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EVALUATION OF COLOR STABILITY AND MARGINAL DISCOLORATION OF A NEW SELF ADHESIVE BULK-FILL RESIN COMPOSITE RESTORATIVE MATERIAL AFTER AGING: A RANDOMIZED CLINICAL TRIAL

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ABSTRACT

Objective: To assess the impact of different aging periods (24 hours - 3 months - 6 months) on surface color stability and marginal discoloration of Surefil one self-adhesive composite and Filtek One bulk-fill composite and evaluate the degree of surface and marginal color improvement of both resin composite materials after polishing.

Materials and methods: A total of 28 class I cavities were prepared in the molar teeth of 14 different patients using split mouth technique and then were divided randomly into two groups (Group 1: Surefil one self-adhesive composite – Group 2: Filtek One bulk-fill composite). A VITA Easyshade spectrophotometer was utilized to measure the baseline surface color of the restoration after 24 hours and degree of surface color change after 3 months and 6 months of composite restoration placement and then degree of color change was measured using the CIE L*a*b* system. Two independent calibrated examiners blinded to the operators performing the treatment; assessed the marginal discoloration of all restorations visually, at baseline after 24 hours and after 3 months and 6 months of composite restoration placement. All discolored restored molar teeth were polished using Sof-Lex aluminum oxide discs and then the degree of surface and marginal color improvement was determined and was then compared to the baseline color measurements. Data was analyzed using Kolmogorov-Smirnov, Shapiro–Wilk and Pearson's Chi square tests.

Results: Filtek One bulk-fill composite resulted in statistically less significant surface color change and marginal discoloration than Surefil one self-adhesive composite after aging. Filtek One bulk-fill composite resulted in higher degree of surface and marginal color improvement of the restoration after polishing than Surefil one self-adhesive composite.

Conclusions: Aging had a detrimental effect on the degree of surface and marginal color stability of resin composite restorations regardless of the resin composite material composition. For discolored resin composite restorations, polishing was an effective way to remove superficial stains.

KEYWORDS: Aging - Color stability - Marginal discoloration - Self-adhesive resin composite.

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INTRODUCTION

Due to their ability to replicate a tooth-like look, resin composites are widely used as esthetically pleasing restorative materials for anterior and posterior teeth [1]. Polymerization shrinkage is a main drawback encountered with resin based composite restorations, where the formation of a cross-linked polymer brings a volumetric shrinkage of about 1.5-6 volume percentage, resulting in production of polymerization shrinkage stresses that can disrupt the adhesive bond between the tooth and the restoration[2]. These undesirable stresses continue to be a major contributor to marginal failure, which frequently leads to microleakage that in turn permits the entry of irritants that can cause pulp inflammation, post-operative sensitivity, secondary cavities, bulk and marginal discoloration [3].

Bulk-fill composites are a class of resin based composites that allow a restoration to be built in thick layers with thickness up to 4-5 mm due to improvements in the filler content and organic matrix, which allow them to have low elastic modulus and low levels of polymerization stresses without compromising on the depth of cure [4]. Modifications in resin-based technology have resulted in resin based composite materials with self-adhesive characteristics. The introduction of materials with self-adhesive qualities has significantly advanced the field of direct restoration by eliminating the need for a particular adhesive protocol, saving time and simplifying use [5]. These materials also have the benefit of being able to be utilized in circumstances where moisture contamination control and cavity isolation are questionable due to the fact that self-adhesive composite resins are less technique sensitive and require less application time [6].

One important factor influencing the clinical longevity of dental resin composites is their surface and marginal color stability in the dynamic oral environment, where resin composite restorations are exposed to different aging conditions in the oral cavity such as continuous temperature fluctuations, chewing forces and chemical attacks by enzymes and acids on the teeth within the oral cavity and from the ingested food [5]. Resin composites can become discolored due to both internal and external reasons. The deep layers and surface matrix of the resin composite are intrinsically colored in the oral cavity because of physical factors such as heat, humidity and ultraviolet radiation or chemical factors such as the polymer matrix structure, the unreacted methacrylate group and the oxidation processes occurring in the amine accelerator [7]. The accumulation of plaque, superficial deterioration of the restorative material and the surface adsorption of coloring agents from exogenous sources are all considered extrinsic causes[8]. It has been noted that one of the most common causes of discoloration in resin composite restorations is incomplete polymerization reaction. Additionally, a significant factor influencing the staining susceptibility of resin composites is the resin composite material composition [9].

Different methods such as bleaching, polishing and replacing the restoration entirely have been suggested to remove discoloration and restore the esthetics of stained resin composite restorations[10]. Polishing is the most popular method for stained resin composite restorations, but it has a disadvantage that it causes some material loss from the polished surface [11].

This study evaluated the esthetic performance of a novel self-adhesive bulk-fill resin composite material that was recently released to the market with that of a conventional bulk-fill composite that was placed using adhesive in accordance with the manufacturer's instructions. Owing to the numerous advantages of self-adhesive bulk-fill composites, which simplify the clinical restoration process by reducing chair time application and technique sensitivity through reducing the clinical application steps, which results in a faster application duration

and lowers the possibility of errors associated with multiple application steps [5]. However, compared to conventional bulk-fill composites, skipping the adhesive step can result in a weaker bond to both enamel and dentin, which can cause various post-operative complications [6].

The aim of this study was to clinically assess the degree of surface color change and marginal discoloration of Surefil one self-adhesive composite and Filtek One bulk-fill composite at different aging periods (24 hours - 3 months - 6 months) and the degree of surface and marginal color improvement after polishing in the patient's mouth. This study was done to weigh benefits and drawbacks of self-adhesive bulk-fill composites in comparison to conventional bulk-fill composites in esthetic performance with aging in the oral cavity and after polishing. The first null hypothesis tested is that Surefil one self-adhesive composite and Filtek One bulk-fill composite will perform similarly regarding surface and marginal color stability. The second null hypothesis is that aging will detrimentally affect the surface and marginal color stability of both tested resin composite restorations.

