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Influence of ultrasound or halogen light on microleakage and hardness of enamel adjacent to glass ionomer cement

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Background. The use of external sources of energy may accelerate the setting rate of glass ionomer cements (GICs) allowing better initial mechanical properties.

Aim. To investigate the influence of ultrasound and halogen light on the microleakage and hardness of enamel adjacent to GIC restorations, after artificial caries challenge.

Design. Cavities were prepared in 60 primary canines, restored with GIC, and randomly distributed into three groups: control group (CG), light group (LG) – irradiation with a halogen light-curing unit for 60 s, and ultrasonic group (UG) – application of ultrasonic scaler device for 15 s. All specimens were then submitted to a cariogenic challenge in a pH cycling model. Half of sample in each group were immersed in methylene blue for 4 h and sectioned for dye penetration analysis. The remaining specimens were submitted to Knoop cross-sectional microhardness assessments, and mineral changes were calculated for adjacent enamel.

Results. Data were compared using Kruskal–Wallis test and two-way ANOVA with 5% significance. Higher dye penetration was observed for the UG ($P < 0.01$). No significant mineral changes were observed between groups ($P = 0.844$).

Conclusion. The use of halogen light-curing unit does not seem to interfere with the properties of GICs, whereas the use of ultrasound can affect its marginal sealing.

Introduction

Glass ionomer cements (GICs) have demonstrated wide clinical use as cavity liners, fissure sealants, luting agents for indirect restorations, and restorative material, particularly in paediatric dentistry, since their development in the early 1970s[1]. Although they possess exclusive properties such as the ability to chemically bond to tooth enamel and dentine and to promote continuous fluoride release, ensuring an anticariogenic effect, some disadvantages limit the indications for their use[2,3]. GICs are sensitive to humidity and undergo a slow setting reaction that may delay the development of their final strength[4]. Consequently, the material is susceptible to fracture and wear until it is fully set. Damage to the cement prior to complete setting leads to a long-term reduction in its physical properties; therefore, accelerating this process would overcome some of the disadvantages associated with slow setting.

The maturing process is essentially based on an acid–base reaction between the polyacrylic acid and calcium/aluminium ions from the glass, but variations were introduced in an attempt to improve clinical performance and mechanical properties. The addition of resin helps to increase some physical properties and allow for a light-initiated setting mechanism[5]. The presence of this component may, however, interfere with the acid–base reaction and impair the ability of the cement to chemically bond to tooth structures and release fluoride. Better clinical performance may also be achieved by enhancing the powder/liquid ratio and consequently shortening the period of the acid–base setting reaction. For this purpose, the high-viscous GICs were developed; their characteristics allow for the performance

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of atraumatic restorative treatment and are more suitable for occlusal restorations[6,7].

Although the mechanical properties of GICs have been reported to gradually increase following an initial period to a value significantly greater than that obtained at 24 h after introduction in the mouth[8,9], the material is very susceptible to syneresis and imbibition prior to maturation, both of which may compromise its early strength, initial wear, and hardness[4,10].

Studies have suggested that faster setting of conventional GICs can be achieved using an external energy source such as light or ultrasonic excitation[9,11–14], which may be useful for improving GIC surface characteristics at early stages, particularly in paediatric dentistry. Faster setting allows for shorter clinical procedures and improves clinical technique. The use of an external energy source, such as preheating capsules, surface exposure from a light-curing unit, or ultrasonic scaler treatment, can result in a significantly enhanced surface hardness during the initial stages of a GIC setting reaction[11–13,15]. There is, however, little information regarding the influence of these extrinsic energy source applications on the enamel adjacent to the restorations after a caries challenge. Some studies have reported that the fluoride release of GIC is enhanced under acidic conditions[16], which are common for *in vivo* situations; therefore, it can be expected that the cariogenic challenge would interfere with the properties of GICs.

Thus, the aim of this study was to investigate the influence of ultrasound and halogen light on the microleakage and hardness of enamel adjacent to GIC restorations after an artificial caries challenge.

Materials and methods

Following approval from an Ethical Board, 60 human primary canines without caries lesions or visible enamel defects, which had been stored in tap water at 4 °C, were obtained from a Human Tooth Bank.

