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EFFECT OF SIMULATED GASTRIC ACID ON SURFACE ROUGHNESS OF GLASS HYBRID RESTORATIVE MATERIAL WITH OR WITHOUT SURFACE COAT

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ABSTRACT

Aim: To evaluate the effect of simulated gastric acid on the surface roughness of a glass hybrid (GH) restorative material, with and without a protective coat.

Materials and Methods: Two groups of GH restorative material, EQUIA Forte HT Fil, with and without the application of EQUIA coat, were tested for surface roughness after exposure to artificial gastric acid (HCl). A total of 28 specimens were prepared using a plastic mold (8 mm in diameter × 2 mm in thickness). Fourteen specimens of each material group were divided based on aging conditions, with n = 7 specimens in each subgroup. One subgroup served as the control (no HCl exposure), while the other was immersed in HCl for aging. In the HCl group, specimens were immersed in HCl for three hours, simulating one year of clinical service. Surface roughness measurements (Ra) were obtained using a contact profilometer.

Results: Data were collected and statistically analyzed where a statistically significant difference ($p < 0.001$) was observed between EQUIA without coat and EQUIA with coat in the HCl test conditions. The application of EQUIA Forte coat significantly improved the surface roughness of EQUIA under acidic conditions. EQUIA without coat showed significantly higher roughness values after HCl exposure compared to no HCL exposure ($p < 0.001$).

Conclusion: Surface protection of EQUIA Forte HT Fil with a resin coat, such as EQUIA coat, is recommended for patients at high risk of acidic exposure to enhance the longevity and resistance to acidic degradation of restorations under endogenous erosion.

KEYWORDS: glass hybrid, EQUIA, coat, surface roughness, HCL, contact profilometer.

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INTRODUCTION

Non-carious cervical lesions (NCCLs) refer to the pathological loss of tooth structure in the cervical area, not caused by caries. These lesions can result from dental erosion and/or abrasion during various stages of lesion development.[1] Dental erosion is the irreversible loss of tooth structure due to chemical processes from extrinsic or intrinsic sources, independent of microorganisms.[2] Intrinsic factors, such as recurrent vomiting in eating disorders and gastroesophageal reflux disease (GERD), contribute to dental erosion through gastric acid exposure.[3]

In recent years, NCCLs have gained recognition as a significant oral health issue due to their association with hypersensitivity, plaque accumulation, and aesthetic concerns.[1] Selecting suitable restorative materials for the treatment of NCCLs is challenging due to factors like enamel loss, difficulty in isolation, sensitivity, aesthetics, lesion anatomy, cervical stress, and dentinal sclerosis. These considerations complicate material selection for effective restoration.[4]

Glass ionomer cements (GICs) have a wide range of clinical applications in managing NCCLs. These materials demonstrate durable adhesion to enamel and dentin, sustained fluoride ion release, favorable biocompatibility, and a coefficient of thermal expansion similar to that of tooth structures, enhancing their clinical performance and compatibility.[5] However, GICs are highly susceptible to abrasion, which can lead to increased surface roughness over time.[4]

It is recommended that conventional GICs be sealed within the first 24 hours during setting to protect them from immediate water contamination. Sealing also helps occlude surface cracks and porosities, thereby increasing wear resistance, toughness, gloss, translucency, and marginal seal.[6,7]

Glass hybrid (GH) restorative materials exhibit superior aesthetic properties compared to conventional GICs due to their increased translucency and wider range of shades. Additionally, advancements in their composition, including reinforced glass phases with smaller reactive silicate particles and high molecular weight acrylic acid, enhance matrix cross-linking and material integrity. These innovations improve the physical and mechanical properties of GH materials, leading to enhanced clinical performance.[8,9]

The application of a protective coat over GH restorations, which is a clear, light-cured resin coating, is recommended. This coating optimizes surface polish, strengthens and protects the material, and significantly improves its wear resistance.[10]

Surface smoothness is essential for minimizing plaque accumulation, discoloration, and wear, as well as enhancing aesthetics, gloss, and color stability in tooth-colored restorations.[11] Increased surface roughness has been associated with higher risks of gingival inflammation and secondary caries. This issue is particularly critical in cases of NCCLs, where overhanging or rough subgingival cervical margins can exacerbate the problem.[12]

Based on the previous data, the purpose of this study was to investigate surface roughness of a GH material under simulated gastric acid, examining the effect of acidic conditions on the material both without EQUIA Coat application and with EQUIA Coat application. The tested null hypothesis was that the application of a coat on the surface of the tested GH material would not affect surface roughness, regardless of the aging condition.

