Microleakage of Glass Ionomer Restoration in Cavities Prepared by Er,Cr:YSGG Laser Irradiation in Primary Teeth

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ABSTRACT

Purpose: The purpose of this study was to evaluate microleakage of cavity preparation in primary teeth made with an Er,Cr:YSGG laser (**L**) or high-speed drill (**HD**) and conventional (**CGIC**) and resin-modified glass ionomer cement (**RMGIC**).
Methods: One hundred primary teeth were divided into 10 groups (N=10): (a) groups 1 and 2 represented cavities prepared by a no. 1012 diamond bur with HD; (b) groups 3 through 10 represented cavities prepared with an Er,Cr:YSGG laser (with a repetition rate of 20 Hz power settings varying for enamel=2.5 W and 3 W and dentine=1.0 W and 1.5 W). After cavity preparation, samples were restored with CGIC (Ketac Molar Easy Mix) and RMGIC (Vitremer), impermeabilized, thermal cycled, stained, washed, and sectioned. The degree of dye penetration was scored by 3 standardized examiners using a light stereoscope at X30 magnification.
Results: The Kruskal-Wallis test detected no statistical differences between the cavity preparation methods ($P<.049$). Neither of the GICs tested were able to avoid microleakage, and the RMGIC showed the lowest statistical degree of microleakage compared with CGIC for both types of cavity preparation.
Conclusions: The Er,Cr:YSGG laser provided an equivalent method of cavity preparation compared to the high-speed drill. The resin-modified glass ionomer cement showed the lowest degree of microleakage. This restorative material should be considered when choosing the cavity preparation method. (**J Dent Child 2008;75:151-7**)

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Modern technology has sought to optimize the quality and longevity of treatment through the use of new devices and materials, with a focus on patient comfort and fast procedures. The pediatric patient should be given special consideration.[1] The search for a more gentle, comfortable, and conservative caries excavation has led to the development of methods aiming to provide minimal thermal changes, less vibration and pain, and removal of infected dentine only.[2] In 1997, the Federal Drug Administration (FDA) approved the use of the Er:YAG laser in hard tissues. Two years later, its use was extended to Pediatric Dentistry. Later, the Er,Cr:YSGG laser was also approved for hard tissue procedures. For cavity

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preparation, this laser device is considered a less traumatic method and may favor behavior management in pediatric clinical procedures.[1-4]

The Er:YAG (2.94 µm) and Er,Cr:YSGG (2.78 µm) lasers present several advantages. These included minimal vibration and noise during cavity preparation and minimal or no need for local anesthesia, when compared with the conventional high-speed handpiece, as its wavelength is coincident with the main absorption band of water and also well absorbed by the hydroxyapatite. The incident irradiation is highly absorbed by the water molecules present in the hydrated organic compounds of the tissues—mainly the intratubular fluid and collagen network—causing sudden boiling and water evaporation. The resulting high-stream pressure leads to the occurrence of successive microexplosions that ablate the tissue and determine the microcrater-like appearance of lased tooth structure.[5-12]

After years of research, the laser has been found to be applicable for caries prevention, tooth structure preservation, and cavity preparation. It is also potentially used for increased acid resistance and effective microbial reduction.[13,14]

As laser use is considered for cavity preparation, it is necessary to determine the quality of restoration margins to ensure efficient marginal sealing and reduce the possibility of gaps between the tooth-restoration interface.[9,15-19] The marginal sealing ability of a restorative material is an important issue in a restoration's longevity. Several adhesives systems and resin composites have been introduced to optimize the bonding of resin restorative materials. As an alternative to composite materials, glass ionomer cements (GIC) have great application for conservative restoration in the pediatric field due to their advantages. These include adhesion to tooth structure, fluoride release, biocompatibility, lower polymerization shrinkage, reduced recurrent caries, reduced microleakage, and acceptable esthetics.[20-22] Resin-modified glass ionomer cements (RMGIC) were further developed to improve the handling and work characteristics of the conventional glass ionomer formulation.[23]

Extensive research has been done on the Er:YAG laser related to cavity preparation and to microleakage and adhesion in both permanent and primary teeth. There is a lack of studies, however, about the quality of cavities prepared with Er:YAG lasers and restored with different GICs.[24-28] The same can be said of the Er,Cr:YSGG laser. This is insufficient research concerning Er,Cr:YSGG laser parameters and GIC restorations in primary teeth.

