ORIGINAL RESEARCH

The Gloss Retention of Esthetic Restorations Following Simulated Brushing with Charcoal Oral Products: An *In-Vitro* Study

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Abstract

Aim: To assess the gloss and gloss retention of two esthetic restorative materials after brushing with a charcoal-infused toothbrush and activated charcoal toothpaste compared to their standard counterparts in all possible combinations.

Materials and methods: In this study,104 disc-shaped specimens were prepared, 52 from each of the two materials: Beautifil II LS composite resin (Giomer) and Fuji II LC resin-modified glass ionomer (RMGI). Specimens of each material were divided into 4 groups ($n = 13$) according to the tested brushing procedure: group A—standard toothbrush + standard non-whitening toothpaste (S-S), group B—standard toothbrush + activated charcoal toothpaste (S-CH), group C—charcoal-infused toothbrush + standard non-whitening toothpaste (CH-S), and group D—charcoal-infused toothbrush + activated-charcoal toothpaste (CH-CH). Gloss was recorded using a gloss meter initially and after each brushing protocol. The data were statistically analyzed with two-way analysis of variance (ANOVA) and Tukey HSD *post hoc* tests using SPSS® v.27 software at 5% significance level.

Results: Beautifil II LS showed the highest gloss values after brushing in group D (44 ± 3.9), which was not significantly different from its initial value (46.1 ± 1.8), followed by groups A (32.2 ± 4), B (23.2 ± 3.6), and C (22.7 ± 3.9), while Fuji II LC showed its highest gloss values after brushing in groups D (16.6 ± 3.7) and a (15.4 ± 8.7), followed by groups C (10.9 ± 6) and B (4.4 ± 2.5), all were significantly lower than their respective initial gloss values.

Conclusion: The gloss of Giomer and RMGI reduced significantly following the brushing with the tested brushing procedures except for the Giomer group brushed with a combination of charcoal-infused toothbrush and activated-charcoal toothpaste.

Clinical significance: The brushing using a combination of charcoal-infused toothbrush and activated-charcoal toothpaste is recommended for the gloss retention of Beautifil II LS restorations. However, the gloss of the Fuji II LC cannot be retained after any of the brushing procedures.

Keywords: Charcoal toothbrush, Charcoal toothpaste, Esthetic restorative materials, Gloss, Simulated brushing.

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Introduction

One of the main demands of esthetic dental restorations is to maintain a lustrous surface against different oral challenges.[1] The surface gloss is an optical phenomenon that describes the material’s capacity to reflect the light,[2] and is determined by the geometrical distribution of light that is reflected from the surface, therefore, it is significantly impacted by the surface irregularity of the esthetic restorations.[3]

The surface gloss is considered an important aspect of the restoration's visual appearance. The human eye is capable of perceiving variations in gloss even when the colors of restoration and the surrounding enamel are identical, making gloss discrepancies between the two surfaces clinically significant. High gloss, however, reduces the influence of color variations as the color of the reflected light dominates the color of the underlying restorative material.[4]

Dental practitioners currently prefer fluoride-releasing restorative materials, these materials have a broad variety of uses as direct restorations due to fluoride’s powerful caries prevention ability.[5] Beautifil II LS is a new bioactive universal hybrid composite (Giomer). It has a unique steric repelling structure (SRS) monomer

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and SPR-G technology to efficiently mitigate polymerization shrinkage and reduce micro-leakage.[6] The second selected material in the current investigation is Fuji II LC resin-modified glass ionomer (RMGI), which can bind chemically to tooth structures. It is a preferred restorative material for the treatment of class V cervical lesions.[7]

The selection of dentifrices and other daily oral hygiene products is one of the factors that have a considerable impact on the clinical performance and longevity of esthetic restorations. A noteworthy change in the field of dental care is the growing popularity of dentifrices that are based on charcoal. This is particularly interesting for individuals who are actively seeking cost-effective and easily accessible teeth-whitening remedies.[8] Activated charcoal, which is a critical component of such kinds of toothpaste, has received significant acclamation for its supposed ability to adsorb extrinsic stains, dental plaque, and debris on the tooth surface. As a result, it offers the potential for a more glowing, whiter, and healthy smile.[9] Manufacturers assert that the porous characteristics of activated charcoal are the source of effective and natural stain removal properties.[10]

Furthermore, the market has witnessed the introduction of charcoal toothbrushes featuring black filaments infused with activated charcoal. These toothbrushes are reported to possess antimicrobial properties and reduce the likelihood of bacterial contamination.[5,6] In addition, manufacturers claim that these products can eliminate surface stains and whiten the teeth.