MATERIALS AND METHOD

A glass hybrid restorative material was used in this study (EQUIA Forte HT Fil and EQUIA coat). The materials, their types, manufacturers, compositions, and lot numbers are detailed in **Table 1**.

Sample size calculation

Sample size for surface roughness testing was calculated using GPower software (Ver. 3.1.9.7; GPower, Kiel, Germany). The calculation was based on a similar study design from a previous study,[3] considering the following parameters: a two-tailed test, an effect size of 2.25, a significance level (α) of 0.05, 80% power, and an allocation ratio of 1. The calculated sample size per group was seven.

MATERIALS

A total of 28 specimens were prepared and divided into two groups (n=14) according to the use of a protective coat (with and without coat). These were further subdivided into two subgroups based on aging conditions (HCl): a test group (immersed in HCl) and a control group (not immersed in HCl), each containing 7 specimens. The other set of specimens with EQUIA coat application was similarly divided into test and control groups.

METHODS

Specimens' preparation

The mold assembly was prepared in the following sequence: a microscopic glass slide was first fixed with tape, along with a Mylar strip. Next, an acrylic mold (2 mm thick × 8 mm in diameter) was placed and filled with the test material following the manufacturer's instructions for use. Finally, another Mylar strip was added, followed by a second microscopic glass slide, which was secured with tape.

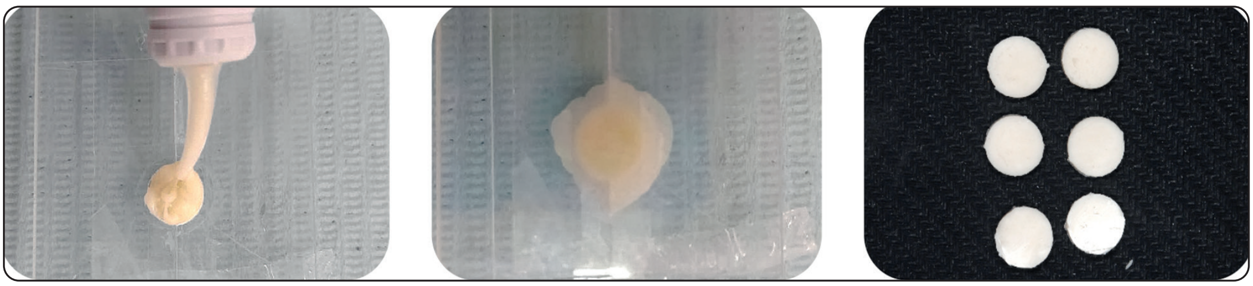
For the preparation of EQUIA specimens, the capsules were mixed in an amalgamator and then injected into the mold. After filling, a second microscopic glass slide with an attached Mylar strip

TABLE (1) Materials used in the study

Material name	Type	Manufacturer	Composition	Lot Number
EQUIA Forte HT Fil (EQUIA)	Glass hybrid	GC Corp, Japan	Liquid: Polybasic carboxylic acid, water. Powder: Fluoroaluminosilicate glass, polyacrylic acid, iron oxide	2302101
EQUIA Forte coat (EQUIA coat)	highly filled, light-cure resin coating agent	GC Corp, Japan	Multifunctional monomer, methacrylate, silicon dioxide, initiator, MDP, stabilizer.	2304111

Erosive solution	Composition	pH
Artificial gastric acid	Pepsin-free and consisted of 0.2% (w/v) sodium chloride in 0.7% (v/v) hydrochloric acid was prepared in the Department of Medical Biochemistry, Faculty of Medicine Mansoura University[15]	pH 1.2 ± 0.2, at 25°C.

MDB= 10-Methacryloyloxydecyldihydrogen phosphate.



a) Injection of the material into the mold space b) Mold pressed with another glass slide and glass slap c) Final shape of material specimens after removal from the mold

Fig. (1) Steps of specimens preparation

was placed on top of the material and pressed lightly with finger pressure. This step was performed to remove excess material and ensure a smooth, void-free surface. The material was then left to self-set for 2 minutes and 30 seconds.

After the material fully self-set, the specimens were removed from the molds, then wet-finished and polished immediately using aluminum oxide discs (Tor VM, Russia) in medium to extra-fine grades, with standardized strokes and force applied by the same operator. The specimens were then stored in distilled water at 37°C for 24 hours in an incubator (BT1020BTC, Cairo, Egypt) to complete the polymerization process.