Based on the facts, the aim of this study was to analyze the influence of laser or bur preparation, combined with 2 different types of glass ionomer cement restorations (conventional and resin-modified), on marginal microleakage.

METHODS

EXPERIMENTAL DESIGN

The factor under study was dye penetration at 10 levels. The experimental units consisted of 100 human primary canines randomly divided into 10 groups (N=10). The microleakage test was carried out to evaluate the interface between dentin prepared with the Er,Cr:YSGG laser under several irradiation or diamond bur protocols and restored with a conventional and a RMGIC.

SAMPLE PREPARATION

After the research project was approved by the Research Ethics Committee of the School of Dentistry of University of São Paulo, 100 sound and recently exfoliated human primary canines were thoroughly cleaned and stored in distillated water until they were used. They were divided into 10 groups (N=10) according to the cavity preparation method (laser or diamond bur), laser parameters, and glass ionomer used, as shown in Table 1.

CAVITY PREPARATION

Class V cavity dimensions were standardized for both cavity preparation methods and calibrated by measuring them with a marked periodontal probe to obtain a cavity with a 3-mm

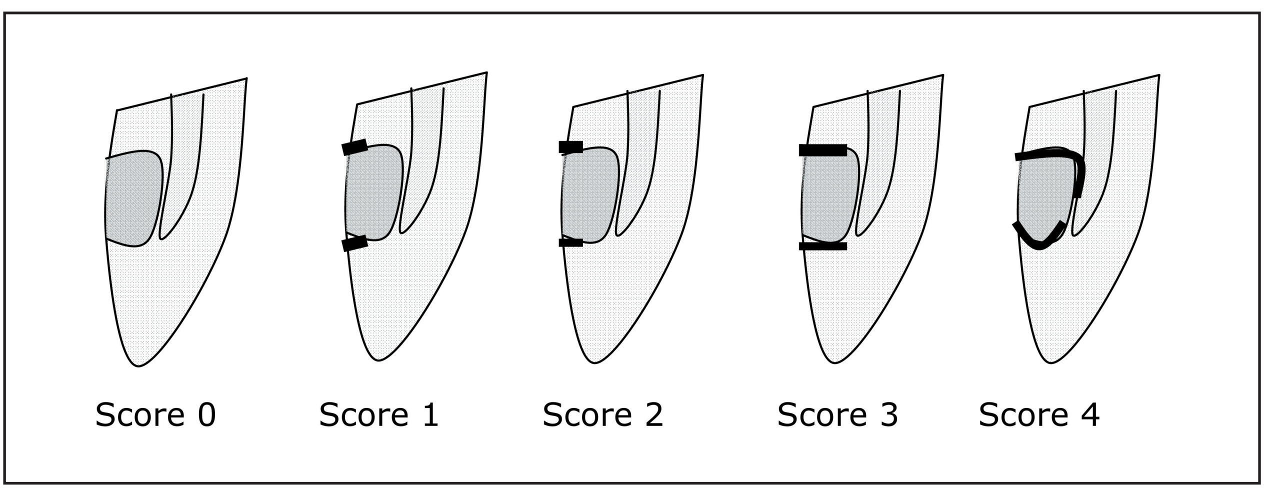

Figure 1. Degree of microleakage based on a 4-grade scale.

Table 1. Description of the Groups

	Group	Glass ionomer	Mean power (W)		Energy per pulse (mJ/pulse)		Energy density (J/cm2)	
			Enamel	Dentin	Enamel	Dentin	Enamel	Dentin
High-speed handpiece	1	Ketac Molar	-	-	-	-	-	-
	2	Vitremer	-	-	-	-	-	-
Er,Cr:YSGG	3*	Ketac Molar	2.5	1.5	125	75	44.6	26.8
	4*	Vitremer	2.5	1.5	125	75	44.6	26.8
	5*	Ketac Molar	2.5	1.0	125	50	44.6	17.8
	6*	Vitremer	2.5	1.0	125	50	44.6	17.8
	7*	Ketac Molar	3.0	1.5	150	75	53.6	26.8
	8*	Vitremer	3.0	1.5	150	75	53.6	26.8
	9*	Ketac Molar	3.0	1.0	150	50	53.6	17.8
	10*	Vitremer	3.0	1.0	150	50	53.6	17.8

diameter and 2-mm depth. The incisal and cervical margins were surrounded by enamel. Groups 1 and 2 (the control groups) had their cavities prepared by a no. 1012 medium particle-sized diamond bur (KG Sorenesen, São Paulo, Brazil) with a high-speed turbine and air/water spray. Burs were replaced after every 5 preparations.

