Original Article

Spectrophotometric Analysis of Color Stability of Three Different Restorative Materials

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ABSTRACT

Objective: To compare in vitro the color stability of three different restorative materials by spectrophotometric analysis at time intervals of 24 hours, 1 week, 2 weeks, and 4 weeks after exposure to cola drink and tea.

Methodology: This in-vitro experimental study was conducted in the Applied Chemistry Research Center at PCSIR laboratory after ethical approval from Institutional Review Board (IRB) of FMH College of Dentistry Lahore. Three different restorative materials [(Biodentine™, Resin-Modified Glass Ionomer Cement (RMGIC), and Glass Ionomer Cement (GIC)] were evaluated for color stability. Eighteen disc-shaped specimens (20 × 2 mm) were prepared using an acrylic ring mould. Color coordinates ($L^*a^*b^*$, ΔL^*, Δa^*, Δb^*, and ΔE^*) were measured using a spectrophotometer. All the fabricated specimens were subdivided into two groups; A and B (n= 9 each) and immersed in distilled water for 24 hours for baseline color evaluation. Thereafter, the specimens of group A and B were immersed in two different beverages *i.e.* cola drink (n= 9) and tea (n= 9), respectively. The restorative materials were evaluated at intervals of 1 week, 2 weeks, and 4 weeks of storage. These specimens were subjected to pH cycling by immersion in demineralizing and remineralizing solution and immersed in cola drink and tea for 30 minutes for the entire duration of the study. Data was analyzed using Statistical Package for the Social Sciences (SPSS) version 20. The color changes (ΔE) were calculated and analyzed by Friedman's test to identify the significant group at a 5% confidence level.

Results: At 24 hours interval, the ΔE of all the restorative materials was statistically insignificant. The statistical analysis depicted that the ΔE of group B (tea) was significantly lesser than that observed with group A (cola drink) for Biodentine™ and RMGIC. On the contrary, ΔE of group A (cola drink) was observed to be lesser for GIC in comparison to group B (tea). The color change gradually decreased over the period of 4 weeks in both groups for all the restorative materials.

Conclusions: Mean color change after 4 weeks of immersion in cola drink and tea was most significant for Biodentine™ in comparison to RMGIC and GIC. However, RMGIC depicted better mean color stability than other restorative materials.

Keywords: *Color Stability. Spectrophotometer. Biodentine™. Glass Ionomer Cement (GIC). Resin-Modified Glass Ionomer Cement (RMGIC).*

INTRODUCTION

Replacement of a missing tooth or a part of the tooth structure has always been a challenging task for dental practitioners. Any effective permanent restorative material should be able to fulfill three main criteria *i.e.* optimal strength, dimensional stability, and ability to replicate natural esthetics for their clinical efficiency over a considerable period. Over the years, patient awareness and demand for esthetically appealing dental replacements have increased. Therefore, a multitude of restorative materials and treatment modalities have been developed to conform with the requirements of the aesthetic properties of restorative materials.[1]

A dental restorative material must not only mimic the natural dentition in color, translucency, and surface texture but should also exhibit long term resistance to color changes on exposure to a wide variety of discoloring substances.[2] Marginal or surface discoloration is one of the leading clinical shortfalls of tooth-colored restorations.[3] Tooth discolorations can generally be classified as extrinsic or intrinsic. Discoloration may also be due to physiochemical reactions in the deeper part of the body of the restorations, known as intrinsic discoloration.[1] Extrinsic discoloration is a broad term, comprising of adsorption and absorption.[3] Adsorption governs the external discoloration due to the accretion of dental plaque and surface stains, while the surface or subsurface color transitions, denoting superficial deterioration or slight ingress and reaction of staining agents with the superficial layer of restorative materials are due to absorption phenomenon.[1] Extrinsic discoloration is usually fostered by coloring agents in beverages and foods.[3] A variety of substances used routinely ultimately cause esthetic compromise. Many dietary factors have a prime role in the staining of oral tissues and dental restorations.[2] A multitude of studies exist on the beverage-dependent discoloration of tooth-colored restorations. The beverages used in most of these studies were coffee, tea, and wine, which are usually cognate with adult tooth stains.[4]