Specimen preparation

Standard class V cavities (3 mm long mesiodistally, 2 mm wide occluso-cervically, and 2 mm deep) were prepared in the cervical third of the buccal surfaces of each tooth with a cylindrical plain cut diamond bur (n. 1090; KG Sorensen, Barueri, SP, Brazil) on high speed under water cooling. The specimens were then washed in running water for 1 min and cleaned with an abrasive paste and a brush at a low-speed rotation.

The high-viscous GIC Ketac Molar Easymix (3M ESPE, Seefeld, Germany) was used as the restorative material following the manufacturer's specifications. The substrate was conditioned with the polyacrylic acid for 20 s[17], and the material was placed in the cavities with an insertion spatula. After these procedures, the specimens were consecutively numbered, and a list of random numbers was generated by a computer to randomly allocate the teeth into three groups according to the technique used during the initial setting reaction. The three groups are as follows:

Control group (CG, n = 20): No additional treatment was performed. After the insertion of the GIC in the cavity, the finger press technique was applied for 10 s.

Light group (LG, n = 20): Immediately after the insertion of the GIC and the finger press for 10 s, these specimens were irradiated with a halogen light-curing unit (KM 50R – DMC; São Carlos, Brazil) operating at 500 mW/cm^2 for 60 s.

Ultrasonic group (UG, n = 20): Immediately after the insertion of the GIC and the finger press for 10 s, a P-tip ultrasonic scaler driven by a Piezon US generator (Jet laxis sonic piezoelet, KaVo®, Biberach, Germany) was placed at the centre of the cement surface of each specimen, and the finger press technique was applied for 15 s. The equipment operated at 30 kHz, and the power was set at 2 (medium).

Excess cement was removed with hand instruments after the finger press technique. Following the curing procedures, the samples were stored in liquid petroleum jelly for 24 h at 37 °C to avoid the syneresis and imbibition phenomenon[15]. Subsequently, they were washed with water and neutral detergent.

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Cariogenic challenge

The dental surfaces were made completely impermeable with two coats of acid-resistant nail varnish (Colorama, L'Oréal Brasil, São Paulo, Brasil), except on the restorations and a 1.5-mm-wide border around them. The apical foramina were covered with epoxy resin.

The specimens were subjected to a pH cycle model for 10 days at room temperature[18]. First, they were individually immersed for 8 h in 50 mL of demineralising solution (2.2 mM $CaCl_2$, 2.2 mM NaH_2PO_4, and 50 mM acetic acid, adjusted to a pH of 4.7). Then, the specimens were then washed in deionised water, dried with paper towels, and immersed in 50 mL of remineralising solution (1.5 mM $CaCl_2$, 0.9 NaH_2PO_4, and 0.15 mM KCL, adjusted to a pH of 7.0), where they were left for 16 h.

After the cariogenic challenge, the specimens in each group were randomly distributed into two subgroups according to the type analysis.

Dye penetration

Ten specimens of each group were immersed in a 0.5% aqueous solution (pH = 7.2) of methylene blue (Fórmula e Ação, São Paulo, Brazil) for 4 h. Then, they were washed in running water for 5 min, dried with absorbent paper, and longitudinally sectioned into two halves (mesial and distal) using a low-speed machine Labcut 1010 (Extec Corp., London, UK). The obtained surfaces were planed out with an automatic grinding/polishing machine (Ecomet 3; Buehler, Lake Bluff, IL, USA) and a sandpaper disc of 1200 grit under running water.

The samples were analysed by three trained evaluators to determine the amount of dying area according to the scores[19], as described in Table 1. To evaluate the interexaminer agreement, the kappa test was used, ranging from 0.85 to 0.92.

Table 1. Scores for dye penetration measurement[19].

Score	Description
0	No dye penetration
1	Dye penetration up to half of the incisal or gingival wall
2	Dye penetration beyond the middle of the incisal or gingival wall, without reaching the axial wall
3	Dye penetration throughout the extent of incisal or gingival wall, reaching the axial wall

Cross-sectional microhardness

To perform the microhardness analysis, the remaining specimens from each group (n = 10) were sectioned with double-face diamond discs (KG Sorensen, Cotia, Brazil) on the restoration centre. Two halves (mesial and distal) were obtained, and each of them was embedded in acrylic resin.