LASER IRRADIATION

For groups 3 through 10, an Er,Cr:YSGG laser (Millennium, Biolase Technology, San Clemente, Calif) was used at a wavelength of 2.78 µm, a repetition rate of 20 Hz, a pulse width of 140 to 200 µs, and an output power ranging from 0 to 6 W. Enamel and dentin were removed in 2 separate steps using different energy parameters (enamel=2.5 W and 3 W; dentin=1.0 W and 1.5 W), as shown in Table 1. A 600-µm-diameter sapphire tip (G6 tip), perpendicular to the surface and 1-mm away from the target area, was used. The cooling system was set in accordance with the manufacturer's instructions: 55% of air and 65% of water.

RESTORATION PROCEDURE

Cavities were randomly restored with 2 different GICs in accordance with the manufacturers' instructions:

1. conventional, chemically cured Ketac Molar Easy Mix (CGIC; 3M, St Paul, Minn); or
2. Vitremer (RMGIC; 3M).

Both materials are manually mixed and release fluoride.

After restoration, specimens were stored in distillated water at 37°C for 24 hours. A finishing process was applied, using moist Sof-Lex discs (3M). Immediately after that, the finishing gloss (3M) was applied and restorations were polymerized for 20 seconds.

MICROLEAKAGE TEST

Restored specimens were thermal cycled for 700 cycles (MTC2–Instrumental, São Carlos, Brazil). Each cycle consisted of a water bath at 5°C±2ºC and 55°C with a 60-second time in each bath. Next, the samples were dried superficially with absorbent paper and sealed with 2 coats of nail varnish, leaving a 2-mm window around the cavity restoration margins. The apical region was also sealed with epoxy glue to prevent dye penetration. Specimens were then immersed in 2% buffered methylene blue solution at pH 7 for 4 hours, after which all specimens were rinsed with tap water for 5 minutes and dried with absorbent paper. Each restoration was cut in the buccolingual direction through the center of the restoration with a low-speed, water-cooled diamond disc (KG Sorenesen). The degree of dye penetration was scored on the basis of a 4-grade scale (Figure 1) by 3 standardized and independent examiners in a blind-manner using a light stereoscope (Meiji 2000, Saitama, Japan) at X30 magnification[29]:

a. score 0=no dye penetration;
b. score 1=dye penetration along the interface to one third of the cavity depth;
c. score 2=dye penetration along the interface to two thirds of the cavity wall depth;
d. score 3=dye penetration to but not along the axial wall; and
e. score 4=dye penetration up to and along the axial wall.

Data was subjected to the kappa test (κ=0.74) and confirmed the positive agreement between the examiners. The nonparametric Kruskal-Wallis test was performed to compare all groups, and the Dunn test was used to determine the differences between the groups.

RESULTS

No statistical differences were found between the cavity preparation methods, diamond bur, and Er,Cr:YSGG laser (P<.05).

Statistical analysis showed that neither of the GIC tested were able to avoid microleakage, irrespective of the cavity preparation. The Kruskal-Wallis nonparametric multiple comparison test, however, detected significant differences between these materials. The RMGIC Vitremer showed the lowest degree of microleakage, presenting a statistically significant difference compared with the Ketac Molar conventional CGIC, and this was more evident in lased cavities (P>.05).

The groups in which the cavities were prepared by laser, using the parameters of 44.6 J/cm^2–2.5 W and 53.6 J/cm^2–3 W in enamel and 17.8 J/cm^2–1 W and 26.8 J/cm^2–1.5 W in dentin showed the least degree of dye penetration. Regarding the restorative material and cavity preparation method combination, there were statistical differences and Vitremer presented the best results in laser-prepared cavities (Figure 2). Concerning the parameters, no statistical significance was found between the diferent protocols (P=.049). When the RMGIC Vitremer was used in combination with all the laser protocols suggested, however, the results showed lower levels of microleakage compared with the Ketac Molar CGIC, and no difference between the protocols was observed (Figure 2).

DISCUSSION

The use of laser technology has brought new philosophies and attitudes to both professionals and patients. Laser is of a multidisciplinary nature, and pediatric dentistry uses this technology in different areas to provide the young patient with comfort and safety.