Many factors can cause restoration surfaces to degrade intra-orally.[11] Brushing is thought to be a key component influencing the gloss of resin-based restorations.[12] Previous studies on the effect of tooth brushing using conventional toothbrushes and toothpastes on the gloss and gloss retention of restorative materials revealed the variable effects of brushing on the gloss values.[13–15] However, to our knowledge, the recently introduced charcoal toothbrushes' and toothpastes impact on the restorative materials gloss retention has not yet been investigated. The null hypothesis in the current study proposed that neither material type, nor brushing with the charcoal-infused toothbrush and activated charcoal toothpaste compared to their standard counterparts in all possible combinations, will have a significant effect on the gloss retention of both tested materials.

Materials and Methods

The present *in-vitro* investigation was carried out at the RAK College of Dental Sciences biomaterials research laboratory for the duration of four months, from December 2023 to March 2024. The study was conducted after receiving approval from the Research and Ethics Committee at RAK Medical and Health Sciences University, with reference number RAKMHSU-REC-040-2022/23-UG-D.

Calculation of the Sample Size

The G*Power application v. 3.1.9.7 for Windows was used to determine the sample size for this investigation, using 8 experimental groups as a basis, the power was set at 0.8 and the effect size had been set at 0.4 as reported in a previous study,[8] with a 0.05 significance level. Accordingly, 13 specimens per group was determined.

The inclusion criteria in the present study were specimens free of visually appearing cracks and surface stains, while the exclusion criteria included specimens with surface cracks or staining after polymerization.

The materials tested in the current investigation are listed in Table 1. Two types of esthetic restorative materials were used low shrinkage Giomer (Beautifil II LS®, Shofu, Japan) and RMGI restorative material (Fuji II LC®, GC Corporation, Tokyo, Japan). Two types of toothbrushes were utilized: a standard electric toothbrush (Oral B Precision clean®, Braun, P&G Manufacturing Ltd, Ireland) and

Table 1: The materials utilized in the current investigation

Brand name and manufacturer	*Material*	*Composition*
Beautifil II LS (Shofu Inc., Kyoto, Japan)	Composite resin (Giomer).	Glass powder, Urethane diacrylate, Bis-MPEPP, Bis-GMA, TEGDMA, polymerization initiator, pigments, and others. Filler loading: 83 vol. (%)
Fuji II LC. (GC Corporation, Tokyo, Japan)	Resin-modified glass ionomer (light-cured RMGI capsule).	Powder: 100% fluoro-alumino-silicate. Liquid: 35% HEMA, UDMA, 25% distilled water, 24% poly-acrylic acid, 6% tartaric acid, and 0.1% camphorquinone.
Crest cavity protection (Procter & Gamble UK)	Standard non-whitening toothpaste.	Active ingredients: sodium fluoride (0.15% w/v fluoride ion) (0.243%); Inactive ingredients: sorbitol, water, hydrated silica, sodium lauryl sulfate, trisodium phosphate, flavor, cellulose gum, sodium phosphate, carbomer, sodium saccharin, titanium dioxide, blue 1.
Colgate Optic White Charcoal (Colgate-Palmolive, Poland)	Activated-charcoal- toothpaste.	Aqua, hydrated silica, sorbitol, glycerin, PEG-12, pentasodium triphosphate, tetrapotassium pyrophosphate, sodium lauryl sulfate, flavor, cellulose gum, cocamidopropyl betaine, sodium saccharin, xanthan gum, charcoal powder, sodium hydroxide, blue 1, red 40, titanium dioxide. Total fluoride content is 1450 ppm.
Oral B Precision clean (Braun, P&G Manufacturing Ltd, Ireland)	Standard toothbrush.	Nylon bristles (replacement head).
Oral-B pure clean (Braun, P&G Manufacturing Ltd, Ireland)	Charcoal-infused toothbrush.	Charcoal-infused bristles (replacement head).

