Do glass ionomer cements prevent caries lesions in margins of restorations in primary teeth?
A systematic review and meta-analysis

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New caries lesions in restoration margins are a frequent concern in dentistry, especially when there is no patient compliance. Thus, this problem has been seen as the main reason for failure and replacement of restorations in primary teeth, with reports showing approximately 8.0% of restoration failures even within 5 years when these caries lesions are filled with polyacid-modified resin composite (PMRC), resin composite (RC), or amalgam.

These restorative materials, in the same way as glass ionomer cements (GICs), have shown satisfactory performance in restorations of primary teeth. However, conventional GIC—a low-viscosity restorative material—has a shorter longevity than do the other materials. Results of a previous systematic review showed that there is a higher number of failed restorations with the atraumatic restorative treatment (ART) technique when it was performed with conventional GIC, whereas the longevity of ART restorations performed with high-viscosity GIC (HVGIC) is higher. HVGIC is also a material for which setting is an acid-based reaction; however, HVGIC performed similarly to the other materials in both occlusal and occlusoproximal restorations.

Conversely, resin-modified GIC (RMGIC)—a GIC with addition of hydroxyethylmethacrylate, similar to HVGIC—also can be considered an alternative to restore dentinal caries lesions. Fluoride interferes with the processes of demineralized and remineralization of caries lesions, and some authors suggest that the fluoride released from GICs is capable of preventing caries. Investigators in previous

ABSTRACT

Background. Fluoride released from glass ionomer cements (GICs) is capable of preventing caries lesions. However, the preventive effect in margins of occlusal and occlusoproximal restorations have not been proved. The aim of this study was to evaluate the ability of GIC to prevent caries lesions in margins of occlusal and occlusoproximal restorations in primary teeth compared with that of other restorative materials.

Types of Studies Reviewed. The authors conducted a literature search in PubMed and MEDLINE to verify the clinical trials available on the outcome of caries lesions. The inclusion criteria were that the subject related to the scope of this systematic review, the study had a follow-up, and the study was not performed in specific groups. The authors performed all meta-analyses by considering the secondary caries rates for the restorations in clinical trials.

Results. The search strategy identified 450 potentially relevant studies, and the authors included 8 of them in the review. The main reasons for exclusion were that the studies were not related to the scope of this review or were not longitudinal trials. The secondary caries rate of the occlusal restorations was not different among the restorative materials (odds ratio, 1.2; 95% confidence interval, 0.5-3.1). For occlusoproximal analysis, GIC was associated significantly with better ability to prevent caries lesions (odds ratio, 1.7; 95% confidence interval, 1.2-2.5).

Conclusions and Practical Implications. Because new caries lesions in the margins of restorations are the main reason for failure and replacement of restorations in primary teeth, it is important to know whether there is a benefit in using GICs in both occlusal and occlusoproximal cavities.

Key Words. Dental caries; glass ionomer cements; fluoride.
studies reported that GIC showed a higher reduction of demineralization in adjacent teeth.\textsuperscript{11,12} However, GIC’s preventive effect has not been proved when compared with all other available materials considered as definitive restorative materials, especially for the occlusal and occlusoproximal surfaces of the primary teeth.

This is important because most caries lesions occur on the proximal surface of the primary teeth,\textsuperscript{13} and the caries progression in this area seems to be faster than on occlusal surfaces.\textsuperscript{14} In this sense, the survival rate of restorations could be different between these surfaces. Furthermore, primary teeth have a higher tubule density and lower concentration of phosphate and calcium in peritubular and intertubular dentin than do permanent teeth\textsuperscript{15,16} which could interfere with the performance of restorative materials. However, to the best of our knowledge, this is the first systematic review and meta-analysis that compares the preventive effect of all restorative materials available on caries lesions in the margins of restorations in both the occlusal and occlusoproximal surfaces of primary teeth. Thus, the aim of this study was to evaluate systematically and quantitatively the ability of GIC to prevent caries lesions in the margins of occlusal and occlusoproximal restorations in primary teeth compared with that of other restorative materials.

**METHODS**

We conducted and reported this study according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.\textsuperscript{17} We registered it on the PROSPERO register under protocol number CRD42013006497.

