflon mold was placed on a clean and dry glass slab. Each tested resin composite was applied inside the mold using a Teflon coated instrument (Goldstein composite instrument, HU-Friedy, Hu-Friedy

TABLE (1) Material names, manufacturer and chemical composition:

Material and manufacturer	Material category and shade	Organic Content	Filler content
Filtek Z350 XT (FZ), 3M ESPE, St. Paul, MN USA	Nanofill packable incremental fil	Bis-GMA, UDMA, TEGDMA, BisEMA	Combination of aggregated zirconia/silica cluster (5-20 nm), and nonagglomerated silica filler (20nm) 78.5% by weight.
Filtek Bulk Fill (FB), 3M ESPE, St. Paul, MN USA	Nanofill packable bulkfil	AUDMA, UDMA, and 1, 12-dodecane-DMA	Non-agglomerated/non-aggregated 20 nm silica filler (20 nm) and zirconia filler (4 to 11 nm), aggregated zirconia/silica cluster filler and agglomerate of ytterbium trifluoride filler (100 nm).
X-tra fil (XF), Voco GmbH, Cuxhaven, Germany	Microhybrid	Bis-GMA, UDMA, TEGDMA	Barium-boron-alumino-silicate glass (2-3 μm) 86% by weight, 70.1 v%

AUDMA: Aromatic urethane dimethacrylate, Bis-GMA: Bisphenol A diglycidyl ether dimethacrylate, BisEMA: 2,2-Bis[4-methacryloxyphenoxyphenyl]propane), TEGDMA: Triethyleneglycol dimethacrylate; UDMA: Urethane dimethacrylate;

Mfg. Rockwell St. Chicago, IL). Incremental fill resin composite (Filtek™ Z350) was placed in two increments of 2 mm each, while the other two bulk fill resin composite were placed as a bulk of 4mm each. In both cases a transparent Mylar strip was placed over the surface of the resin composite disc and pressed hard with a glass slide to ensure proper adaptation and the absence of voids in resin composite disc. Then the glass slide was removed and the specimens were cured using a light emitting diode curing device (L-460B, SEKER, China) placed at a zero distance from the top of the mold at an intensity of 1400 mW/cm². The output power of the curing unit was verified regularly every five exposures using a light radiometer (Kerr; Orange, CA, USA). Filtek™ Z350 was light activated in two increments for 20 seconds each. Filtek™ bulk was light activated in one increment of 4 mm high for 20 seconds, while X-tra fil was light activated for 10 seconds only. All the specimens were finished from the sides to remove any rough or excess material using gray rubber points (Politip Finishers, Ivoclar, Switzerland) in order to attain a smooth surface similar to the clinical circumstances.

Preparation of storage beverages

In order to prepare black coffee, a digital balance (Shinko Denshi, AF-R220E, Japan) was used to weight 4 gm of coffee powder and 0.12 gm of methyl paraben (an anti-fungal and preservative, el Gomhouria CO, Egypt), while prefabricated tea bag of 4 mg was used for black tea preparation. Each (preweighed black coffee or the black tea) was placed in 200 ml boiling distilled water at 100 °C after being mixed with 0.12 gm methyl paraben. In both beverages the mix was stirred with a glass rod for 30 seconds and left for 5 minutes. Then, each solution was poured into a dark tightly sealed labelled glass container after being filtered from any debris using double layers of filter paper (Double Ring, China) placed inside a metallic sieve. Ten specimens of each tested material where placed in the prepared beverage when the solution temperature reached 55 °C. As for the Lipton lemon ice tea and the coffee milk Mochaccino beverages, ten specimens of each tested restorative material were placed into 200 ml of each beverage without adding methyl paraben inside the dark labelled tightly sealed glass

container. The pH of each solution was checked using pH meter (Jenway 3510, U.S.A) after placing the specimen in each beverage. Ten specimens of each restorative material were left in distilled water for one day in a dark container to be used for baseline color assessment. All specimens were stored inside an incubator at 36 ± 1 °C. The color of each specimen was assessed for one day and then for seven days.