MATERIALS AND METHODS

Ethical approval and protocol registration

The scientific content and adherence to applicable research and human subjects regulations of the study protocol and informed consent were reviewed and approved by the IRBs/ECs (Institutional Review Boards/Ethical Committee) in the Faculty of Dentistry, Minia University with serial no. 87/597. Besides, the study has been registered on the Clinical Trials Registery (www.clinicaltrials.gov) with trial number NCT06463574. The materials utilized for teeth restorations were one self-adhesive bulk-fill resin composite (Surefil one self-adhesive composite), one conventional bulk-fill resin composite (Filtek one bulk-fill composite) and 3M all in one self-etch universal adhesive (Table 1).

Sample size calculation

The calculation of the sample size was done according to the following equation: [$n= t^2 \times p(1-p) /m^2$], where n = required sample size, t = confidence level at 95% (standard value of 1.96), p = estimated measurements, m = margin of error at 5% (standard value of 0.05). According to the formula $n= 1.96^2 \times 0.013(1-0.013)/0.05^2 =20$, the sample size must be at least 20 posterior class I cavities in the current study [12]. This study used split mouth technique and enrolled a total of 14 patients, surpassing the calculated sample size to accommodate potential patient drop out. Each participant had at least two carious posterior molar teeth. The researcher assumed responsibility for all aspects of the research, which encompassed participant recruitment, explaining the study procedures and performing them.

Trial design and setting

This study was a prospective randomized clinical trial (RCT) that followed the Consolidated Standards of Reporting Trial Statement (CONSORT) [13] with a follow up period of 6 months (Figure 1). Split mouth technique was used in the current study for the purpose of reduction of the risk bias, where both materials were placed in an identical clinical environment. The current study was double blinded where the clinical examiner and the participant were kept unaware of the treatment being administrated and it was achieved in the Operative Dentistry Department Clinic, Faculty of Dentistry, Minia University.

Eligibility Criteria of Participants

Participants in this study had to be healthy adult men and women patients with age range from 25 to 45 years of age, with class I caries in their maxillary or mandibular molars with a maximum of approximately 4 mm final cavity depth. They were required to have an acceptable oral hygiene level and teeth shade A2 according to Vitapan classical shade guide.

TABLE (1) Specifications, composition, manufacturers and lot number of materials used in the current study.

Material	Specification	Composition	Manufacturer	Lot Number
Surefil one™ self-adhesive bulk-fill composite	Self-adhesive, fluoride releasing composite shade A2	**Powder:** Aluminium-phosphor-strontium-sodium-fluoro-silicate glass, highly dispersed silicon dioxide, ytterbium fluoride and pigments. **Liquid:** Acrylic acid, modified polyacid, polycarboxylic acid(MOPOS), bifunctional acrylate(BADEP), stabilizer, camphorquinone, self-cure initiator and water.	Dentsply sirona, Rowntree Dairy Rd Unit, Woodbridge, Canada.	2019000342
3M Filtek™ One high viscosity bulk-fill restorative	Bulk-fill, light cured resin composite shade A2	**The resin matrix:** Bis-GMA, Bis-EMA, TEGDMA, UDMA, AFM, AUDMA and DDDMA. **The filler system:** Non agglomerated/non aggregated silica filler, non agglomerated/non aggregated zirconia filler, aggregated zirconia/silica cluster filler and agglomerated ytterbium trifluoride, filler loading is nearly 76.5% weight and 58.4% volume.	3M ESPE, St. Paul MN, USA.	NE09753
3M All in one single bond universal adhesive	Single step, self-etch adhesive	10-methacryloyloxydecyl dihydrogen phosphate (10MDP), vitrebond copolymer, HEMA, filler, water, ethanol, initiators and silane.	3M ESPE, St. Paul MN, USA.	9122737
3M ESPE Scotchbond™ Universal Etchant	Etchant	35% phosphoric acid, water soluble polymer, silica, alcohol, water and thickener.	3M ESPE, St. Paul MN, USA.	N800798

Patients were excluded from participating in the current study, if they suffered from a para-functional habit such as traumatic occlusion or heavy bruxism. Additionally, patients with poor oral hygiene or active periodontal disease, exposed or endodontically treated teeth were excluded. Patients participated in a clinical trial within 6 months before the beginning of this trial, declined to participate in the study or sign the written consent or were unable to come back for the follow up visits were also excluded.

Randomization and allocation

Simple randomization was applied to randomly allocate the molar teeth into the two different comparative treatment groups. Once the patient consented to take part in the study and cavity preparation and rubber dam isolation were finished, opaque sealed envelope (www.sealedenvelope.com) was used to randomize the composite resin to be inserted in each tooth. Each envelope had an identification serial number inscribed on it. A researcher who was not involved in any of the experimental phases completed this step.