**Search strategy and selection criteria.** We performed a comprehensive literature search through PubMed and MEDLINE to identify articles up to August 19, 2014, in which the investigators evaluated the prevention of caries lesions in the margins of occlusal and occlusoproximal GIC restorations in primary teeth. To retrieve all relevant articles, 2 authors (T.K.T. and A.F.B.C.) screened reference lists of included articles and related reviews. We used the following search strategy: ((((((amalgam OR resin*) OR composite*) OR composite resin*) OR resin composite*) OR compomer*) OR polyacid modified composite resin*) OR polyacid-modified composite resin*) AND (((((demineralization OR tooth demineralization) OR teeth demineralization) OR teeth) OR carious) OR tooth decay) OR teeth decay) OR dental caries) OR caries susceptibility)) AND (((((dental restoration*) OR restoration) OR dental restoration, permanent) OR tooth restoration) OR teeth restoration)) AND (((((glass ionomer cement*) OR glass-ionomer cement*) OR GIC) OR ART) OR atrumatic restorative procedure*) AND ((clinical[Title/Abstract] AND trial[Title/Abstract]) OR clinical trials[MeSH Terms] OR clinical trial[Publication Type] OR random*[Title/Abstract] OR random allocation[MeSH Terms] OR therapeutic use [MeSH Subheading]).

Initially, both reviewers independently assessed the identified publications, which we selected by title and abstract on the basis of the inclusion criteria: to investigate occlusal and occlusoproximal GIC restorations and to be a longitudinal study with a follow-up of at least 12 months. We did not include studies performed in specific groups (for example, irradiation, special patients, and teeth with amelogenesis imperfecta). The reviewers were trained and calibrated for article selection (κ = 0.929) by a experienced researcher in studies about caries lesions in margins of restorations (D.P.R.). We resolved any discrepancies through a third reviewer (D.P.R.). We made a final decision about inclusion on the basis of the full-text articles of the potentially relevant studies in accordance with the exclusion criteria: having a dropout rate of more than 30%, not being a randomized or quasi-randomized clinical trial, not having a control group (amalgam, PMRC, or RC), not evaluating GIC as a definitive restoration (HVGIC or RMGIC), not being performed in primary teeth, and not evaluating caries lesions in margins of restorations as the outcome. In the case of studies reporting the same sample, we included those that presented more information.

**Data extraction.** The 2 reviewers independently collected the data of the eligible studies. For each article, they systematically extracted the following data: publication details (title, authors, and year), sample characteristics (age of participants, caries experience, number of participants, number of restorations for each material), study methodology (study design, restorative materials, type of restored cavity), and outcome information (survival of restorations, follow-up, and dropout).

Afterwards, we assessed the risk of bias in the included studies (κ = 0.945) by using specific study design–related risk-of-bias assessment forms.\textsuperscript{18} We divided the criteria into 7 main domains related to randomization, masking, outcome data, and characteristics of the sample at baseline. We evaluated the studies by rating each of the study criteria as yes (low risk of bias), no (high risk of bias), or unclear (no information or uncertainty about the potential for bias). For the final classification of risk of bias, we resolved disagreements between the reviewers through discussion.

**Statistical methods for the meta-analysis.** We performed all meta-analyses by using statistical software (MedCalc Version 12.5.0.0; Microsoft Partner). We

considered the secondary caries rate of occlusal and occlusoproximal restorations that were shown as the reason for failure reported in the clinical trials. For both types of restored cavity, we performed the meta-analysis by using the longest follow-up of each study. We used random-effects models for all calculations. For the pooled studies, we used an Egger test to aid the analysis of publication bias. It was not possible to perform a meta-analysis of HVGIC versus other materials and of RMGIC versus other restorative materials in different follow-up periods because there was insufficient information to be included in the pooling. Thus, we analyzed these data descriptively.

RESULTS

Study selection. The search strategy identified 448 potentially relevant records. We identified another 2 studies from the reference lists of related reviews. After screening titles and abstracts, we retrieved 53 full-text articles for more detailed information. Most of the studies not included were not related to the scope of this review (240; 60.5%) or were not longitudinal clinical
trials (149; 37.5%). Finally, 8 articles met the eligibility criteria, and we included them in the review. The flow diagram summarizes the study selection process and the reasons for exclusions (Figure 1).