Color assessment

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Before color assessment each specimen was rinsed with distilled water for 2 minutes and blotted dry using absorbent tissue paper. The relative spectral reflectance of each specimen was assessed using a spectrophotometer (Cary 5000, Agilent Technologies, U.S.A). The measurements were done in the visible range of wavelength (400-800nm). Each specimen was measured 3 times and the mean measurement was recorded. Colorimetric values of the specimens were determined using the $L^* a^* b^*$ system of the Commission Internationale de l'Eclairage (CIE $L^* a^* b^*$ color scale) against a black background ⁽²¹⁾. L^* is a measure of lightness, a^* value is a measure of redness or greenness and b^* is a measure of yellowness or blueness. ΔL , Δa and Δb were calculated by subtracted the mean value of each measurement from that of the baseline value. Then, the color difference ΔE^* was calculated for each sample using the following equation:

In order to compare the change of color of each material at the two aging periods the results of ΔE of each material after seven days storage was subtracted from that of the one day storage. The same was done for ΔL , Δa and Δb of each tested resin composite in each beverage.

The normal curve adherence test was performed to determine the data distribution regarding its normality. All data was not normally distributed that is why non-parametric Kruskal-Wallis test was used to compare between the results of the ΔE , ΔL , Δa and Δb of each tested resin composite in each beverage at the two storage periods. A significance level of 5% was set for statistical analyses.

RESULTS

The effect of storage time and beverage on each resin composite material:

The figures 1, 2, 3, 4 show the ΔE (DE), Δa , Δb and ΔL respectively of the three tested materials after storage in the four tested beverages for one day (a) and for seven days (b). Kruskal-Wallis statistical test showed that there is a statistically significant difference between Xtra- fil and Z350 after storage for one day and after 7 days in all the storage beverages where ($p < 0.05$) where Z350 showed the statistically significant highest ΔE , Δa , Δb and the lowest ΔL except after storage in coffee milk for 7 days where Xtra- fil showed the lowest ΔL . It was noticed that Xtra- fil showed the lowest statistically significant ΔE , Δa , Δb and the highest ΔL in all beverages at the two storage periods. There was no statistically significant difference in the mean values of ΔE , Δa , Δb and ΔL of Filtek bulk and these two materials.

The effect of storage beverages on each restorative material:

At the two storage periods, black tea caused the highest statistically significant ΔE , Δa , Δb and ΔL in the three tested resin composite while coffee milk caused the lowest statistically significant ΔE , Δa , Δb and ΔL in the three tested resin composite. On the other hand, black coffee and lemon tea caused was no statistically significant difference in the mean values of ΔE when compared with the other two beverages in the three tested resin composite after storage in any of the two storage periods.

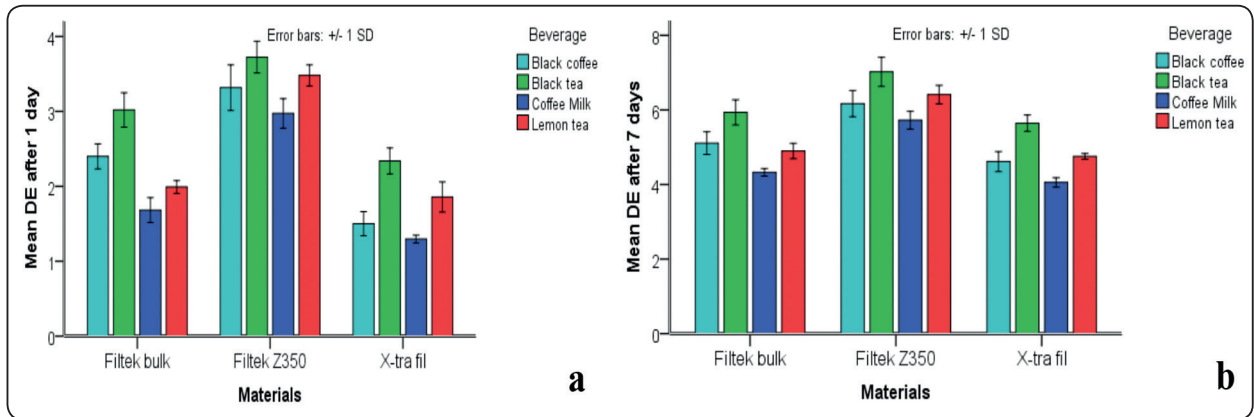


Fig. (1) Bar chart showing the mean values of ΔE (DE) of the three tested materials after storage in the four tested beverages for one day (a) and for seven days (b).