A notch was created using a diamond bur (1.2 mm) to mark the direction for surface roughness measurement (roughness measurements were taken in the same direction as the notch), with finishing performed against the notch direction.

Two groups were tested: one without EQUIA coat and another with EQUIA coat application. The coat was applied 2 minutes and 30 seconds after mixing, following finishing and polishing, and was light-cured for 20 seconds using an LED curing unit (Bluelex-LD-105, Monitex, Taiwan) with an intensity of 1000 mW/cm^2. All specimens were cleaned using an ultrasonic cleaner (JP-4820, AZDENT, USA) to remove debris. Testing was conducted 24 hours after specimen preparation.

Aging by artificial gastric acid.

The specimens were immersed in glass containers, each containing 5 ml of artificial gastric acid.[13] The composition of the artificial gastric acid is detailed in **Table 1**. The pH was measured using a pH meter (STARTER 2100, OHAUS, Parsippany, NJ, USA). The storage duration was three hours, simulating one year of clinical service,[14] The solution was refreshed every hour after verifying its pH and was kept in an incubator at 37°C.[14]

Surface roughness measurement

Surface roughness was measured using a contact profilometer (Mitutoyo SJ-210) equipped with a 5 μm diamond stylus and a tip angle of 90°.[16] The stylus traced a 5.6 mm length at a speed of 0.5 mm/second, moving toward the notch direction and against the finishing and polishing direction.[17] Three measurements were taken per specimen, averaged, and compared to the control groups. The profilometer recorded surface topography data, capturing parameters such as Ra (arithmetical average roughness). Advanced software analyzed and processed the data, providing quantitative results to evaluate the surface quality of the tested materials.[18] The profilometer's software (Version 3004, Surftest SJ-201P, Mitutoyo, Japan) utilized the stylus's vertical movements to calculate surface roughness parameters, including Ra values.

Statistical analysis

Descriptive and analytical data were collected and analyzed using SPSS (version 26). Normality was assessed using the Shapiro-Wilk test, which showed no significant deviation from a normal distribution ($p > 0.05$). Surface roughness (Ra) data were presented as mean and standard deviation (SD) across test groups under different aging conditions. Multiple comparisons were conducted using Tukey's HSD test, and significant differences in roughness among the tested groups were identified using one-way ANOVA ($p < 0.05$).

RESULTS

The data in **Table 2** represent the mean and standard deviation (SD) of Ra values. In the control group, material without protective coat showed moderate surface roughness (Ra = 0.46 ± 0.13), while material with protective coat in the control group had even lower mean surface roughness values (Ra = 0.35±0.10) but nonsignificant with the control of material without coat. In the HCl test group, material without protective coat exhibited a considerable increase in surface roughness (Ra = 4.07 ± 0.63) compared to material with protective coat, which demonstrated a much lower surface roughness (Ra = 0.16 ± 0.02) in the HCl group than material without protective coat.

The *p*-values (<0.001) showed a statistically significant difference in HCL exposure between materials without a protective coat and with a protective coat. While no statistically significant difference *p*-value (0.11) was noted between both groups of materials in no HCL exposure (control). Significant difference with *p*-values of (<0.001) was also noted between material without a protective coat in HCL exposure and in no HCL exposure (control). While material with a protective coat in both HCL exposure and no HCL exposure (control) showed no statistically significant difference *p*-value (0.008).

TABLE (2) Comparison of Ra values for the two groups of restorative materials exposed to HCl aging.

Material	Aging		
	No HCL exposure (Control) (mean)(SD)	HCL exposure (mean)(SD)	*p*-value
Without a protective coat	0.46±0.13	4.07±0.63	<0.001*
With a protective coat	0.35±0.10	0.16±0.02	0.008
***p*-value**	0.11	<0.001*	

Each column and each row is independent in p-value*
Significant at p-value <0.05

DISCUSSION

Direct restorations for NCCLs are often exposed to chemical challenges in the oral environment. The current study evaluated the surface roughness of a commonly used tooth-colored restorative material, GH restorative material, when exposed to simulated gastric acid, both with and without a protective surface coat. Profilometric analysis was used to measure surface roughness, offering insights into material durability in NCCLs, particularly regarding intrinsic erosion caused by gastric acid. Glass ionomer cement could be used for restoring NCCLs. GICs chemically bond to tooth structure and calcified substrates, making them suitable for cases involving dentine sclerosis without the need for extensive enamel beveling.[19] Additionally, GICs release fluoride, which facilitates ionic and polar interactions with enamel and dentin. This molecular interaction allows fluoride ions to exchange with hydroxyl ions within the enamel's apatite structure.[20]