Bis-GMA, bisphenol A diglycidyl ether dimethacrylate; Bis-MPEPP, bisphenol A polyethoxy methacrylate; HEMA, hydroxyl ethyl methacrylate; PEG, polyethylene glycol; TEGDMA, triethylene glycol dimethacrylate; UDMA, Urethane dimethacrylate

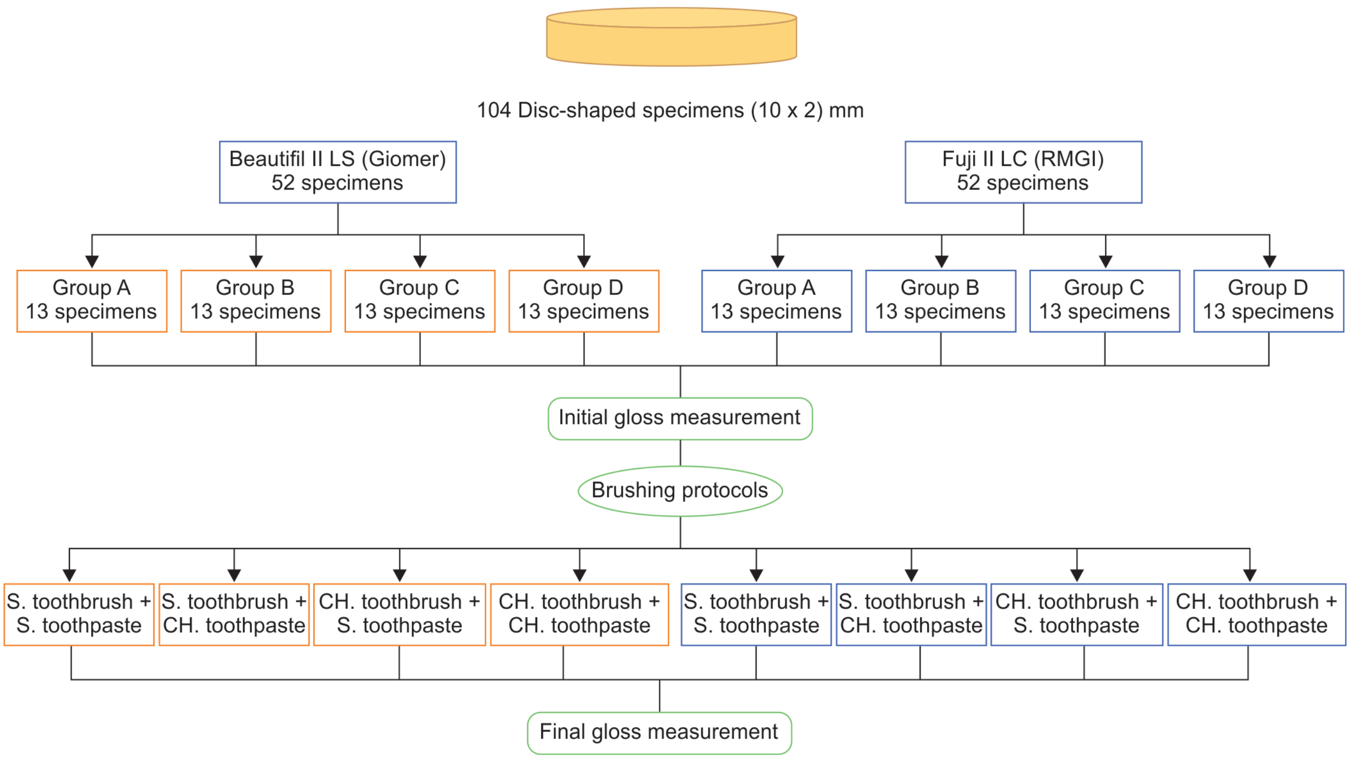

Fig. 1: Flowchart diagram of the study design

an electric toothbrush infused with charcoal (Oral-B pure clean®, Braun, P&G Manufacturing Ltd, Ireland). Additionally, two types of toothpaste were used: a standard non-whitening toothpaste (Crest cavity protection®, Procter & Gamble UK) and a toothpaste containing activated charcoal (Optic white Charcoal, Colgate-Palmolive®, Poland).