The surfaces of the samples were planed out with an automatic grinding/polishing machine and a sandpaper disc of 600, 1200, and 1400 grit under running water for 60 s. They were then polished with diamond paste (1 and 0.25 μm). Cross-section microhardness measurements of the adjacent enamel were taken using a Knoop indentor attached to a microhardness tester (Shimadzu Micro Hardness Tester HMV-2; Shimadzu Corporation, Kyoto, Japan). Three lines of indentations in the enamel were performed at 50, 150, and 250 μm from the enamel surface and 100, 200, and 300 μm from the margin of the restoration. The indentation load was 50 g with 30 s of dwell time.

The normal distribution of data was confirmed using the Kolmogorov–Smirnov test. Subsequently, Kruskal–Wallis and two-way ANOVA tests were carried out for statistical comparisons of values obtained from the microleakage and microhardness analyses, respectively, at a significant level of 5%.

Results

The Kruskal–Wallis test showed that an accelerating setting rate with ultrasound results in a significantly higher occurrence of microleakage at the restoration margins; the UG presented a mean dye penetration that was statistically significantly higher than that in the other groups ($P < 0.05$), as shown in Fig. 1. No statistical differences were observed between the CG and LG ($P > 0.05$).

With regard to mineral alterations after the cariogenic challenge, two-way ANOVA revealed that no differences were found in

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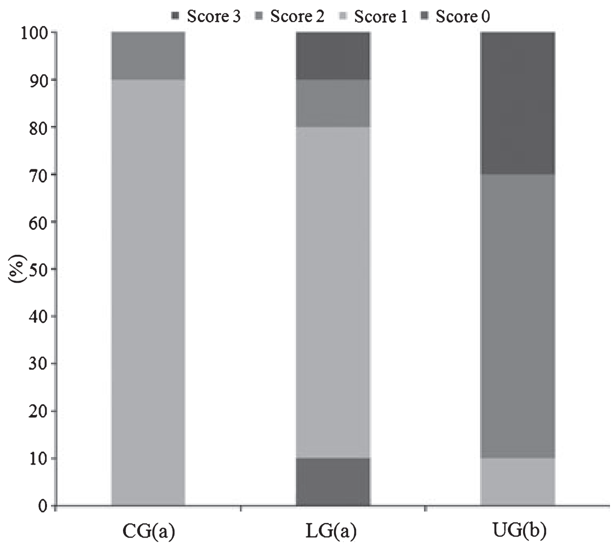

Fig. 1. Score distribution after dye penetration analysis for each group (different letters correspond to a significant statistic difference).

Table 2. Mean values for cross-sectional microhardness (Knoop hardness number – KHN) analysis for enamel adjacent to glass ionomer cement after artificial cariogenic challenge.

Groups	Means (KHN)	Standard deviation
CG	223.4	20.3
LG	229.0	26.8
UG	225.2	20.7

CG, control group; LG, light group; UG, ultrasonic group.

surface microhardness values for the enamel around the restorative material at the distinct distances tested ($P > 0.05$) for the three groups (Table 2).

Discussion

The long setting reaction of GICs is one of their drawbacks, and its reduction is desirable in paediatric dentistry. The short-term sensitivity to water results in surface softening; as a consequence, low wear resistance limits the full application of the material. The first 24 h, when the matrix is still forming, is considered to be the critical period; for that reason, it is imperative to protect the GIC surface during this time[4].

The introduction of resin-modified GICs was an attempt to combine the favourable properties of composite resin with those of GIC, including the command setting behaviour and good wear resistance of the former and the cariostatic properties of the latter. The initial set of these cements occurs as a result of polymerisation of HEMA, while the acid–base reaction serves to harden and strengthen the already-formed polymer matrix. They have, however, some of the disadvantages that are inherent in the use of resins such as polymerisation shrinkage and lesser biocompatibility; in addition, the mechanical properties are not always sufficiently improved[20–22].

Several laboratory studies have demonstrated that ultrasonic excitation or light application during the initial setting reaction may not only improve the instant set of the material but also its hardness in the first 24 h[13]. Because external sources of energy application do not modify the chemical composition of the material, this step would overcome the disadvantage associated with the resin-modified GIC. The majority of studies, however, evaluate the effect on the material itself without considering the possible influence on the adjacent enamel after a cariogenic challenge, as regularly occurs in clinical conditions. This study aimed to verify whether external energy sources can affect the anticariogenic properties of GIC on the surrounding enamel as a consequence of the accelerated setting reaction.