Study characteristics. Table 1 shows the main characteristics of the included articles. All studies were performed in participants aged 5 to 8 years. Investigators in most studies (62.5%) compared RMGIC with other materials: RC, amalgam, or PMRC. However, investigators in 4 studies used HVGIC.

Considering the type of restored cavity, investigators in all trials evaluated occlusal proximal restorations, whereas investigators in only 5 studies evaluated occlusal cavities. However, Daou and colleagues presented the survival data of the occlusal and occlusal proximal restorations together.

The main criterion of the outcome evaluation was based on US Public Health Services criteria, which were used in 75% of the studies. This criterion considers marginal adaptation, discoloration, secondary caries, anatomic form, color match, and surface texture. Furthermore, most of the studies followed up the patients for 12 and 24 months.

Risk of bias. Table 2 shows the final assessment of risk of bias in the included studies. Investigators in 5 articles reported masking of outcome assessment. We found there was a lack of information about allocation concealment and masking of participants and personnel in the studies. Investigators in only 1 study reported sample characteristics at baseline, and investigators in 2 other studies reported other sources of fluoride.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Main characteristics of data sets from randomized studies.</th>
</tr>
</thead>
<tbody>
<tr>
<td>STUDY</td>
<td>AGE OF PARTICIPANTS IN YEARS, MEAN (STANDARD DEVIATION)*</td>
</tr>
<tr>
<td>Donly and Colleagues, 1999</td>
<td>8 (1.2)</td>
</tr>
<tr>
<td>Dutta and Colleagues, 2001</td>
<td>6.5</td>
</tr>
<tr>
<td>Talfour and Colleagues, 2002</td>
<td>6.5</td>
</tr>
<tr>
<td>Andersson-Wenckert and Sunnegardh-Grönberg, 2006</td>
<td>8</td>
</tr>
<tr>
<td>Ersin and Colleagues, 2006</td>
<td>8.07 (1.51)</td>
</tr>
<tr>
<td>Daou and Colleagues, 2008</td>
<td>7 (0.5)</td>
</tr>
<tr>
<td>dos Santos and Colleagues, 2009</td>
<td>5 (0.75)</td>
</tr>
<tr>
<td>Hilgert and Colleagues, 2014</td>
<td>6.8 (0.40)</td>
</tr>
</tbody>
</table>

* Standard deviation is not available for all studies, as some studies mentioned the age range of the included children and not the mean (standard deviation).
† RMGIC: Resin-modified glass ionomer cement.
‡ USPHS: US Public Health Service criteria.
§ HVGIC: High-viscosity glass ionomer cement.
# RC: Resin composite.
** Index is mean (standard deviation).
†† PMRC: Polyacid-modified resin composite.
### TABLE 1 (CONTINUED)

<table>
<thead>
<tr>
<th>TYPE OF RESTORED CAVITY</th>
<th>INDEX</th>
<th>FOLLOW–UP TIME, MONTHS</th>
<th>DROPPED OUT, %</th>
<th>PERCENTAGE OF SECONDARY CARIES ACCORDING TO ALL FAILURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occlusoproximal</td>
<td>USPHS</td>
<td>6, 12, 24, and 36</td>
<td>30</td>
<td>Occlusoproximal: RMGIC: 23.08 Amalgam: 29.41</td>
</tr>
<tr>
<td>Occlusoproximal</td>
<td>USPHS</td>
<td>4, 8, and 12</td>
<td>6.9</td>
<td>Occlusoproximal: RMGIC: 4.7 Amalgam: 1.2</td>
</tr>
<tr>
<td>Occlusal, occlusoproximal</td>
<td>ART†</td>
<td>36</td>
<td>22.1</td>
<td>Occlusal: HVGIC: 7.4 Amalgam: 14.1 Occlusoproximal: HVGIC: 3.2 Amalgam: 5.5</td>
</tr>
<tr>
<td>Occlusoproximal</td>
<td>USPHS</td>
<td>12 and 24</td>
<td>9.1</td>
<td>Occlusoproximal: RMGIC: 3.1 RC: 11.3</td>
</tr>
<tr>
<td>Occlusal, occlusoproximal</td>
<td>USPHS</td>
<td>24</td>
<td>17.8</td>
<td>Occlusal: HVGIC: 15.6 RC: 11.1 Occlusoproximal: HVGIC: 28.1 RC: 24.6</td>
</tr>
<tr>
<td>Occlusal, occlusoproximal</td>
<td>USPHS</td>
<td>6 and 12</td>
<td>2.6</td>
<td>Occlusal/Occlusoproximal: RMGIC: 3 HVGIC: 12 Amalgam: 2.8 PMRC: 8.3</td>
</tr>
<tr>
<td>Occlusal, occlusoproximal</td>
<td>USPHS; visible plaque index</td>
<td>12, 18, and 24</td>
<td>12.5</td>
<td>Occlusal: RMGIC: 6 RC: 3.3 PMRC: 5.5 Occlusoproximal: RMGIC: 23.7 RC: 21.4 PMRC: 40</td>
</tr>
<tr>
<td>Occlusal, occlusoproximal</td>
<td>ART restoration criteria</td>
<td>6, 12, 24, and 36</td>
<td>24.3</td>
<td>Occlusal: HVGIC: 20 Amalgam: 20 Occlusoproximal: HVGIC: 4.9 Amalgam: 2.6</td>
</tr>
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</table>