Conventional glass ionomer cement (GIC) are fluoride-releasing dental restorative materials that are prone to discoloration. Modern developments led to the production of newer materials such as composites, polyacid modified composites, and resin-modified glass ionomers (RMGIC); all of which have

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significantly better mechanical as well as esthetic properties. However, there is meager data available relating to the color stability of these hybrid restorative materials.[2]

Progressive tooth discoloration has also been reported to be the result of the penetration of endodontic materials into dentinal tubules.[5] Many endodontic procedures like; direct pulp capping, pulpotomy, perforation repair, and retrograde fillings require the placement of restorative materials in the coronal part of the tooth, which may cause tooth discoloration after some time of treatment completion.[5-6] Therefore, the color stability of endodontic materials is considered an important factor for clinical success; particularly in endodontically treated teeth.[7]

This mandates that the material selection should not rely entirely on biological and functional criteria alone, but aesthetic considerations should also be taken into account. [5,8]

Biodentine™ is a calcium silicate-based restorative material. This material is an advanced Mineral Trioxide Aggregate (MTA) based cement and therefore, it has been proposed as a "dentine replacement" material.[9] Earlier, MTA has been known for its excellent marginal adaptation, cell proliferation induction, and the formation of a high-quality hard tissue barrier. [10] Biodentine™ claims to have improved physical and handling properties, which were the shortfalls of MTA. This material has an array of clinical applications, including a variety of endodontic repairs and pulp capping.[11]

Discoloration can be assessed clinically to determine the outcomes over a long period of time but in-vitro analysis using a spectrophotometer are a prescribed standard for assessment of the quantity of color transition in restorative materials. It involves using systematized colorimetric equipment for matching and measuring color that provides accurate data about reflectance curve as a function of wavelength in the complete range.[1] This study was aimed to assess and compare the color stability of three different restorative materials, Biodentine™, RMGIC, and GIC, after exposure to frequently used beverages, cola drink and tea, which causes staining in restorations.

METHODOLOGY

This in-vitro experimental study was conducted at Applied Chemistry Research Center at PCSIR laboratory after ethical approval from IRB of FMH college of Dentistry Lahore. The total duration of the study was three months. A total of 54 specimens, 18 specimens for each restorative material i.e. Biodentine™, Glass Ionomer Cement (GIC), and Resin Modified Glass Ionomer Cement (RMGIC) were included in the study.

Specimen Fabrication:

An acrylic ring mould (20×2 mm) was used to fabricate standardized specimens of each restorative material**.** All specimens were made following the manufacturer's instructions for accurate material manipulation. Biodentine™ and RMGIC were manipulated in an amalgamator for 10 seconds to achieve a homogenous smooth mix. The mould was filled with the mixed materials individually and covered with a Mylar strip to ensure the surface smoothness and adaptation of the set materials. Glass Ionomer Cement was hand-mixed by following the standard protocols and the specimens were fabricated using a similar mould.

All the fabricated specimens of the three materials were subdivided into two groups A and B (n=9). Group A was cola drink (The Coca-Cola Company, Atlanta, GA) and group B was tea (one Lipton yellow label tea bag dipped in 200ml boiling water for 10 minutes). These specimens were preserved in distilled water for 24 hours at ambient temperature to prevent desiccation. Before the spectrophotometric analysis, the specimens were rinsed and then dried with blotting paper.

Baseline Color Evaluation:

The baseline color was measured with the help of a spectrophotometer (Nicolet Evolution Model 100 UV, Thermo Electronic Corporation) at 24 hours interval (T1). The color parameters were based upon an illuminating view geometry d/10 and average daylight (D65: 6504 K) standard. A white standard was used for calibration. The specimens were positioned on aperture individually, and values were recorded according to Commission Internationale de l'Eclairege L*a*b* color space (CIELAB).[12]

Specimen Processing For Staining:

After the baseline color evaluation, the specimens were immersed in two different beverages *i.e.* cola drink (group A) and tea (group B). The specimens were treated for pH cycling by bathing in the demineralizing solution for 7.5 hours and then its mineralizing solution for 16 hours daily. For this purpose, the demineralizing solution was prepared using 2.2mM $CaCl_2$, 2.2mM NaH_2PO_4, and 50mM Acetic acid of pH 4.8. The remineralizing solution was prepared using 1.5mM $CaCl_2$, 0.9mM NaH_2PO_4, and 0.15 M KCl adjusted to pH 7. These solutions acted as a preservation medium for the specimens to simulate the ongoing changes in the oral environment.