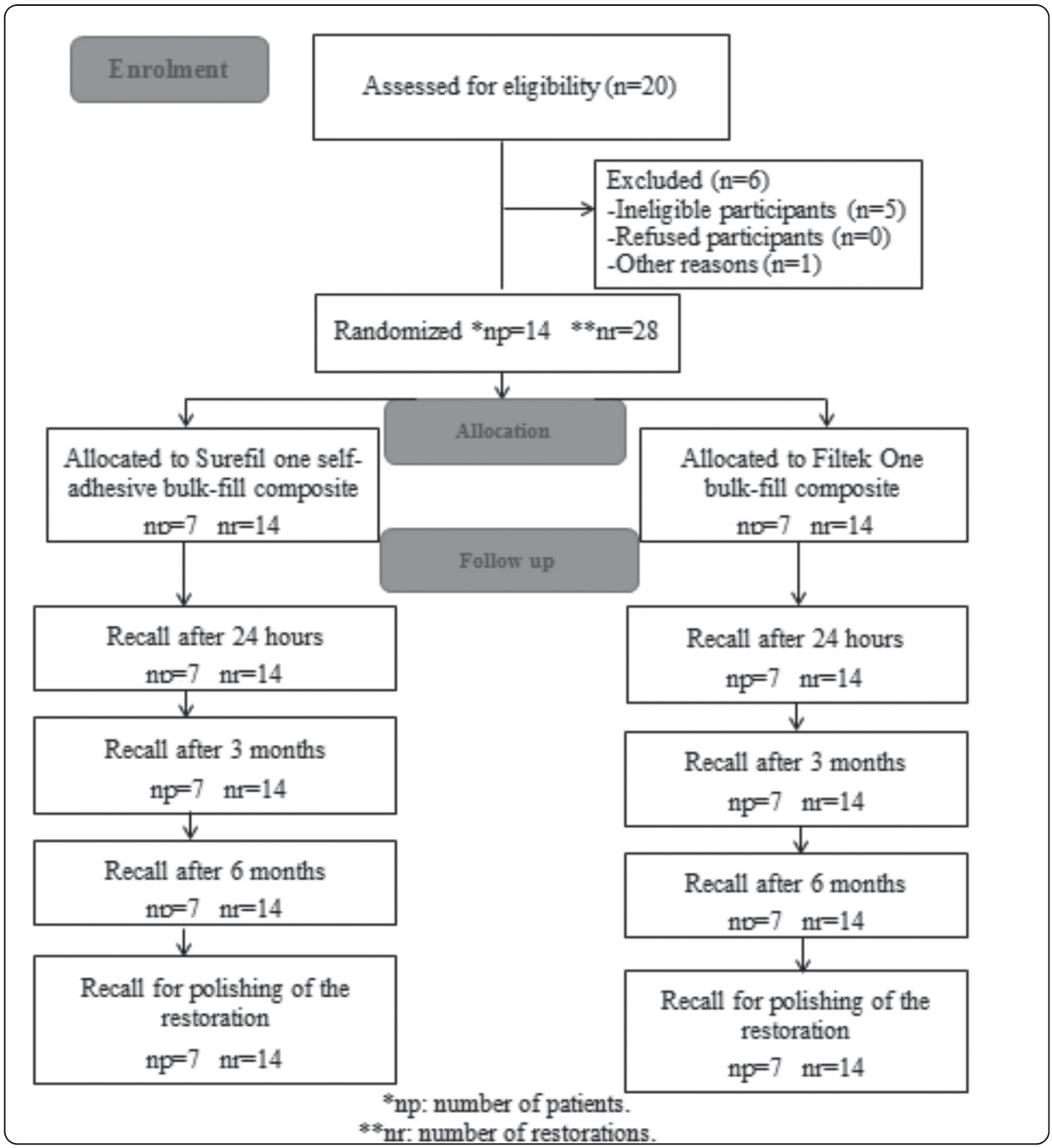

Fig. (1) Flow chart of the current study (Consolidated Standards of Reporting Trials [CONSORT] 2010)

Grouping of patients

A total of 28 molar teeth from 14 different patients of which 8 were females and 6 males were divided randomly into two main groups depending on the type of the composite material (C), the first group (C1) used Surefil one self-adhesive composite for restoring 14 posterior class I cavities and the second group (C2) used Filtek One bulk-fill composite for restoring 14 posterior class I cavities.

Clinical procedures

Oral hygiene instructions were explained to all patients before beginning in the operative treatment. Full mouth scaling and polishing was performed to all patients. Periapical radiographs of the teeth requiring treatment were taken before the beginning of restorative procedures and Parkell Pulp vitality tester (Parkell Electronics DN, Farmingdale, NY, USA) was used to examine the teeth vitality. Anesthesia was administrated before the beginning of the procedure to ensure minimal amount of discomfort and rubber dam was used for complete isolation of the teeth during restoration of the prepared cavities to avoid moisture contamination.

A total of 28 class I cavities were prepared in 28 different molar teeth of 14 different patients with a high-speed handpiece (Dentsply Sirona, Long Island City, NY 11101, United States) using water spray and a 330 high speed carbide bur (JOTA AG Rotary Instruments, 9464 Rüthi, Switzerland). To ensure that all cavities were approximately the same size, with cavity depth not exceeding 4 mm depth, the depth of all prepared cavities was measured using a periodontal probe (Nordent Williams periodontal probe, ISO 9001:2008, Elk Grove Village, IL, USA). During the whole trial period, only Surefil one self-adhesive composite and Filtek One bulk-fill composite were placed in the selected patients molar teeth. With the use of magnifying loupes, a single operator placed all the restorations. Following cavity preparation, teeth were rinsed to remove any debris and small sponges were used to get rid of excess moisture. The enamel of the prepared cavities was selectively etched for 30 seconds using a 35% phosphoric acid gel, then it was rinsed and gently air dried**.**Surefil one self-adhesive composite capsule was activated by full seating of the activation button against a hard surface, then the capsule was mixed in a capsule mixer (Dental amalgamator SDS Kerr 4000, KerrHawe SA, UK) for 10 seconds and then placed in capsule applicator gun (ROYAL DENT, Tbilisi, 0162, Georgia, USA). The material was then extruded immediately on the tooth surface then light cured for 20 seconds. A micro-brush (Dental Bond Brush, Unipack, China) was used to apply 3M all in one universal adhesive to the prepared cavities walls and floor, then it was light cured for 20 seconds and Filtek One bulk-fill composite was then applied as one bulk to the cavities using gold plated composite resin applicator (AMERICAN EAGLE composite SET, United States) and light cured for 20 seconds.