Grouping of the Specimens and the Study Design

A total of 104 disc-shaped specimens, 52 from each of the two restorative materials, were prepared and randomly split into four groups ($n = 13$) according to the applied brushing methodology as follows (Fig. 1):

- Group A (S-S): the specimens were brushed using a standard toothbrush with a standard non-whitening toothpaste (positive control).
- Group B (S-CH): Specimens were brushed using a standard toothbrush with activated charcoal toothpaste.
- Group C (CH-S): Specimens were brushed using a charcoal-infused toothbrush with a standard non-whitening toothpaste.
- Group D (CH-CH): Specimens were brushed using a charcoal-infused toothbrush with activated charcoal toothpaste.

Preparing the Specimen

A silicon mold was used to prepare the specimens (10 mm in diameter and 2 mm in height). Each tested material was applied into the mold as one increment and then was gently pressed with a 10 mm wide polyester strip (TOR Transparent Strips No. 1.040, TOR VM, Moscow, Russia) covered with a glass plate to remove any excess material and create a uniformly smooth surface. Following the manufacturer's instructions, specimens were light-cured for 20 seconds on each surface using a light-emitting diode curing lamp (Coltolux LED, Coltene Whaledent, USA) and to ensure proper polymerization, the specimens were stored in distilled water for 24 hours at 37°C before testing.

Figs 2A to D: Clinical images of the devices utilized in the study. (A) The standard toothbrush replacement head; (B) The charcoal-infused toothbrush replacement head; (C) The electric toothbrush; and (D) The gloss meter

Simulated Brushing of the Specimens

One surface of each sample was brushed for a total of 4 minutes. For each toothpaste, a slurry was made through the mixture of 1 gm of toothpaste with 2 gm of deionized water, as advised by the International Organization of Standardization (ISO/TR 14569-1:2007) and documented in earlier research.[15]

The brushing was performed using an electric toothbrush (Oral-B, Braun, Germany) that rotates continuously (Fig. 2). The electric

Table 2: Gloss (GU) means and standard deviations (± SD) of the two tested restorative materials initially and after each brushing protocol

	Beautifil II LS (Giomer)				*Fuji II LC (RMGI)*				
	Group A (S-S)	*Group B (S-CH)*	*Group C (CH-S)*	*Group D (CH-CH)*	*Group A (S-S)*	*Group B (S-CH)*	*Group C (CH-S)*	*Group D (CH-CH)*	*p-value*
Baseline	46.7 (2.3)^{Aa}	47 (1.7)^{Aa}	48 (1.4)^{Aa}	46.1 (1.8)^{Aa}	37.2 (4.2)^{Ba}	31.7 (4.5)^{Ba}	33.8 (4.2)^{Ba}	30.9 (4.2)^{Ba}	0.001*
After brushing	32.2 (4)^{Ab}	22.7 (3.9)^{Bb}	23.2 (3.6)^{Bb}	44 (3.9)^{Ca}	15.4 (8.7)^{Db}	4.4 (2.5)^{Eb}	10.9 (6)^{Fb}	16.6 (3.7)^{Db}	0.000*
p-value	0.0001*	0.000*	0.000*	0.42	0.001*	0.001*	0.001*	0.001*	

Means with different superscript uppercase letters within the same row are significantly different, means with different superscript lowercase letters within the same column are significantly different, *$p \leq 0.05$

brush was fixed to a specially designed attachment device with a 200 gm weight, following ISO 11609:2017 guidelines. A precision scale was used to adjust the load while brushing. The specimens were mounted to a silicon holder, each specimen had a new brush head placed in direct contact with and parallel to its surface. The toothbrush heads were replaced according to the brushing technique used in the study. Following the brushing procedure, the specimens were properly rinsed with distilled water and then dried before being tested.