The specimens were daily withdrawn from pH cycling solutions and bathed in cola drink and tea for 30 minutes for the entire duration of the study. After immersion and pH cycling, the color change was evaluated after 1 week (T2), 2 weeks (T3), and 4 weeks (T4).

Measuring the Color Change:

All the readings were measured at specified time intervals of 1 week (T2), 2 weeks (T3) and, 4 weeks

(T4). The values of ΔL* (degree of lightness), Δa* (hue i.e. color), and Δb*(Chroma i.e. vividness/dullness) were calculated after taking the three individual measurements on the spectrophotometer (Nicolet Evolution Model 100 UV, Thermo Electron Corporation).[13] Resistance to discoloration was expressed in ΔE unit and estimated from the mean ΔL*, Δa*, and Δb* values for each specimen by using the formula $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.[14]

STATISTICAL ANALYSIS

The study data gathered was entered and processed with Statistical Package for the Social Sciences (SPSS) version 20.0. Descriptive statistics i.e. mean and the standard deviation were calculated. The comparative assessment of mean color change (ΔE) as a function of two different beverages on specified time intervals was obtained using the Friedman test and the significant groups were identified at a 5% confidence level. Wilcoxon signed-rank test was employed to assess the mean color change between the two groups (i.e. A and B).

RESULTS

Mean color change (*ΔE*) of the specimens bathed in distilled water for the first 24 hours (T1), followed by immersion in cola drink at different time intervals (*i.e.*T2, T3, and T4) is shown in Table 1. The mean color change (*ΔE*) of the specimen immersed in distilled water for the first 24 hours (T1) and then in tea at different time intervals (*i.e.*T2, T3, and T4) is depicted in Table 2. The overall effects of both the beverages on Biodentine™, GIC, and RMGIC are illustrated in Figures 1, 2, and 3, respectively.

Closer to zero reading of *ΔE* is suggestive of increased staining (*i.e.* color change) on spectrophotometric analysis. The statistical interpretation depicted that the *ΔE* of group B (tea) was significantly lesser than that of group A (cola drink) for Biodentine™ and RMGIC (Figure 1 and 3). On the contrary, *ΔE* of group A (cola drink) was observed to be lesser for GIC in comparison to group B (tea) (Figure 2). The most significant mean color change was recorded for Biodentine™ in both groups A and B from T1 to T4 intervals (Table 1 and 2). The color change depicted a gradual increasing trend over the period of 4 weeks (T4) in both the groups for all the restorative materials (Table 1 and 2). The only nearly stable observations were recorded for RMGIC at T2 (Mean ±SD =71.65±1.00) and T3 intervals (Mean ±SD =71.63±1.14) in group B (Table 2).

The overall results of the study revealed that the maximum mean color change appeared to be at T4 of immersion in cola drink and tea for all the restorative materials. The mean color change in all the restorative materials gradually increased over a period of 4 weeks. The most significant increase in mean color change was observed for Biodentine™ as compared to GIC and RMGIC (Table 1 and 2). It is thus hypothesized, based on the statistical interpretation of the data, that RMGIC relatively indicated better mean color stability than that manifested by Biodentine™ and GIC (RMGIC; p=0.016 and p=0.092 for group A and B, respectively) (Table 1 and 2).