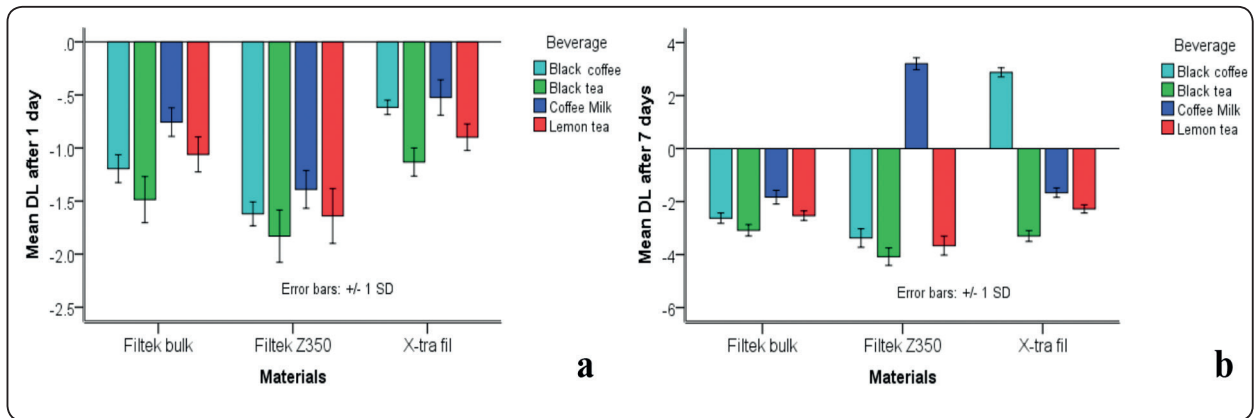


Fig. (2) Bar chart showing the mean values of ΔL (DL) of the three tested materials after storage in the four tested beverages for one day (a) and for seven days (b)

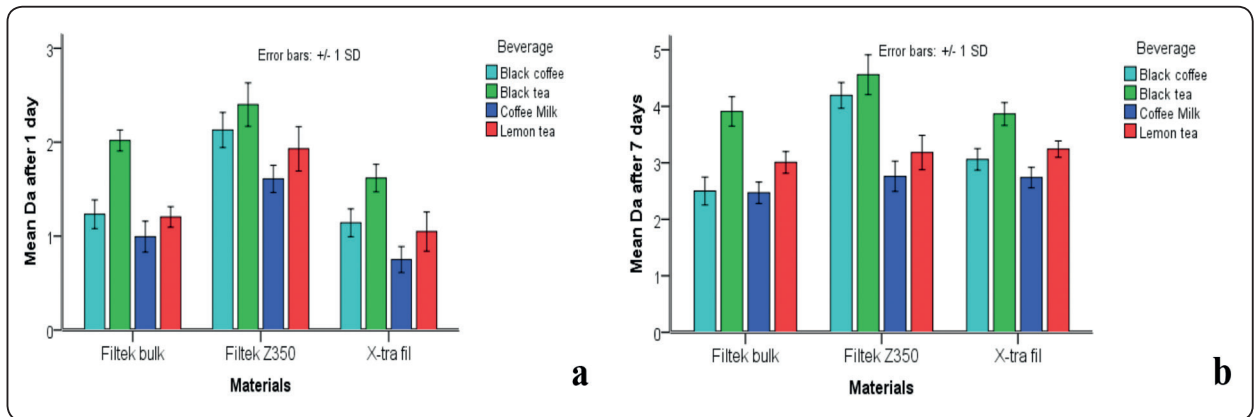


Fig. (3) Bar chart showing the mean values of Δa of the three tested materials after storage in the four tested beverages for one day (a) and for seven days (b).