Bluephase N® polywave LED light curing device (Ivoclar Vivadent Inc., Amherst, N.Y., USA) was used for curing both resin composite materials in all patients with the same power density. The light curing tip was placed directly on the occlusal surfaces of all teeth to standardize the curing distance. All restored molar teeth were finished using diamond fine shaped composite finishing bur TR-13EF (MANI, INC. UTSUNOMIYA, TOCH IGI, JAPAN) under water cooling and then composite polishing paste (Aluminum Oxide Polishing Paste, ENA, Italy) was applied on the restoration and polished using fine-grit Sof-Lex discs (KerrHawe SA, 6394 Bioggio/Switzerland) during the same appointment immediately after all restorative procedures were completed.

Color change measurement

VITA Easyshade spectrophotometer (VITA North America, Savi Ranch STE, Yorba Linda, Canada) was utilized to measure the baseline surface color of the restoration after 24 hours and degree

of surface color change after 3 months and after 6 months of composite restoration placement and then degree of color change was determined using the following equation: $\Delta Eab = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)2]^{1/2}$. The tip of the spectrophotometer was placed directly on the center of the occlusal surface of all restored molar teeth. In order to standardize the site of the readings, a silicon mold was fabricated with even thickness for each patient, where it was used as a guide for the measurements of each molar tooth at the baseline and after the different follow up periods. All restored molar teeth at the different measurement periods were examined under the same day lightening conditions [12].

Color assessment was done according to Commission Internationale de l'Éclairage L*, a*, b* (CIELAB) standard three dimensional color space system. The visual lightness scale (L*) goes from 0 (totally black) to 100 (totally white). The value of (a*) represents the amount of redness and greenness, where a positive change denotes a shift in redness and a negative change denotes a shift in greenness. The value of (b*) represents the amount of yellowness and blueness, where a positive change denotes a shift in yellowness and a negative change denotes a shift in blueness. The relative color difference of dental materials or tooth surfaces before and after an intervention is represented by ΔE. Values of ΔE less than 3.3 are insignificant to human eye and are considered as clinically acceptable, while if ΔE values exceeded 3.3, it is considered clinically unacceptable [14]. The spectrophotometer was calibrated before each measurement regarding the manufacturer's recommendations.

Two independent calibrated examiners blinded to the operators performing the treatment; assessed the marginal discoloration of all restorations visually using dental light source with the aid of magnification loupes (Eye Mag Pro F, Carl Ziess Meditec Ag, Germany) following modified United States Public Health Service criteria as follow: Alpha: no marginal discoloration, Bravo: slight marginal discoloration, Charlie: evident marginal discoloration [15]. Pre-calibration of the blinded assessors was performed on ten patients who were not part of the trial and they achieved 90% reliability. Significant close to ideal agreement was noted between the examiners. Restorations evaluation was done after 24 hours of restoration placement (baseline), then after 3 months and 6 months of restoration placement.

After measuring the degree of surface color change and marginal discoloration, all discolored resin composite restored molar teeth of both tested resin composite materials were polished with a series of variable thickness of Sof-Lex aluminum oxide discs (coarse - medium - fine), where each disc thickness was used for 15 seconds on each restored molar tooth.[11] The degree of surface color improvement was then determined by subjecting all polished molar teeth to a new color measurement using (CIELAB) color space system and then the results were compared to those of the baseline surface color measurements. For determining the degree of marginal color improvement, all polished restorations were visually re-evaluated and received a score of either Alpha, Bravo or Charlie and were then compared to the baseline marginal scores. Alpha and Bravo scores were considered a clinical success.

Statistical analysis

Data were fed to the computer using IBM SPSS software package version 24. Mean and standard deviation were used for describing quantitative normally distributed data. Numbers and percentages were used for describing qualitative data. Independent t-test was used for comparing the data between two independent populations and ANOVA test was used to examine the data from more than two populations. Chi-square test was used for comparing the categorical variables between the groups. Significance of the obtained results was judged at the 5% level.

RESULTS

Filtek One bulk-fill composite resulted in statistically less significant surface color change after 3 months (P=0.046) and after 6 months (P=0.029) aging periods in the patient's mouth, with higher degree of surface color improvement after polishing (P=0.016) and statistically less significant marginal discoloration after 3 months (P=0.049) and after 6 months (P=0.05) aging periods in the patient's mouth, with higher degree of marginal color improvement after polishing (P=0.049) than Surefil one self-adhesive composite in different patient's ages and genders in the current study (Figure 2,3).

There was a statistically significant difference in degree of surface color change between different aging periods of both resin composite materials tested and after polishing, where Surefil one self-adhesive composite showed higher surface color stability after 3 months aging period (Mean=4.14) than after 6 months aging period (Mean=5.37) and showed slight improvement in surface color after polishing (Mean=5.24). Also, Filtek One bulk-fill composite demonstrated higher surface color stability after 3 months aging period (Mean=3.52) than after 6 months aging period (Mean=4.42) and then showed slight improvement in surface color after polishing (Mean=3.82) (Table 2) (Figure 4).