Through the absorption of water and hydroxyapatite, the Er:YAG and Er,Cr:YSGG lasers—with adequate parameters and water spray—can cause hard dental tissue ablation. This can promote a punctual selective action, removing the carious lesion and preserving healthy tooth structures without causing pulp damage.[3,5,7,30-34] In a study by Celiberti et al in 2006, laser equipment was almost 2.5 times slower than the steel burs for preparing cavities of similar size, and the authors demonstrated the difficulty in controlling caries excavation due to the noncontact mode. The erbium laser presents some advantages, however, such as the absence of contact and vibration, reduced or modified noise, the possibility of not requiring anesthesia in a large number of cases, and more conservative cavity preparations.[2,33,35,36] Furthermore, these advantages make the treatment less traumatic for young patients, thus increasing acceptance of dental treatment and the number of returns to the consulting room.[1] The Er,Cr:YSGG laser uses a pulsed-beam system, fiber delivery, and a sapphire tip bathed in a mixture of air and water spray that works 1 mm away from the surface. The higher repetition rate promotes faster procedures, similar to the conventional steel burs. When dental hard tissue is irradiated by the Er,Cr:YSGG laser with water spray, the temperature is suppressed and cutting efficiency increases.[11]

When the micromorphologic characteristics of cavities prepared with erbium lasers are assessed by scanning electronic microscopy, an absence of the smear layer, exposure of the enamel rods, and opening of the dentinal tubules may be observed. This creates a microretentive morphologic pattern that favors adhesive material retention.[6,8-10,18,26,32,37] The choice of an ideal restorative material for the pediatric patient, however, is also a very important aspect in preserving the tooth structure. GICs are materials that combine characteristics such as adhesiveness to the dental structure, biocompatibility, and antimicrobial and anticariogenic potential through constant fluoride release.[20,21] Thus, it could be a reasonable and advantageous option to associate laser technology with GIC. There is a lack of studies that assess cavity preparations with the Er,Cr:YSGG laser in primary teeth, however, particularly regarding this wavelength restored with different GICs. Moreover, the manufacturer specifies protocols for the use of Er,Cr:YSGG lasers in pediatrics, without scientific basis for its correct use with the different types of restorative materials.

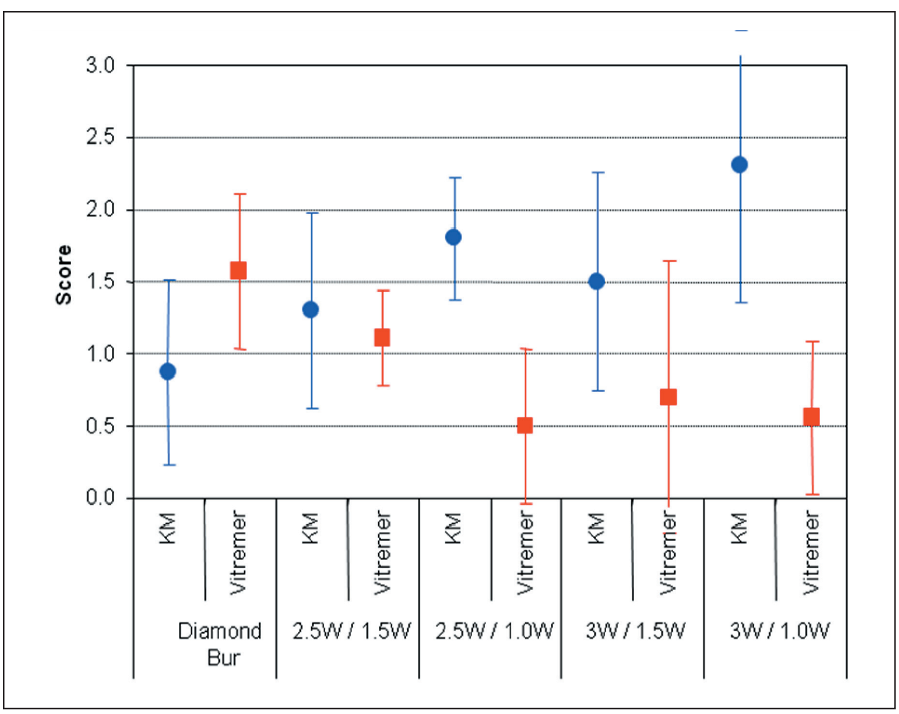

Figure 2. Statistical analysis for microleakage in the different groups evaluated.

In accordance with the present study's results, there was no differen-ce between the cavity preparation methods used (ie, laser or high-speed diamond bur). Similar results were found by Quo et al in 2002[26] and Aranha et al in 2005,[19] who studied Er:YAG and Er,Cr:YSGG lasers, respectively.