The Gloss Test Measurement

Gloss measurements were recorded using a small area gloss meter (AMTAST Precise Gloss-Meter, USA) with a 60° measurement mode (Fig. 2D), which complies with the International Organization for Standardization (ISO) standard (ISO 2813:2014), for specimens of medium gloss. Before testing, the device was calibrated using a black glass reference that the manufacturer supplied, and a black opaque lid blocked all ambient light. A positioning custom-made apparatus was constructed to position each specimen in the center of the reading window and ensure repeatable measurements using the same specimen orientation. The light beam reached the specimen's surface before being reflected to the sensor at the two tested time points: baseline and after treatment. Three gloss unit (GU) values were recorded from each specimen and averaged to represent the mean gloss value.

Statistical Analysis

Means and standard deviations (SDs) were calculated for each group. Data were statistically analyzed using the Statistical Program for Social Sciences (SPSS®, Version 27, IBM, NY, USA). The data was normally distributed according to the Kolmogorov–Smirnov test and the Shapiro–Wilk test. Two-way analysis of variance (ANOVA) test was conducted to test the null hypothesis, followed by Tukey HSD *post-hoc* test with Bonferroni's correction for multiple pairwise comparisons between the groups. The significant level was set at $p \leq 0.05$.

Results

The initial and post-brushing gloss values' means and SD of the current study are presented in Table 2. The two-way ANOVA test revealed significant differences and interactions between the groups ($p < 0.001$). Inter-group comparison between the two materials revealed that the initial gloss values of the Giomer (average ≈ 46 GU) were significantly higher than the RMGI (average ≈ 33 GU), ($p = 0.001$). After brushing, the gloss values of Giomer remained significantly ($p = 0.000$) higher in all the groups, A: 32.2 ± 4, B: 22.7 ± 3.9, C: 23.2 ± 3.6, and D: 44 ± 3.9 than the RMGI groups, A: 15.4 ± 8.7, B: 4.4 ± 2.5, C: 10.9 ± 6, and D: 16.6 ± 3.7.

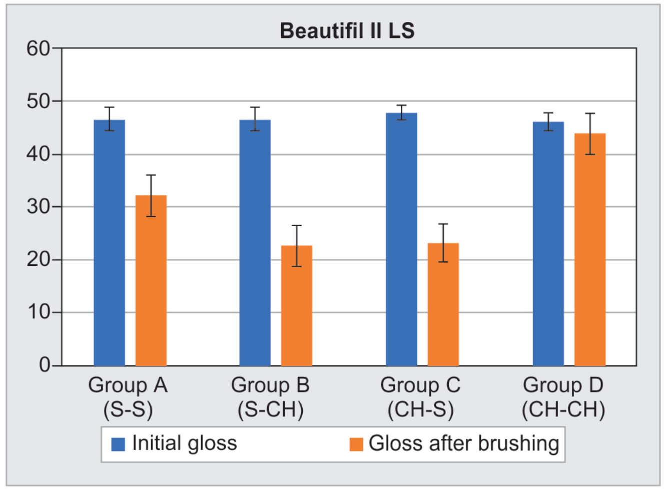

Fig. 3: Bar chart showing the gloss of Beautifil II LS (Giomer) initially and after each brushing procedure

Intragroup comparison between initial and after-brushing gloss values within the same material revealed that the Giomer showed a significant reduction in the gloss after brushing in all the groups ($p = 0.000$) except for the group D; brushed with a combination of charcoal-infused toothbrush and activated charcoal toothpaste (CH-CH), where the reduction in gloss value was not significant ($p = 0.42$) (Fig. 3). The RMGI gloss values reduced significantly in all of the brushing groups ($p = 0.001$) and groups D (16.6 ± 3.7) and a (15.4 ± 8.7) showed the highest gloss values with statistically no difference between both, while the lowest gloss was recorded for group B (4.4 ± 2.5) (Fig. 4).

Discussion

The present study investigated the gloss retention of two esthetic restorative materials after using charcoal-infused toothbrush and charcoal-based toothpaste compared to their standard counterparts. The toothpaste and toothbrush combinations used in this study were considered to mimic actual clinical settings, where patients are recently attracted to the charcoal oral hygiene products to eliminate teeth staining with little information about their effect on the esthetic restoration properties. Significant variations in the gloss of each material across the brushing protocols were revealed by statistical analysis. Therefore, the null hypothesis was rejected.