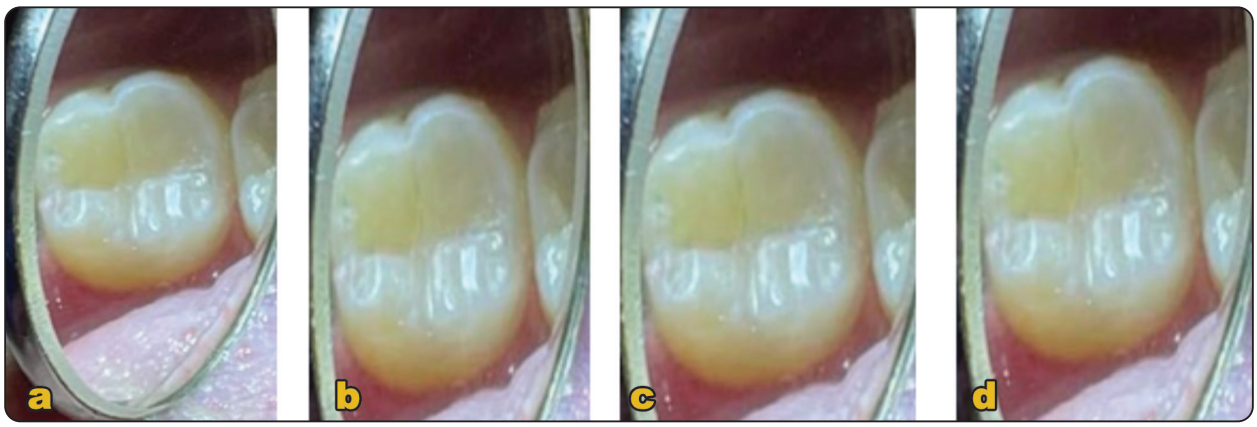

Fig. (2) Clinical photographs of tooth number 31 restored with Surefil one self-adhesive composite. a: baseline, b:after 3 month aging period, c: after 6 months aging period, d: after polishing.

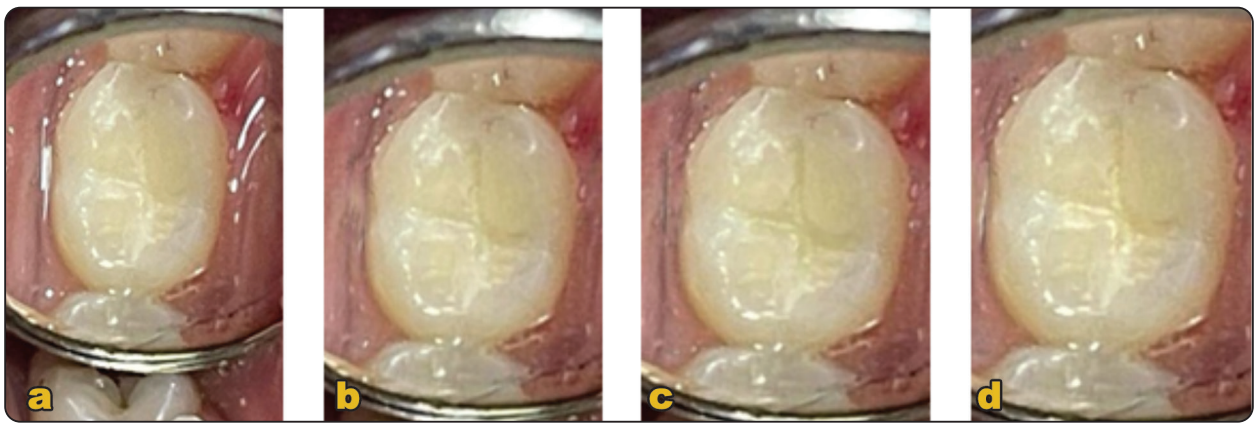

Fig. (3) Clinical photographs of tooth number 18 restored with Filtek One bulk-fill composite. a: baseline, b:after 3-month aging period, c: after 6 months aging period, d: after polishing.

TABLE (2) Comparison of degree of surface color change between the two studied groups at different aging periods and after polishing.

	Degree of surface color change (ΔEab)		
	24H - 3M	**24H - 6M**	**24H - After polishing**
Group I (Surefil one self-adhesive composite)			
Min-Max	3.62-4.78	4.60-5.88	4.15-5.81
Mean± SD	4.14^{Ca}±0.39	5.37^{Aa}±0.43	5.24^{Ba}±0.51
Group II (Filtek One bulk-fill composite)			
Min-Max	3.20-4.01	3.91-5.39	3.01-5.27
Mean±SD	3.52^{Cb}±0.20	4.42^{Ab}±0.43	3.82^{Bb}±0.64
t-test	1.98	2.01	2.88
P value	0.046*	0.029*	0.016*

Means with different capital letters in the same raw indicate significant difference, means with different small letters in the same column indicate significant difference. p was significant if (≤ 0.05) * Significant difference

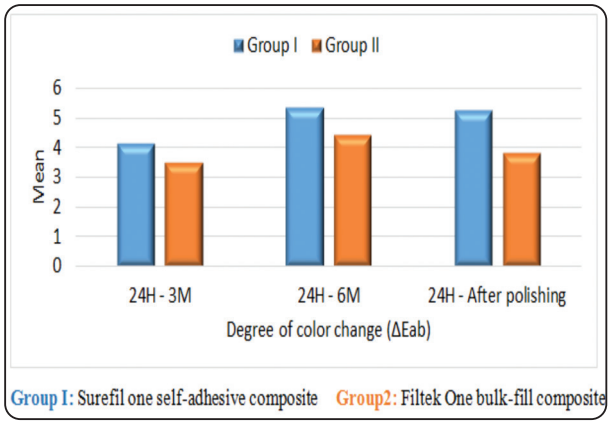

Fig. (4) Bar graph representing comparison of degree of surface color change between the two studied groups at different aging periods and after polishing. Blue color represents Surefil one self-adhesive composite that showed higher degree of surface color change at different aging periods and after polishing than Filtek One bulk-fill composite represented by orange color.