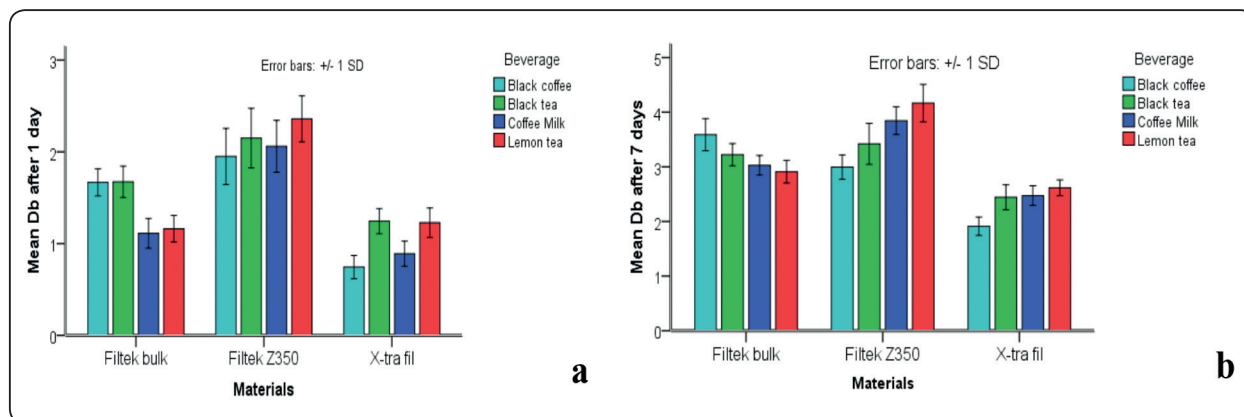


Fig. (3) Bar chart showing the mean values of Δa of the three tested materials after storage in the four tested beverages for one day (a) and for seven days (b).

The effect of storage time on the color of each restorative material in each beverage:

The tables (2) show the mean values of Δ E, Δa, Δb and ΔL respectively of each tested resin composite in each beverage after storage for 7 days when subtracted from that of the one day storage, only Xtra-fil showed a statistically significant difference in the mean values of Δ E. Where black

tea showed the lowest difference while coffee milk showed the highest difference and there was no statistically significant difference between them and black coffee and lemon tea. For each significant test, capital letters showed comparison between restoratives materials for same beverage denoted by P-value 1, lower letters showed comparison between beverages for each material denoted by P-value 2.

TABLE (2) Kruskal-Wallis statistical test examined the difference in the mean values of ΔE, ΔL, Δa, Δb of the four restorative materials in each beverage after storage for one and 7 days

	Storage Beverages	Restorative Materials			P-value 1
		Filtek bulk	Filtek Z350	X-tra fil	
		Mean± Std.	Mean Std.	Mean ±Std.	
ΔE (ΔE of 1day- ΔE of 7 days)	Black coffee	-2.71±0.31	-2.85±0.51	-3.11±0.31 ab	0.249
	Black tea	-2.92±0.40	-3.30±0.60	-3.31b±0.12	0.125
	Coffee Milk	-2.64±0.24	-2.75±0.40	-2.76±0.08 a	0.677
	Lemon tea	-2.91±0.23	-2.93±0.24	-2.90±0.20 ab	0.827
P-value 2		0.478	0.354	0.006	
ΔL (ΔL of 1day- ΔL of 7 days)	Black coffee	1.43± 0.23 AB	1.75 ± 0.43Aab	-3.49 ± 0.22 Bb	0.005
	Black tea	1.60 ± 0.16	2.25 ± 0.55A	2.17 ± 0.24 a	0.051
	Coffee Milk	1.08 ± 0.36A	-4.59 ± 0.34Bb	1.14 ± 0.14Aab	0.009
	Lemon tea	1.47 ±0.21	2.02 ± 0.47 Ab	1.38 ± 0.16Ab	0.080