In 1990, the American Dental Association (ADA) recommended the application of varnish or light-cured resin as protective coatings to shield GIC during their setting phase, as water is critical to the primary setting process.[21] Dehydration or water contamination during this phase negatively affects the material's physical properties. These coatings effectively prevent dehydration, reduce the occurrence of crazing and cracking, and enhance the mechanical properties of the material.[21]

Evidence indicates that water contamination during the setting phase of GICs increases surface roughness, decreases wear resistance, and compromises the physical properties of the material.[21] This highlights the need to investigate the effect of surface coating on GICs in terms of surface roughness under acidic conditions.

The restorative materials selected for this study were EQUIA Fort HT Fil with and without the protective coat, chosen to investigate the protective effect of the coating regarding resistance to acid degradation, as claimed by the manufacturer.[22]

The clinical performance of restorative materials is influenced by erosion, similar to natural tooth structure. Previous research has shown that acidic exposure negatively impacts the surface integrity and physical properties of different tooth-colored restorations, such as GI-based and resin composite restorations.[23] Restorative materials can undergo degradation due to the low pH of certain endogenous acids. Gastric juice, which has a pH ranging from 1.0 to 3.0, was simulated using HCl (artificial gastric acid) in this study.[15]

The longevity of direct dental restorations depends on the durability and physical properties of the material, such as wear resistance, hardness, and surface roughness. According to Bollen et al.,[24] roughness values higher than 0.2 μm must be analyzed with caution, as this level of roughness can increase plaque accumulation, the risk of caries, and periodontal inflammation.[25]

In this research, we focused on material surface roughness to investigate the effect of erosion on GH restorative material, a type of tooth-colored restorative material.[26] For surface roughness measurement, a contact profilometer was used, as it is widely recognized as the standard and most commonly used method for surface roughness measurement.[27] Since the 1900s, the stylus profilometer has proven to be a reliable and simple method for measuring surface roughness.[27, 28]

In light of this study, EQUIA without the coat showed significantly higher surface roughness values in the HCl group compared to EQUIA with the coat, indicating that the material was more prone to surface degradation or roughness in an acidic environment, such as in patients experiencing GERD or bulimia nervosa. The control group exhibited much lower roughness values. This can be attributed to the behavior of materials in acid challenges due to their chemical structure. The dissolution process is driven by the presence of H^+ ions in the acidic environment. The more acidic the solution, the more H^+ ions are released, leading to a higher degree of material dissolution.[29]

The internal structure of the material, including the size, shape, and quantity of filler particles, plays a significant role in affecting the surface condition. Numerous silanols are present on the surface of glass particles, and the Si–O–Si glass bond is continually broken when H^+ ions are exposed to the cement surface. Porosity forms on the cement's surface as a result of the dissolution process of the glass particles, which causes hydrolysis and dissolution mainly in the polyalkenoate matrix. [30]

The EQUIA with coat group showed minimal surface roughness values under HCl aging, slightly lower than those of the control group, highlighting the protective effect of the coating against surface degradation.

A previous study conducted by Mohanad et al.[31] supported these results, though using AFM, and showed significant differences in surface roughness among the test groups (Resin modified GIC and conventional GIC with and without coat application). In all coated groups, surface roughness decreased within the first 24 hours, while uncoated groups showed an increase in surface roughness during the same period. This finding highlights the importance of coating restorations to prevent moisture contamination during the critical initial 24 hours.[31]

Another study [32] reported that the application of a surface coating provided protection against water diffusion for at least 48 hours. However, the exact duration of this protective effect remains undefined.[33]

In contrast, a study testing the protective effect of a nanofilled resin coat found that the application of the coat showed no positive effect on the wear resistance of the tested materials. This could be explained by the fact that the coating prevents the material from being worn by degrading itself. However, after a certain period of use, its protective effect is lost as the coating is completely degraded from the surface in function.[34]

Based on the results of surface roughness, the null hypothesis stating that there was no statistically significant difference in surface roughness among the test groups under the same aging condition (HCl) is rejected.

CONCLUSION

Within the limitations of this study, clinicians should consider using EQUIA Forte HT Fil restorative material with a protective resin coat for patients at higher risk of acidic exposure, such as those with frequent acid reflux or high consumption of acidic foods and beverages. When coated, these materials demonstrate enhanced resistance to surface roughness compared to the same material without a protective coating.

Conflict of interest

There are no conflicts of interest

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