Regarding marginal discoloration, a statistically significant difference was denoted between different aging periods in the patient's mouth and after polishing of both resin composite materials tested, where after 3 months aging period resulted in 50% Alpha and 50% Bravo scores in Surefil one self-adhesive composite and 90% Alpha and 10% Bravo scores in Filtek One bulk-fill composite, while after 6 months aging period resulted in 40% Alpha and 60% Bravo scores in Surefil one self-adhesive composite and 80% Alpha and 20% Bravo scores in Filtek One bulk-fill composite. After polishing, both materials showed some marginal color improvement, where Surefil one self-adhesive composite showed 50% Alpha and 50% Bravo scores and Filtek One bulk-fill composite showed 90% Alpha and 10% Bravo scores (Table 3) (Figure 5).

The inference of the study is that self-adhesive bulk-fill composite (Surefil one) showed higher degree of surface color change and marginal discoloration and lower degree of surface and marginal color improvement after polishing than conventional bulk-fill composite (Filtek One). Aging negatively affected surface and marginal color stability of composite restorations disregarding the resin composite composition.

TABLE (3) Comparison of degree of marginal discoloration between the two studied groups at different aging periods and after polishing.

Time	Group I (Surefil one self-adhesive composite) (n=10)		Group II (Filtek one bulk-fill composite) (n=10)		P value
	No	%	No	%	
After 24 hours (baseline)					
Alpha	8	80.0	10	100.0	0.36
Bravo	2	20.0	0	0.0	
After 3 months					
Alpha	5	50.0	9	90.0	0.049*
Bravo	5	50.0	1	10.0	
After 6 months					
Alpha	4	40.0	8	80.0	0.05*
Bravo	6	60.0	2	20.0	
After polishing					
Alpha	5	50.0	9	90.0	0.049*
Bravo	5	50.0	1	10.0	

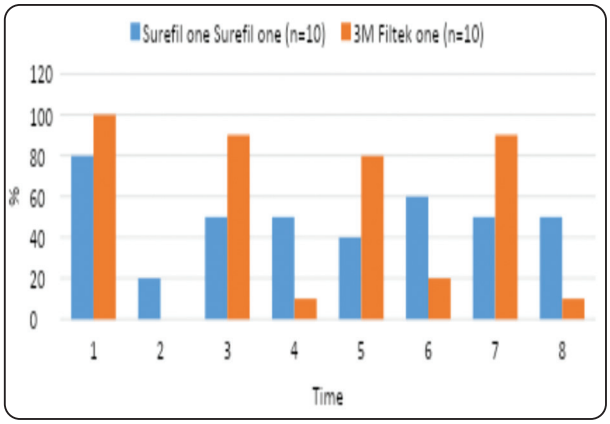

Fig. (5) Bar graph representing comparison of marginal discoloration scores between the two studied groups at different aging periods and after polishing. Blue color represents Surefil one self-adhesive composite that showed higher degree of marginal discoloration at different aging periods and after polishing than Filtek One bulk-fill composite represented by orange color.

DISCUSSION

Resin composites are extensively used world-wide because of their ability to easily replicate the tooth like appearance. Bulk-fill resin based composites were introduced to the market as a way to simplify clinical handling without requiring the time consuming incremental technique of application with the advantage of less technique sensitivity, where bulk-fill composites allow placement of large increments up to 5 mm, as they contain monomers that function as reaction modulators to achieve low polymerization shrinkage [16]. They also incorporate more reactive photo-initiators to enable a deeper cure and they are more translucent, allowing more light to pass through the material [17].

In response to the clinical need of simplifying the bonding procedure in terms of faster, less technique sensitive and more user friendly adhesive system, self-etch adhesives are currently used as they overcome the drawbacks of total etch adhesive system that include high technique sensitivity, risk of over etching or insufficient rinsing and the potential of leaving over dried or over wet dentin [6]. Self-etch adhesives overcome the multiple step

procedures in total etch adhesives, where self-etch adhesive is a one step adhesive system that does not need a separate etching step, which reduces the working time in the patient's mouth [18].

The introduction of resin composites with self-adhesive property allowed further reduction of the treatment steps by omitting the need for adhesive application, which significantly advanced the field of direct restoration with the privilege of time saving, ease of usage and application in cases where moisture contamination control is difficult[19]. There is currently little evidence of the in-vivo performance of self-adhesive resin composites, where few researches have examined the color stability of these materials [20], thus the aim of the current study was to test the degree of surface color change and marginal discoloration after aging in the patient's mouth and the degree of surface and marginal color improvement after polishing of both Surefil one self-adhesive composite without universal adhesive application and Filtek One bulk-fill composite with universal adhesive application and then compared the results of both resin composite restorative materials.

Surefil one self-adhesive composite was selected as it contains modified poly-acid polymer as a primary component, that is a main reason in it's high mechanical strength by promotion of network formation and attachment to the tooth structure. Modified poly-acid system is different from other technologies in that it modifies the poly-acid base polymer with polymerizable groups in a hydrolytically stable way[21]. It is a nano-hybrid composite that combines nano-fillers with dimensions of 0.02-0.05 μm for improving mechanical strength and micro-fillers with dimensions of 0.3-1 μm to promote overall mechanical strength, polishability, esthetics and surface details [5]. In order to readily standardize the cavity dimensions and C-factors, class I restorations were chosen.