P-value 2		0.064	0.008	0.001	
Δa (Δa of 1day- Δa of 7 days)	Black coffee	-1.27±0.24 Ab	-2.06±0.29 Bb	-1.92±0.23 AB	0.011
	Black tea	-1.89±0.34 a	-2.16±0.46 b	-2.25±0.20	0.289
	Coffee Milk	-1.48±0.18 AB ab	-1.15±0.14 Aa	-1.99±0.09 B	0.003
	Lemon tea	-1.80 ±0.18 ABa	-1.25±0.22Aab	-2.19B±0.25	0.004
	P-value 2	0.008	0.003	0.069	
Δb (Δb of 1day- Δb of 7 days)	Black coffee	-1.92± 0.32B	-1.04± 0.31 A	-1.17±0.2 ABa	0.015
	Black tea	-1.55±0.29	-1.27±0.49	-1.20a±0.29	0.224
	Coffee Milk	-1.92±0.25	-1.78±0.48	-1.58b±0.07	0.140
	Lemon tea	-1.75±0.26	-1.8±10.49	-1.39ab±0.08	0.057
	P-value 2	0.199		0.054	0.014

DISCUSSION

This study was carried out to examine the color stability of two bulk fill resin composite and an incremental fill resin composite after storage in black tea, black coffee, lemon tea and coffee milk. Color change was carried out using Spectrophotometer because instrumental measurement is more accurate, provides quantitative detection below the threshold of visual perception and eliminates the subjective errors that may occur in visual color interpretation^(22,23). Spectrophotometers demonstrate digitally the color of an object using the Standard Commission International de L'Eclairage Color System (CIE-Lab system) which is recommended by the American Dental Association. The CIE system uses three-dimensional colorimetric measurements: L* values correspond to the brightness of the color, a* values correspond to the red–green content and the b* values correspond to the yellow–blue content⁽⁹⁾. Negative Δa* values indicate a shift towards green color, while positive Δa* values indicate a shift towards red color. On the other hand, positive Δb* values indicates a shift towards yellow color, while negative Δb* values denote a shift towards blue

color⁽²⁴⁾. Chroma is calculated as $C^* ab = (a^{*2} + b^{*2})^{1/2}$ and hue difference is calculated as $H^* ab = (E^{*2} ab - L^{*2} - C^{*2} ab)^{1/2}$ ⁽²⁵⁾. Positive ΔL* values indicate that the specimens became lighter, whereas negative ΔL* values indicate that the specimens became darker. The color changes (ΔE) are calculated from the following formula $\Delta E lab^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ which determine the three-dimensional color space⁽²⁶⁾.

When the difference in color matching between spectrophotometric assessment and the human-eye perception were compared, values of ΔE < 1 were not appreciable by the human eye, while 1 < ΔE < 3.3 can be recognized by skilled operators, but were considered clinically acceptable. Values of ΔE > 3.3 were considered appreciable by nonskilled persons and were considered clinically unacceptable^(27, 28). The results of the present study showed that mean values of Δ E of the two tested bulk fill restorative materials were > 1 after storage in all beverages for one day, but their mean values of Δ E were raised after seven days to be > 3.3 after storage in all beverages indicating that their color became clinically unacceptable this agrees with Al-Kheraif

in 2011⁽²⁹⁾ and Domingos *et al.*, 2011⁽³⁰⁾. On the other hand, the mean values of ΔE of the incremental fill Filtek Z350 were >3.3 after storage for one and seven days in all the tested beverages except after storage for one day in milk coffee where ΔE was >1 confirming the results of previous studies⁽³¹⁻³⁴⁾ who found that Z 350 showed the least color stability. Barutçigil *et al.*, 2012 explained that to be as a result of the hydrophilicity of Filtek Z350 resin matrix which contains Bis-GMA and TEGDMA⁽³⁴⁾.