Even though no statistically significant difference was observed regarding microleakage, differences were found between the restorative materials used. Other studies corroborated this affirmation.[9,25,38-40] When cavity preparations made with a laser negatively affected the marginal sealing of restorative materials, the differences were related to the equipment used, its wavelength, and the parameters chosen.[28,42,43] These variables should be discussed and compared.

In the present study, statistically significant differences could be observed among the restorative materials used, and the Vitremer presented the lowest degree of microleakage. When analyzing restorative material interaction with the preparation method, Vitremer in laser-prepared cavities also presented the lowest degree of microleakage. Scores of less infiltrated samples were observed in groups treated by the Er:YAG laser, and the least leakage occurred in the group treated by the dentin preparation parameter, followed by cavity restoration with RMGIC, as shown in a study by Mello et al in 2006.[47]

Studies conducted with conventional cavity preparations restored with ionomeric cements presented similar results to those in the present study; RMGIC presented the lowest microleakage scores when compared with CGIC.[22,44-46] The largest part of CGIC chemically adheres to the dental substrate through ionic exchanges between the material's carboxylate ions and the dental tissue's phosphate and calcium ions. There is also slight adhesion through micromisalignment. Through misalignment of its resinous part (BisGMA), the RMGIC adheres to the dental structure; there is also a chemical adhesion mechanism from the polyacrylic acid component and the formation of a hybrid layer from the hydrophilic HEMA. Chinelatti et al[28] showed that the Er:YAG laser had a negative effect on the marginal sealing of cavities restored with RMGIC in permanent teeth. The authors used fluency of 128.33 J/cm^2 for cavity preparation. This difference in relation to the present study may have occurred as a result of applying energy densities higher than those used in this study. High energy densities may result in damage to the morphologic structure, altering collagen fibrils and negatively affecting the adhesion between the restorative material and the cavity preparation. Similarly, Corona et al[27] demonstrated that laser had a negative influence on marginal sealing and caused higher degrees of microleakage in cavities restored with RMGIC.

Concerning Ketac, a hypothesis for the present study's results could be that when the dental chemical composition is altered, a laser would interfere in the reaction of the CGIC's polycarboxylate ions with the calcium and phosphate of the dental substrate, thus diminishing the adhesion of this material. Another possibility is that the 11.5% polyacrylic acid, used in the dental treatment before the CGIC restoration, is a weak acid and is unable to modify the lased dental tissue.

On the other hand, RMGIC presented the lowest degrees of microleakage. The modification in the dental substrate morphology caused by laser creates a morphologic pattern similar to that of acid etching, with an irregular, microretentive surface that could enhance the adhesion, as previously discussed. This pattern would favor the penetration and adhesion of the resinous part (BisGMA) of GIC. The application of the primer etchant with acidic monomers could have increased the wettability and surface energy. This result, associated with the morphologic alterations caused by the dentinal tubules opening and absence of smear layer, increased micromisalignment and, consequently, adhesion between the restorative material and the tooth.

Important factors to consider are correct protocols and the evaluation of clinical aspects, such as the cavity's type and depth, quantity of carious tissue involved, and patient aspects like the risk of caries development and cooperation during proceedings. The energy levels tested in this study were not capable of preventing microleakage. The combination of all energy levels with the RMGIC, however, showed the lowest degree of microleakage.

Thus, further investigations focusing on the long-term effect of the ultrastructural changes observed in erbium laser-irradiated dental substrate, specifically in primary teeth, should be carried out and may provide restorations with increased marginal sealing. This may, therefore, lead to improved microleakage prevention and more widespread applicability of these new technologies in the clinical practice. Furthermore, the association of a technology—one that promotes greater tooth structure preservation with a preventive restorative material—is ideal for the pediatric dentistry patient and could be a promising alternative in a social proposal for preventive health education programs.

CONCLUSIONS

Based on this in vitro study's results, the following conclusions can be made:

1. Regarding the microleakage study and dye penetration, there were no differences between the cavities prepared by an Er,Cr:YSGG laser and those prepared by air turbine.
2. The resin-modified glass ionomer cement Vitremer showed the best results for preventing microleakage in both conventional and laser-prepared cavities at all energy levels.
3. Where microleakage is concerned, the restorative material must be considered more important than the preparation method due to the differences found between resin-modified and conventional glass ionomer cements.

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