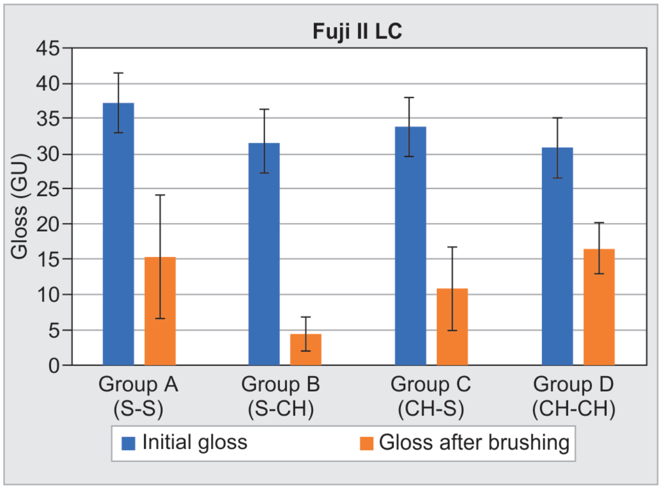

Fig. 4: Bar chart showing the gloss of FUJI II LC (RMGI) initially and after each brushing procedure

The restorative materials chosen for this investigation are fluoride-releasing and therefore have a broad variety of uses as direct restorations due to fluoride's powerful caries prevention ability.[16,17] To standardize the surface evenness of all the specimens before testing, a Mylar strip was applied to the top of each specimen before curing and pressed with a glass slide without polishing. Previous research has shown that using polyester strips to prepare restorative materials specimens resulted in a smoother surface.[5,18]

The simulated tooth brushing in the current study was adapted from previous studies.[16,19] Assuming that daily oral hygiene procedures on the same intraoral zone necessitate 10 seconds of brushing per day, the simulated brushing period in the current study was 4 minutes or around one month's duration of brushing.

Gloss was assessed using a gloss meter set at a striking angle of 60°, which closely approximates the angle at which an individual of average height perceives the surface reflected light. This measurement angle adheres to the (ISO 28132014) standard.[20] The gloss of 40–60 GUs is considered visually acceptable for esthetic restorations as reported by the American Dental Association (ADA) as well as in previous studies,[13,21] accordingly; the initial gloss values of Giomer recorded in the present study are considered clinically acceptable (average ≈ 46 GU), which is significantly higher than the gloss values recorded initially for RMGI. The RMGI gloss values are even lower than the accepted limit (average ≈ 33 GU), this variation in the initial gloss values of the currently tested materials is in line with a study by Rodrigues Jr. et al.,[22] in which it was noted that the gloss is affected by the microstructural characteristics of the material, such as the size, shape, and refractive index of the filler particles, as well as the viscosity and refractive index of the matrix, and the homogeneity of the matrix-filler complex. Smaller filler particles result in lower diffuse reflection of light and subsequently a higher gloss value.[23] The lower gloss values of RMGI were also reported in a study by Vance et al.,[7] his finding was justified by the higher water sorption nature of the RMGI than resin composites. A previous study done by Müller et al.[24] has shown that the glass ionomer's activation by light is not effective against water sorption, in contrast; the hydrophilic resin (HEMA), in RMGI, causes it to act like a hydrogel, which leads to surface deterioration and subsequent decreased gloss values.