On the contrary, X-tra fil showed the least statistically significant ΔE , Δa , Δb and the highest ΔL after one day storage in all tested beverages. It also showed the least statistically significant ΔE and Δb after storage for 7 days in all tested beverages. Xtra fil is a universal shade bulk fill resin-composite, several studies have found that its ΔE values showed close color-matching to (A1, A2, A3, A3.5, and A4) resin composite⁽³⁵⁾. It has high translucency which may increase its lightness when compared with the other two materials⁽³⁶⁾. Many studies have found that the absolute color change depend on the initial color of the resin composite; the lighter the initial color, the higher the absolute color difference⁽³⁷⁻³⁹⁾. Kim and Lee in 2007 evaluated the color changes after polymerization using spectrophotometry and found that polymerization caused significant changes in brightness and chroma. They explained that composite shade becomes lighter after polymerization due to the reaction of camphorquinone and the formation of polymer chains⁽¹⁰⁾. The conversion of monomer to polymer causes an increase in the refraction coefficient of the matrix phase while, the refraction coefficient of filler phases remains unchanged^(40,36). This explained why polymerized resin composites have higher diffuse reflectance ΔL than unpolymerized resins. Malekipour *et al.*, 2012 explained that unconverted photoinitiator as camphorquinone decreases the degree of conversion and causes yellowish discoloration⁽⁹⁾.

Mundim *et al.*, 2010⁽¹⁵⁾ shown that the type of polymerization system and the polymerization conditions are important parameters which greatly affect the color stability of resin composite materials. The color stability decrease when the degree of conversion decreases due to water sorption and the release of products such as methacrylic acid and formaldehyde⁽⁴²⁻⁴⁴⁾. YAP *et al.*, 2004 explained that the degree of conversion is greatly affected by the composition of the resin matrix and the size and percentage of inorganic fillers⁽⁴⁵⁾. The degree of conversion different monomer is in the following order Bis-GMA < Bis-EMA < UDMA < TEGDMA⁽⁴⁶⁾. Silami *et al.*, 2013⁽⁴³⁾ found that the degree of polymerization of Bis-GMA is 20% lower than other monomers. Filtek Z 350 contains Bis-GMA & Bis-EMA whose degree of conversion varies between 45-85%⁽⁴⁴⁾.

Xtra-fil and Filtek Z350 contain both TEGDMA and BISGMA in their organic matrix. BISGMA contains hydrophilic hydroxyl groups and TEGDMA contains ethoxy group that react by hydrogen bonding to oxygen of water⁽⁴⁵⁾. ERTAS *et al.*, 2006 found that the addition of TEGDMA to Bis-GMA based resins increased the resin hydrophilicity and hence its water sorption⁽⁴¹⁾. This was evident in the present study as Filtek Z350 showed the highest mean values of ΔE , Δa , Δb and the lowest mean values of ΔL when compared with the other two resin composite materials in all the storage beverages at the two storage periods which is in agreement with several studies^(46,47,48). This was confirmed by Le Prince⁽⁴⁹⁾ who found that water uptake of Bis-GMA-based resin composite increased from 3-6 % as the percentage of TEGDMA is increased from 0-1%. The presence of TEGDMA in X-tra fil did not affect its color stability which may be due to the lower percentage of TEGDMA added to BISGMA and the presence of UDMA in X-tra fil organic matrix. This agrees with Vichi *et al.*, 2004 who stated that materials that replace part of TEGDMA for UDMA may have less color change⁽⁵⁰⁾. Although

Z350 contains Bis-EMA which is more hydrophobic than TEGDMA, it seems that its percentage was not high enough to decrease its staining ability. On the other hand, Filtek bulk fil contains UDMA and AUDMA that are hydrophobic and are more stain-resistant than Bis-GMA^(41, 51). Khokhar et al., 1991 found that under normal curing conditions, UDMA-based resin composite resin showed lower water sorption and higher color stability than other dimethacrylates that is why Filtek bulk fil showed insignificant color change when compared to the other two materials⁽⁵²⁾. Another important factor affecting the color stability is the filler particle type, size and percentage⁽¹⁰⁾.