### TABLE 2

<table>
<thead>
<tr>
<th>STUDY</th>
<th>RANDOM SEQUENCE GENERATION</th>
<th>ALLOCATION CONCEALMENT</th>
<th>MASKING OF PARTICIPANTS AND PERSONNEL</th>
<th>MASKING OF OUTCOME ASSESSMENT</th>
<th>NO INCOMPLETE OUTCOME DATA</th>
<th>NO BASELINE IMBALANCE</th>
<th>OTHER SOURCES OF FLUORIDE EXPOSURE</th>
</tr>
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<tbody>
<tr>
<td>Donly and Colleagues,19 1999</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Dutta and Colleagues,20 2001</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Taifour and Colleagues,21 2002</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Andersson-Wenckert and Sunnegardh-Grönberg,22 2006</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ersin and Colleagues,23 2006</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Daou and Colleagues,24 2008</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
</tr>
<tr>
<td>dos Santos and Colleagues,25 2009</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Unclear</td>
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<tr>
<td>Hilgert and Colleagues,26 2014</td>
<td>Yes</td>
<td>Unclear</td>
<td>Unclear</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Studies were evaluated by rating each of the study criteria as yes (low risk of bias), no (high risk of bias), or unclear (no information or uncertainty about the potential for bias).
Survival rate and meta-analysis results. Figures 2 and 3 present the main results of the meta-analyses. We observed no heterogeneity in all meta-analyses. Results from the Egger test showed no publication bias in all meta-analyses.

When we considered the secondary caries rate of the longest follow-up of all included studies for occlusal analysis, it was verified that no differences between the materials—GIC (HVGIC and RMGIC) versus amalgam and RC—(odds ratio, 1.2; 95% confidence interval, 0.5-3.1) (Figure 2). For the longest follow-up of all included studies for occlusoproximal analysis, GIC (HVGIC and RMGIC) was associated significantly with better ability than that of amalgam and RC to prevent caries lesions in the margins of occlusoproximal restorations (odds ratio, 1.7; 95% confidence interval, 1.2-2.5) (Figure 3).

Furthermore, investigators in 1 of the included studies presented the secondary caries rate of occlusal and occlusoproximal restorations together. Investigators in only 1 study evaluated separated data for PMRC and those in 4 studies evaluated separate data for HVGIC. However, the last 4 trials were conducted with different follow-ups. Similarly, investigators in only 5 studies evaluated RMGIC also with different follow-ups. For that reason, we did not conduct meta-analysis to evaluate these factors individually, and we did not assess statistical heterogeneity further.

DISCUSSION
Caries lesions in the margins of restorations remain a major reason for the replacement of restorative materials worldwide. To decrease this failure rate, investigators in previous studies have targeted the effect of fluoride release by GIC in the prevention of caries lesions. In our systematic review, we evaluated the available evidence of the
ability of GICs to prevent adjacent caries lesions in occlusal and occlusoproximal restorations in primary teeth compared with that of other restorative materials.