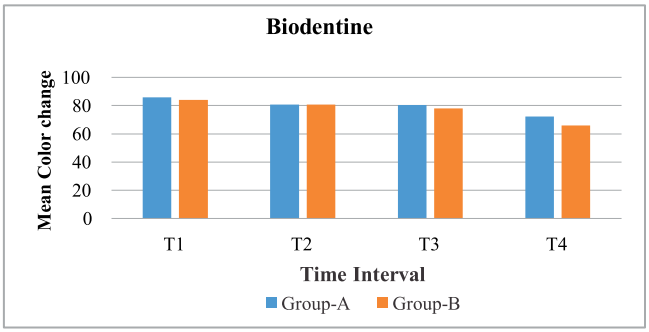

Figure 1: Mean Color Change (ΔE) of Biodentine™ After Storage in Cola Drink (Group A) & Tea (Group B)

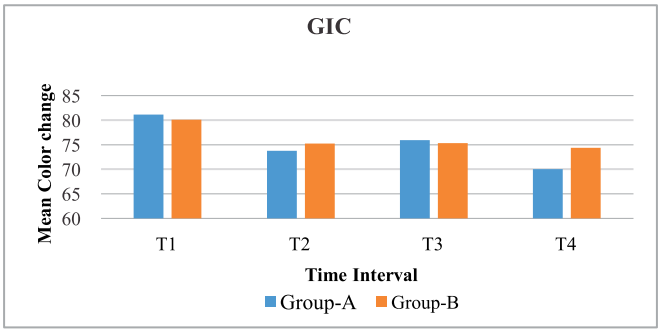

Figure 2: Mean Color Change (ΔE) of GIC After Storage in Cola Drink (Group A) & Tea (Group B)

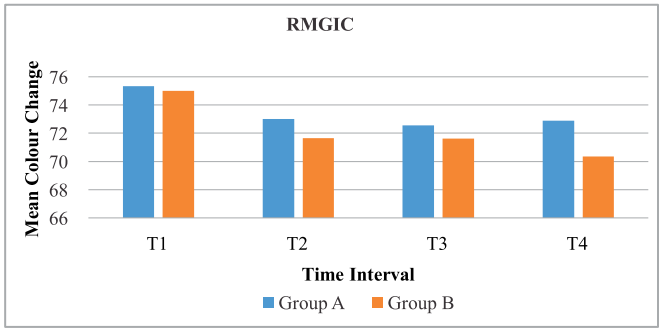

Figure 3: Mean Color Change (ΔE) After Storage in Cola Drink (Group A) & Tea (Group B) on RMGIC

Table 1: Mean Color Change (ΔE) After Storage in Cola Drink (Group A) on Three Different Restorative Materials at Specified Time Intervals (n=9)

Material	Time Intervals	Mean±SD	p-value
Biodentine™	T1	85.83±0.64	0.000
	T2	80.76±1.99	
	T3	80.34±1.77	
	T4	72.17±1.96	
GIC	T1	81.18±2.89	0.000
	T2	73.77±2.07	
	T3	75.93±1.62	
	T4	70.04±0.74	
RMGIC	T1	75.34±1.10	0.016
	T2	73.01±2.28	
	T3	72.56±1.73	
	T4	72.88±1.56	

T1: 24 hours (Baseline), T2: 1 week after immersion, T3: 2 weeks after immersion, T4: 4 weeks after immersion

Table 2: Mean Color Change (ΔE) After Storage in Tea (Group B) on Three Different Restorative Materials at Specified Time Intervals (n=9)

Material	Time Intervals	Mean±SD	p-value
Biodentine™	T1	84.04±2.72	0.000
	T2	80.57±1.26	
	T3	78.01±2.49	
	T4	65.80±2.96	
GIC	T1	80.11±0.82	0.000
	T2	75.21±1.39	
	T3	75.33±1.10	
	T4	74.38±0.58	
RMGIC	T1	74.99±2.18	0.092
	T2	71.65±1.00	
	T3	71.63±1.14	
	T4	70.35±1.06	

T1: 24 hours (Baseline), T2: 1 week after immersion, T3: 2 weeks after immersion, T4: 4 weeks after immersion

DISCUSSION

The color stability of three different dentine-replacement restorative materials namely Biodentine, glass ionomer cement (GIC), and resin-modified glass ionomer cement (RMGIC) was evaluated and compared by spectrophotometric analysis after immersion in tea and cola. A standardized solution of tea (one Lipton yellow label tea bag dipped in 200ml boiling water for 10 mins) and cola drink (The Coca-Cola Company, Atlanta, GA) were used for immersion of specimens to replicate the oral environment, where these beverages may be consumed occasionally or regularly.