Several studies have shown that the degree of conversion decreases when filler particles size is close to the wavelength of the activating light. This occurs because fillers of this size scatter the incident light and reduces the amount of light transmitted through the resin composite^(53,54). Both Filtek bulk and Filtek Z350 contain nanofiller particles which may reduce their degree of conversion. On the other hand X-tra fil contains microhybrid fillers which allowed the incident light to properly penetrate its organic matrix increasing its degree of conversion and hence its color stability^(51,55). This agrees with Malhotra et al., 2011⁽⁵⁶⁾ who found that when the particle size increases the organic matrix proportion is reduced and consequently the degree of color change decrease⁽⁹⁾. Another important factor is the resin-filler interface, where when the size of particles decreases their interface with the organic matrix increases and hence the surface area of the silanized filler particles^(57,58). Since silane is hydrophilic this will increase water sorption especially if the organic matrix has low percentage of hydrophobic monomer^(59,60). This was also proven by Choi et al., 2005 who found that water molecules can penetrate into the nano spaces between the nanofillers or nanoclusters and the polymer chains and react with their functional groups by hydrogen bonding⁽³³⁾. They explained that to be as the result

of the presence of porosity in the clusters formed by the aggregated zirconia/silica nanoparticle fillers that facilitate color penetration⁽³³⁾. Regarding the percentage of fillers the lower the filler content the greater the color changes due the increase in resin matrix this was shown in the present study and several other studies^(37, 50, 56, 61, 62, 63,64). X-trafil contains the greater percentage of fillers 86% by weight, followed by filtek Z350 which contains 78.5% by weight and finally Filtek bulk 76.5% by weight. The response of Filtek bulk to discoloration agrees with the results of Patel et al., 2004 who found that, the increase in the percentage of resin matrix is not always associated with an increase in color change because it depends on the type of resin matrix and the filler size as explained before⁽⁶⁵⁾. Also, Halvorson et al., 2003 explained that the increase in the filler-matrix ratio may decrease conversion, because increasing the amount of filler particles is considered an obstacle for polymer chain propagation⁽⁶⁶⁾.

The objective of this study was to investigate the cumulative effect of the different beverages on the resin composites shade. Satou et al., 1989 stated that if the resin matrix is capable of absorbing water, it is also capable of absorbing any other fluid leading to bulk discoloration of the resin composite⁽⁶⁷⁾. Fay et al., 1999 found that water sorption is also influenced by the chemical composition of the beverage as it affects the color stability and surface integrity of the resin composites⁽⁶⁸⁾. The coffee manufacturer calculated the average time for consumption of one cup is 15 minutes, and the average consumption is about three cups per day. Guler, et al., 2005 found that material storage in coffee for 15 days simulated consumption for one year and the one day' storage simulated consumption for 1 month⁽⁶⁹⁾. In the present study the specimens were stored for one and seven days which could simulate one and six months of consumption respectively. When subtracting the mean values of ΔE of 1day from that of ΔE of 7 days in each tested resin composite material in each

beverage all subgroups showed negative values in indicating that ΔE increase with time which agrees with the results of several studies^(26,30,32,46,70,71,72).

In addition, the mean values of ΔL , Δa and Δb (of 1day- 7 days) of the three tested resin composite material were only significant when stored in black coffee which means that coffee discoloration increase significantly with aging. This finding is in confirmation with the findings of many studies^(9,41,71,73,74). Gupta et al., 2005 found that coffee chromatogens are released slower than that of tea⁽⁷⁴⁾. Um and Ruyter in 1991 stated that both tea and coffee contain yellow chromotogen with different polarities⁽⁷³⁾. The higher polar components of tea are released first especially at high temperature, followed by the lower polarity components in coffee that are released later⁽⁷¹⁾.

When comparing the effect of each beverage on each tested resin composite material we found that black tea caused the highest discoloration (ΔE , Δa) and the least ΔL in the three materials at the two storage periods this agrees with several studies^(47,75,76,77,78,79). Other studies explained that tannins in tea are responsible of its high staining ability and that its compound cause chemical interactions that may lead to stable discolorations^(41,48,80). On the contrary, coffee milk showed the lowest (ΔE^*) and Δa^* and the highest (ΔL^*) when compared to the other beverages in the three tested resin composite materials at the two storage periods and this agrees with Guler et al., 2005 who found that the addition of milk to coffee lightened its color and the interaction of coffee with milk casein may decrease its polarity and concentration⁽⁶⁹⁾. Previous studies have shown that a significant increase in color occurred after the addition of sugar and milk to tea and coffee^(69,81). This can be explained by the fermentation of sugar and milk in such beverages after storage for 7 days at 37°C, but this did not occur in the present study due to the presence preservative in such beverage. Guler et al., 2005 explained that the increase in color

difference may be due to the sticky effect of sugar on the staining of coffee or tea⁽⁶⁹⁾. As for black coffee and lemon tea, there was no statistically significant difference in ΔE in the three resin composite materials at the two storage periods.