We observed that all restorative materials performed similarly on occlusal surfaces. Conversely, GIC was better able to prevent caries lesions in the margins of occlusoproximal restorations. We can hypothesize that this difference is related to the higher risk of this surface developing caries lesions because of the presence of contact areas, which results in areas that are difficult to reach by toothbrush and are accessible only by flossing. In this sense, investigators in a previous study reported a lower survival rate of the restorations on proximal surfaces associated with poor oral hygiene. Because biofilm results in greater demineralization in the approximal region, the presence of fluoride from GIC in this region appears to be more important; this hypothesis is a possible explanation for our results. The hypothesis of the benefit of GIC in preventing caries lesions in the margins of occlusoproximal surfaces is related to the fluoride-releasing ability of this material when compared with RC and amalgam. Investigators conducted previous studies to verify this material property, which has been confirmed in both in vitro and in situ studies. Thus, although the other restorative materials can have satisfactory performance in bond strength and retention, these factors are different outcomes compared with secondary caries lesions. This condition must be considered in the choice of restorative material because a fractured restoration could be repaired. However, in the presence of caries lesions, restorations must be replaced.

In this systematic review, we observed that the longer the follow-up period, the better RMGIC tends to perform compared with other nonfluoride-releasing restorative materials. This finding is expected because there is an increase of this preventive effect because of the fluoride-releasing ability and uptake. However, the small number of studies does not allow us to conduct subgroup analyses considering different follow-ups to confirm this hypothesis.

We did not perform quantitative synthesis on HVGIC separately because there were not enough studies to do so. It is important to highlight that the HVGIC restorations, which we included in our systematic review, were placed as ART. This technique is based on partial caries removal, different from the conventional restorative treatments, which in most cases are conducted with total caries removal. However, the differences between the techniques seem not to be related to secondary caries formation. Moreover, the longevity of HVGIC occlusoproximal restorations already has been reported in a previous meta-analysis, in which the investigators suggested using this GIC because there are no differences between it and the other available materials. Furthermore, GIC is easier to work because it does not need light curing, and a shorter time is required for the application protocol, which is a fundamental characteristic of pediatric dentistry. In this sense, we encourage further clinical trials to verify the preventive effect of this material, given that the use of HVGIC seems to result in greater cost-effectiveness than does RMGIC.

In the same way, it was not possible to perform a meta-analysis comparing GIC with PMRC because of the number of trials screened. However, investigators in most included studies observed that there was a trend of RMGIC performing better than PMRC. A possible explanation for this result could be related to the composition of this material that behaves more like an RC and releases fluoride at a lower rate than does GIC.

Otherwise, the risk of bias assessment showed that investigators in most of the studies did not report important data for clinical trials. Thus, this lack of information could interfere in the quality analyses of these studies. Likewise, there is no information about the sample size calculated, which may not be representative of the population, limiting the extrapolation of results. Moreover, these evaluated studies had up to 36 months of follow-up, which seems to be a brief time to evaluate caries lesions as an outcome. Investigators have performed some research with longer follow-ups; however, most did not fulfill the eligibility criteria, because even if the patients did not return for the evaluations because of exfoliation of primary teeth, they were considered to have dropped out. Although tooth longevity appears to be our goal as a clinical outcome, in our systematic review we focused on development of secondary caries. Thus, tooth longevity could not be considered a success because of the impossibility of evaluating secondary caries.

We also observed that there are no records about other sources of fluoride exposure because only 1 study showed these data. This information is important because the presence of fluoride can mask the preventive effect of GIC or lead to overestimation of the ability of other materials in the prevention of caries lesions. However, for these reasons, we collected this information for quality analyses. It seems to be more important in the parallel studies that the benefit of other sources of fluoride exposure cannot have been considered, because there were no baseline balance data. However, most of the studies included in this meta-analysis (62.5%) were split-mouth design, which may have resulted in little or no influence of the presence of other sources of fluoride exposure on the outcome.

A possible limitation of our systematic review is related to the literature search that we conducted only in PubMed and MEDLINE. However, although Embase results in a higher number of studies indentified, this difference between databases seems unimportant for biomedical studies because the Embase search shows many studies that did not pass the inclusion and exclusion criteria. Hence, this wider search
does not always result in higher quality citations. In this sense, the search only in PubMed and MEDLINE seems a good option for systematic reviews in medical science.

CONCLUSIONS

Thus, we can conclude that there is moderate strength of evidence for a positive association between GIC and the prevention of caries lesions only in the margins of occlusoproximal restorations of primary teeth.

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