The gloss of Giomer in the current investigation decreased significantly beyond the accepted limit after brushing in the groups A (S-S), B (S-CH), and C (CH-S), these results are in line with a previous study by Lefever et al.[25] and Yu et al.[26] who found that reduction in the gloss occurred in composite resin after simulated tooth brushing. On the other hand, the reduction in group D (CH-CH) was not significant compared to its initial gloss values, this finding suggests that the abrasion power was less after brushing with a combination of charcoal-infused toothbrush and activated-charcoal toothpaste compared to the remaining groups. One explanation could be that the charcoal-infused toothbrush has a high capacity for adsorbing ions from the toothpastes, which limited the free movement of the abrasive particles and distributed the abrasive force evenly over a larger surface area of the Giomer specimen, resulting in a smoother surface. Gupta et al.[27] suggested in a previous research that because charcoal has a high absorption capacity, toothpaste containing charcoal may inactivate fluoride or other active ions, reducing the toothpaste's ability to remineralize the oral tissues and prevent caries formation. According to research by Vaz et al.,[28] activated charcoal's high porosity allows it to effectively adsorb and retain the chromophores in the oral cavity, and thus it can be used to clean teeth. However, in the present study, the high adsorption capacity of the charcoal-infused toothbrush was effective in gloss retention when combined with charcoal toothpaste in group D but not in group C; where it was combined with the standard non-whitening toothpaste, this is most likely caused by the variations in the tested toothpastes' relative dentin abrasivity (RDA), which is used to gauge how abrasive the toothpastes are to dentin. Higher RDA dentifrices usually cause more abrasion.[8] The abrasive capacity of the dentifrices was not evaluated in this trial; nevertheless, prior research indicates that crest cavity protection has a comparatively greater relative dentin abrasivity (RDA = 98.6)[29] than Colgate Optic White Charcoal (RDA = 76).[30] The ISO, however, classifies both toothpastes as medium abrasives (ISO 11609:2017). This result is further corroborated by Osmanaj et al.[31] who examined the abrasion characteristics of various charcoal toothpaste formulations on human dentin. It was determined that the amount of activated charcoal in charcoal toothpastes had little effect on the observed abrasive behavior when using electric toothbrushes; therefore, it does not appear that the amount of activated charcoal dominated the abrasive behavior, and silica content in the toothpaste appeared to have a more significant, if not dominant, role. The current study's finding, however, contradicts the results of Matroja et al.[32] who discovered that coated manual toothbrushes, including charcoal toothbrushes, caused more abrasion than nylon noncoated toothbrushes, similar findings were reported by Koc Vural et al.[8] and Pertiwi et al.[33] which stated that the utilization of toothpaste containing charcoal has the potential to exacerbate the surface irregularity of tooth enamel with subsequent reduction in surface gloss. This discrepancy may be attributed to the experimental design of the current study, which focused on restorative materials rather than natural enamel.

The RMGI demonstrated a significant reduction in all of its brushing groups compared to their initial gloss values, range (16.6–4.4 GU), these values were also significantly lower than the gloss values of the brushed Giomer groups, this finding is in agreement with a study by Komandla et al.[34] and has probably occurred because the RMGI material is made of unreacted glass particles encapsulated in a matrix of poly-salt resin. A possible assumption is that the tooth-brushing stimulation induces a selective removal of the softer matrix, which in turn causes the harder, unreacted glass particles to protrude from the surface. According to an earlier study by Carvalho et al.,[35] these large and irregular filler particles can then readily separate from the resin matrix and become trapped against the specimens, functioning as an additional abrasive agent, resulting in a change in the light reflections with subsequent reduction of the gloss.

Certain clinical variables that were not included in the current *in-vitro* investigation, such as the effects of saliva, varying temperatures, and other factors of the oral environment, can be considered limitations that can be replicated in future studies. Further research should be conducted to determine how various toothpaste formulations interact with the charcoal-infused toothbrush and whether increasing the number of brushing cycles affects the gloss retention of the restoration.

Conclusion

Considering this *in-vitro* study's limitations, the gloss of both the Beautifil II LS and Fuji II LC was reduced significantly following the brushing with the tested brushing procedures, except for the Beautifil II LS group brushed with a combination of charcoal-infused toothbrush and activated-charcoal toothpaste, in which the gloss was retained within the visually accepted limit. Further studies should consider the effects of charcoal-infused toothbrushes and activated charcoal toothpastes on the gloss retention of other restorative materials.

Clinical Significance

Based on the outcome of the current study, brushing using a combination of charcoal-infused toothbrush and activated-charcoal toothpaste can be recommended by clinicians to patients having Beautifil II LS restorations, to maintain their glossy appearance, however, the gloss of the Fuji II LC cannot be retained after any of the brushing procedures and may require professional re-polishing or replacement upon recall visits.

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