Color stability in the oral environment is one of the main concerns encountered in the use of resin based restorative materials, where the resin restoration should resemble the natural tooth in appearance. This directly relates to the material color stability as well as color harmony with neighboring natural teeth, where in the oral cavity, resin composite restorations are exposed to a variety of aging conditions [22]. The assessment of composite discoloration can be done visually or with the aid of instruments. The advantage of using instruments is that they remove the possibility of subjective interpretations of the color change, consequently Vita Easyshade Spectrophotometer was utilized to detect the degree of surface color change in this study. Since Commission Internationale de l'Éclairage L*, a*, b* (CIELAB) is a widely used technique for quantifying color variations, it was chosen for surface color evaluation in this investigation [23].

The results of the current study demonstrated a significant difference in degree of surface color change between both materials, where Surefil one self-adhesive composite showed significantly higher degree of surface color change than Filtek One bulk-fill composite. This might be related to the fluoride releasing ability of Surefil one composite, where fluoride-releasing composites are expected to have high solubility as they require water diffusion to occur in order to be effective. This water solubility increases the degree of water absorption, expanding the gaps between composite polymer chains and leaching out unreacted monomers [24]. These results were similar to those found by Huang et al., [8] who examined the color stability of variable resin composite materials and reported a finding that the composition of the material had a strong effect on the color change values of resin composite restorations.

Valizadeh et al., [23] investigated how various staining solutions affected the color retention of resin composites and agreed with our study, where they examined the impact of different staining solutions on resin composites ability to maintain color

and found that different resin composites in the various staining solutions showed different degrees of discoloration with the highest degree of discoloration encountered in self-adhesive composites. Arregui et al. [25] also concurred with our results, where they examined discoloration capacity of different resin composite materials and concluded that self-adhesive resin composites showed the highest level of water sorption, which resulted in significant increase in color change values. The high degree of color change of self-adhesive resin composites can be explained by their hydrophilic properties due to their carboxylic acid and phosphate group content, where the presence of carboxylic, hydroxylic and phosphate groups in self-adhesive composites makes them more liable to water sorption [26].

This study used modified united states public health service criteria scores to assess any marginal color change, where the following scores were used: Alpha: the color and translucency of the restoration are in harmony with the neighboring teeth. Bravo: the restoration translucency and color deviate slightly from the neighboring teeth, although they still lie in the normal range of tooth shades. Charlie: the restoration shows significant change in color and translucency compared to the neighboring teeth [15]. These scores also allowed comparison with previous studies.

In terms of marginal discoloration, Surefil one self-adhesive composite showed increased degree of marginal staining in comparison to Filtek One bulk-fill composite, where Surefil one self-adhesive composite received higher Bravo scores and lower Alpha scores than Filtek One bulk-fill composite after 3 months and 6 months aging periods in the patient's mouth. The discoloration that was noticed was considered acceptable clinically. It is possible that the patient's dietary regimen and smoking habits contributed to the discoloration [27].

These results were supported by Sabry et al.[6] who investigated the clinical effectiveness of Surefil one self-adhesive composite and found that it was not suitable to be used clinically in long term restorations in terms of color match and marginal discoloration. Additionally Ellithy et al. [5] examined the marginal color stability and color match of Surefil one self-adhesive composite and revealed a conclusion that it showed higher level of marginal discoloration in comparison to 3M Filtek One bulk-fill composite over a year follow up period. This might be a consequence of marginal leakage at the resin composite to dentin adhesive joint, where the lack of adhesive is a primary cause of the lack of wettability at the interface between resin composite and dentin. This has the disadvantage of formation of inadequate bond between the monomers in the adhesive and the calcium salts in dentin, which opens up a microscopic pathway for bacteria and colorants found in food [23]. Furthermore, Filtek One bulk-fill composite blends nano-sized fillers with dimensions of 4–11 and 20 nm to create a smoother surface with micro-sized fillers with dimensions of 100 nm to improve light scattering and reflection, significantly enhancing light penetration that increases the depth of cure and reduces the stresses caused by polymerization shrinkage, improving the mechanical properties and resistance to wear [5].

On the other hand, Cieplik et al. [18] stated that the clinical results of Surefil one self-adhesive resin composite were favorable regarding esthetic and mechanical properties and it could be suggested for clinical application. Our results also contradicts the results of Kalola A et al. [28] who evaluated the esthetic performance of self-adhesive flowable resin composites compared to conventional flowable resin composites clinically and claimed that self-adhesive resin composite materials appeared to be clinically promising. This might be explained by the modified poly-acid system that is hydrolytically stable, where it works as a co-polymerizing cross-linker in the cured material and improves adhesion to dentin and enamel [18].

One important factor influencing the clinical longevity of dental resin composite restorations is their color stability in the dynamic oral environment.

One of their esthetic drawbacks is that they might discolor intrinsically or extrinsically as resin composite restorations are subjected to various challenges with aging in the patient's mouth that the material has to endure [29]. Fillers can only absorb water on their surface, unlike the resin matrix of composite materials which can absorb water from the environment into the majority of it's structure. However, increased water sorption might limit the life of a resin composite by hydrolyzing the silane, expanding and plasticizing the resin component and encouraging the development of micro-cracks. Because of this, the filler-matrix interface could have micro-cracks or interfacial gaps that would permit stain penetration and discoloration [30].

The results of the current study revealed that both Surefil one self-adhesive composite and Filtek One bulk-fill composite resulted in significant increase in the degree of surface and marginal color change with aging in the patient's mouth. These outcomes were verified by the study performed by Hashir et al. [30] who found that different types of resin composite restorations showed negative color changes as a result of aging, where they observed a direct proportional relationship between the degree of color change and the lengthening of the aging time. Our findings also align with Badr et al. [12] who compared the clinical behavior of different resin composites in class I and II cavities on posterior teeth and concluded that aging had a negative effect on the color stability of resin composite restorations, regardless of the type of resin composite material utilized. This would be related to the main factor contributing to staining in the oral environment which is the absorption of colorants present in different foods and beverages. Water carries the coloring pigments into the resin matrix, where the high resin matrix to filler ratio and hydrophilicity of the resin matrix are the primary causes of high water sorption and the consequent color change [31].