Bagheri et al., 2005 stated that the discoloration caused by tea occurred by the adsorption of highly polar colorants onto the surface of the resin that can be removed by brushing⁽⁵¹⁾, while in case of coffee it contains tannic acid and other small particles of lower polarity that become adsorbed and absorbed onto and into the organic phase of the resin composite leading to more stable discoloration⁽⁴⁾. This adsorption and penetration of colorants into the organic phase of the resin composite were explained by the high compatibility of the polymer phase with the yellow colorants of coffee especially to low polymerized resin⁽⁷³⁾. The degree of polarity of dyes determines their degree of penetration into the resin. Less polar dyes, such as coffee, can penetrate easily into the polymer matrix, while more polar dyes, such as tea only impregnate the surface of the material.

As for lemon tea, although it has the lowest pH it showed an insignificant color change (ΔL^* , Δa^* , ΔE^*) when compared to the other beverages in the three tested resin composite materials at the two storage periods. Filtek Z350 showed the highest statistically significant (Δb^*) when stored in lemon tea at the two storage periods. There are no previous studies that tested the effect of this beverage on resin composite. Only one study added lemon to black tea and found a significant change in color as a result of the decrease in tea pH⁽⁸²⁾. In addition, other studies found that pH of staining solutions have an effect on the color stability apart from the solution color⁽⁸³⁾. On the other hand, West et al., 2000 mentioned that the total acidity of beverages can be influenced by a number of factors, including temperature, titratable acidity, pH, chelation potential, acid character, concentration and timing of intake⁽⁸⁴⁾. This agrees with the result of the present study and with Tan et

al., 2015 who mentioned that although black tea and coffee have acids in their composition and their pH is 6.8, they cause increased chemical erosion and staining⁽⁸⁵⁾. We should not also neglect that the specimens were immersed in these two beverages at 55°C which increased their triturability and penetration into the resin composite matrix. On the hand carbonated beverages like the lemon tea contain carbonic acid which is a mild acid that does not bind with cations and forms chelate which is responsible of discoloration^(86,87).

All tested resin composite showed positive mean values of Δa^* and Δb^* indicating a shift towards the red and yellow color respectively after storage in any of the four tested beverages when stored either for one or seven days which agrees with several studies^(9,47,82,88,89). Manojlovic et al., 2015 found that color change after storage in tea and coffee usually result from the change in chroma⁽⁹⁰⁾. Moreira et al., 2012 explained that the absorption of melanoidins which are high-molecular-weight nitrogenous brown compounds and the final products of the Maillard reaction formed during coffee roasting are the cause of the brown color of coffee⁽⁹¹⁾.

Black tea showed the least lightness (ΔL^*), the highest (ΔE^*) and (Δa^*) in the three tested materials at the two aging periods this can be due to the color of tea which is considered reddish than coffee and more concentrated than lemon tea. Black coffee showed the highest (Δb^*) in Filtek bulk after one and seven days storage, while it showed the lowest (Δb^*) with the other two resin composite materials at the two storage periods. This may be as a result of the compatibility of coffee component with that of Filtek bulk this agrees with several studies^(83,88,92).

CONCLUSION

Under the condition of the present study, the following conclusions can be reached:

- Only Xtra-fil and filtek Z350 differ in their color at the two storage periods in all tested beverages.

- Black tea caused the highest discoloration in the three tested materials at the two storage periods while coffee milk showed the opposite.
- The high temperature and concentration of black tea and coffee positively influenced resin composite discoloration.
- Storage time did not increase ΔE and increased ΔL , Δa and Δb especially in black coffee.

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