It is hypothesised that the effect of ultrasonic excitation or light application on GIC may partially be explained by the heating effect. Adding kinetic energy to the material is responsible for an increase in temperature that can accelerate the setting rate. In cases involving ultrasonic equipment, the vibration movement may possibly improve the mixing of the particles in the powder with the liquid, which enhances the total reactive surface and, consequently, the setting time. Kleverlaan *et al.*[15] reported a temperature rise of approximately 13 °C when the ultrasonic curing method was used for 45 s. Under normal conditions, the setting reaction of the GIC provoked a temperature rise of 1 °C. O'Brien *et al.*[12] found no significant temperature rise between specimens treated with the ultrasonic equipment

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and control samples. The authors suggested that an improvement in the setting rate of GICs by ultrasonic application is less influenced by temperature increase and more by mechanical excitation of the scaler tip itself. Halogen light-curing units also provoked higher temperature increases on the material. Although small increases in temperature occur when using external energy sources, a critical rise in temperature is not expected because both the ultrasound and light were applied with parameters routinely used in clinical situations. Furthermore, temperature increases may vary according to the restoration thickness because of differences in material volume.

As our results suggest, ultrasound excitation may interfere with adaptation of the conventional GIC in the cavity because higher dye penetration occurred after microleakage test when compared with the CG. During the formation of the polycarboxylate network, viscosity increases and steadily reduces the flow capacity of the cement, particularly in the case of high-viscous GIC. Using the ultrasound device, the curing process occurs even faster, and it hinders the cement flow before the cavity is completely filled. The chemical adhesion capacity of the cement is related to the initial reaction of jellification; therefore, mechanical acceleration of the curing process may jeopardise this property. The use of an ultrasonic device should be recommended before the finger press technique with solid petroleum jelly when the cement still presents the clinical aspect of surface shine. In this phase, the cement is still capable of bonding to dental structures, and its eventual displacement should be avoided.

In contrast, the protective effect of the restorative material was not affected as a result of ultrasound equipment. No significant differences in hardness values were observed in the enamel adjacent to the restorations in any of the experimental groups. Thanjal *et al.*[23] studied the influence of ultrasound and radiant heat on the kinetics of fluoride ion release from dental restorative GICs. It was observed that ultrasound-accelerated setting enhances fluoride release from GICs and that heat-accelerated setting has the opposite effect. It is possible that these differences are not significant enough to cause a greater protective effect during the cariogenic challenge; however, they do not agree with the results found in our study. Considering that shortening the acid–base setting reaction period, as occurs with high-viscous GICs[24], can accelerate the network formation, it was thought that the fluoride-releasing property could also be diminished. This effect, however, was not observed because enamel hardness was not altered.

With the purpose of overcoming the initial sensitivity of GICs, new highly viscous GICs with fast-setting properties, the 'fast-set' GICs, were introduced a few years ago. Compared to their regular-set analogues, the time required for the maturing process of these materials was reduced to roughly half the time, which suggests that fast-setting GICs can also accept mastication forces earlier. However, no differences were observed in compressive and tensile strength during the initial week between the regular-set Fuji IX and fast-set Fuji IX Fast[25]. Additionally, these new cements did not present better wear performance in the early stage compared to the regular-set versions[26].

In conclusion, the use of halogen light to accelerate the setting reaction of GICs does not seem to interfere with the microleakage and hardness of the enamel adjacent to the GIC restorations. The halogen light may represent a good alternative for use in paediatric dentistry. Higher leakage was observed between the restorative material and the adjacent enamel after using an ultrasonic device; however, this difference was not able to affect the caries inhibition effect of the GICs.

What this paper adds
- Even though it has been proved that extrinsic energy sources can accelerate glass ionomer setting reaction, there was little information regarding the influence of this procedure on the enamel margins adjacent to restorations. This paper shows that the use of them does not seem to interfere with cement's anticariogenic properties.

Why this paper is important to paediatric dentists
- Faster setting promoted by external energy source such as light or ultrasonic excitation allows for shorter clinical procedures and can improve surface characteristics of the GIC at early stages, which is particularly interesting to paediatric dentists.

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