According to their evaluation of bulk-fill resin composites degree of color stability, Barutcigil et al. [32] reported that bulk-fill resin composites degree of color change dramatically increased over time. Durão et al. [33] were on the same hand with our results, where they revealed a conclusion that the discoloration potential of various resin composite materials was a complicated issue affected by a number of variables, one of them was aging. This could be the result of degradation of the polymer material and consequent filler exposure. It is believed that aging of resin composite in the oral cavity leads to loss of organic material and depletion of silica fillers from the restoration surface, which results in elemental oxygen loss, increase in the percentage of organic materials and deterioration of the restoration surface [34].

Furthermore, Loguercio et al. [35] tested the impact of accelerated artificial aging on the color change of resin composites and found that resin composite restorations showed significant unsatisfactory color changes after aging. This is presumably the result of low degree of monomer conversion, which together with changes in oral cavity temperature and pH fluctuations cause unreacted residual carbon–carbon double bonds to oxidize and residual amines to degrade, which eventually leads to discoloration of resin composites [36].

Polishing, which is an essential component of the clinical treatment, is primarily employed to remove stains from the tooth or restoration. On the other hand, polishing procedures provide two primary challenges in the clinical routine, first is that patients may experience a sensation of roughness in their teeth following the procedure and secondly is the undesirable coloring that frequently returns following previous polishing treatment. Since Sof-Lex discs have abrasive particles made of aluminum oxide, the method of stain removal by polishing discs involves abrading the surface [37]. To properly remove superficial stains from resin composite components, the abrasives must be harder than the composite filler, otherwise the polishing procedure would only remove the soft resin matrix, leaving the filler particles visible above the surface [38].

The results of the present study revealed that polishing significantly reduced the surface staining and marginal discoloration of Filtek One bulk-fill composite. This could be attributed to occurrence of staining in the most superficial layer, which possibly allowed easy reduction of the discoloration. These results were on the same hand with the study conducted by Islam et al. [39], where they concluded that glycerin gel coating or polishing using polishing discs might enhance the color stability of resin composites and Uctasli et al. [11] who tested the effect of polishing on stained resin composite restorations that were exposed to frequently consumed beverages and reached a conclusion that reducing surface stains in resin composite restorations could be achieved with the use of polishing. The reason for these results can be explained by the wear resistance and polishability of resin composite materials. In resin composite materials that are more likely to wear, polishing would be more advantageous since small filler particles facilitates wear [40].

Additionally, Fouda et al. [10] examined the effect of various polishing techniques on resin composite materials following their exposure to a staining agent and came to the conclusion that polishing is an effective way to reduce stains on resin composite restorations. Also, Farahani et al. [41] reported that polishing is a useful stain reduction technique but still cannot bring back the original color of stained resin composite restorations. This can be attributed to the fact that in composite materials with smaller, softer fillers and lower filler loading, polishing can successfully remove the discolored surface layer because the aggregated fillers break down into their primary nano-fillers during the polishing process [42].

On the contrary, polishing didnot significantly reduce the surface and marginal stains of Surefil one self-adhesive composite, where the results of the present study showed that Surefil one self-adhesive composite showed statistically less significant reduction in degree of surface color change and marginal discoloration than Filtek One bulk-fill composite after polishing. This may be due to bulk discoloration of Surefil one self-adhesive composite, where polishing is a simple procedure for stain removal, indicated only in surface staining of resin composites [43]. Another explanation could be the differences in composition between Filtek One and Surefil One bulk-fill composites, specifically regarding the type and amount of inorganic fillers.

The findings of the current study showed that despite the negative influences of mechanical and thermal dynamic cycles that occur in the oral cavity on various bulk-fill composites, regardless of their composition, it is advisable to use bulk-fill composites with a higher percentage of nano-fillers to improve their mechanical properties and wear resistance, which increases their clinical success and longevity.

One of the current study limitations is that it limited the comparison between Surefil one self-adhesive composite and conventional Filtek One bulk-fill composite using all in one universal adhesive, excluding the use of the three-step etch and rinse adhesive system. Also, different commercial brands of self-adhesive composites may exhibit different features and clinical performance, which may impact their suitability for specific clinical situations. Additionally, the shortage of long-term evidence, where it is necessary to conduct more extensive clinical studies to fully evaluate their efficacy over longer follow up periods.

Clinically, Surefil one self-adhesive composite performed inferiorly compared to Filtek One bulk-fill composite regarding degree of surface color change and marginal discoloration, therefore the first null hypothesis was rejected. Aging in the patient's mouth negatively influenced the degree of surface and marginal color stability of resin composite restorative materials, regardless of the resin composite material composition proving the second null hypothesis.

CONCLUSION

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

1. Self-adhesive bulk-fill composites with no adhesive application displayed bulk discoloration, while conventional bulk-fill composites with adhesive application displayed a more superficial discoloration.
2. Aging had a detrimental effect on surface and marginal color stability of resin composite restorations regardless of the composition of the resin composite material.
3. Polishing is a successful method of superficial stain removal from resin composite restorations but it is not capable of restoring the original color of the restoration.

RECOMMENDATIONS

1. In order to obtain long term clinical success, it is recommended to use self-adhesive composites with adhesive application, especially in cases where it will be used as a final restoration.
2. It is advisable to use more advanced techniques than polishing with Soft-Lex discs for removal of stains from resin composite restorations.

CONFLICT OF INTREST

The authors declare that they have no conflicts of interest.

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