The surface discoloration is closely related to the thickness of the restoration, Therefore, the thickness of experimental specimens used in this study was 2 mm as per International Orgainzation for Standardization standards [12] and spectrophotometry requirements.[5] This

thickness of specimens has been reported as technically acceptable to reduce the background effect and minimize error.[14-16] The American Dental Association (ADA) suggests the application of the CIELAB color differential system for estimating chromatic differences and changes which was employed for this study.[17]

In this study, a pH cycling procedure was employed to imitate oral environmental conditions. It has previously been demonstrated that fluoride-releasing materials have a greater ion release potential when exposed to pH variations than when solely kept in artificial saliva or saline.[2] These facts could instigate lower color stability of GIC in comparison to RMGIC as evident from the results of the present study and studies conducted by Bezgin et al., and Savas et al.[18,19] They concluded that there was a significant ($p<0.05$) change in the level of staining of GIC after immersion in cola drink for 28 days.

Resin-Modified Glass Ionomer Cement (RMGIC), being resin-based possesses comparatively low fluoride release, and for this reason, it has shown the least amount of discoloration due to the reduced ionic interchange between the material and the environmental solutions (Table 1 and 2) (Figure 2 and 3). Furthermore, the susceptibility of resin-based materials, even if it is to a lesser extent, may be accredited to their extent of water sorption and hydrophilic characteristics of the resin matrix.[18,19] This denotes if the resin component can absorb water, it is also likely to absorb other staining fluids like tea and coffee.[5]

In this study, the maximum mean color change took place after 4 weeks (T4) of storage in cola drink and tea solutions for all three restorative materials. Our findings are in contradiction to the observations of a previously conducted study. Hotwani et al., delineated in their work that staining after 1 week of immersion differed remarkably from all the following weeks and the maximum amount of color change appeared during the first week.[20] This difference in observations can be ascribed to the choice of test restorative materials as Biodentine™ was not introduced at that point in time and this material has the greatest influence on the results of the present study.

The highest mean color change was observed for Biodentine™ when compared to GIC and RMGIC of immersion in both the beverages [Table 1 and 2]. These findings may be attributable to the fact that Biodentine™ possesses entirely different physicochemical properties than GIC and RMGIC.

Calcium silicate-based materials are hydraulic, self-setting materials with intrinsic physiochemical properties appropriate for pulp therapy. Biodentine™ exhibits superior clinical physical properties such as good sealing, increased compressive strength, decreased porosity, higher density, bioactivity, the release of ions acting as epigenetic signals, the immediate formation of calcium hydroxide, biomineralization ability, biointeractivity, and color stability compared to mineral trioxide aggregate (MTA).[21] Biodentine™ with Chlorohexidine (CHX) should be avoided because of its propensity to cause clinically perceptible severe discoloration.[5] In contradiction to this, a number of recent studies have depicted high color stability of Biodentine™.[22,23] In the present study, Biodentine™ demonstrated the maximum amount of discoloration (Figure 1). This may be ascribed to the coarse surface texture and hydrophilicity of the set material.

In the present study, group B (tea) demonstrated a more pronounced mean color change in comparison to group A (cola drink) except for T2 and T4 in GIC (Figure 1, 2, and 3). This finding may be attributable to the concentration of the tea solution used in this study.

CONCLUSIONS

It can be concluded that the most significant increase in mean color change has been observed for Biodentine™ when compared to GIC and RMGIC. It can be enunciated that RMGIC manifests greater resistance to staining in comparison to the Biodentine™ and GIC at each time interval.

LIMITATIONS AND RECOMMENDATIONS

The limitations of the current study are that the impact of only two beverages (cola drink and tea) on the color change of three different restorative materials was evaluated. Also, only a single thickness of the test specimens was used (i.e. 2mm). Samples used in this study had smooth surfaces for standardization requirements. However, in clinical situations, the majority of cement does not possess a flat and absolute finished surface and the pH values of the oral cavity vary amongst individuals.

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