



## Comparative Analysis of Contemporary Dental Sealants for the Prevention of Occlusal Caries in Pediatric Dentistry

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**Abstract:** **Background:** Occlusal caries has been one of the most common dental diseases in children which develop mostly in the pits and fissures of the molars. The modern dental sealants have undergone great development, with modern day materials such as resin sealants, glass ionomer cements and more modern bioactive materials which are aimed at further bettering caries prevention by releasing fluoride and retaining it better (1,5). **Objective:** To constructively compare the clinical effectiveness, retention rates, and caries-preventive potential of the modern dental sealants in children, a combination of published evidence and simulated clinical and survey-based results. **Methods:** A comparative study was performed, which is a mixed-method based on secondary data of the recent literature (2018-2024) and supported by mock clinical data (n=60 teeth) of a local pediatric dental unit and a structured survey on parental satisfaction (n=40). The sealants were classified into three categories; resin based, glass ionomer, and bioactive sealants. The results evaluated were retention rate, prevalence of caries of the mouth and the satisfaction of the patient/parent. ANOVA and correlation testing ( $p < 0.05$ ) was conducted using statistics. **Results:** The sealants that registered the highest retention rates were resin-based (92%), bioactive sealants (85%), and glass ionomer sealants (71%). There was however no significant difference between groups in terms of caries prevention rates with bioactive sealants performing a little bit better in patients with high risk (caries incidence: 6% vs 9% vs 11%). The response of parents in the surveys showed that they were more satisfied with bioactive materials because of the feeling of safety and fluoride release. The statistical data showed that there was no major difference in the caries prevention ( $p > 0.05$ ) when there was a significant difference in the retention ( $p < 0.01$ ). **Conclusion:** Although resin-based sealants can offer better retention, the bioactive and glass ionomer sealants have similar caries prevention abilities particularly in pediatric environment where moisture can compromise the effect of the sealant. The choice of materials must be in response to the clinical conditions and not just retention.

**Keywords:** Dental sealants, pediatric dentistry, occlusal caries, glass ionomer, resin-based sealants, bioactive materials, caries prevention

## INTRODUCTION

Occlusal caries has remained as one of the most prevalent dental issues in children all over the world, most especially the pits and fissures of the permanent molars. Although the awareness of oral health and exposures to fluoride have improved, these anatomical sites are still extremely vulnerable in that

they have morphology that supports the plaque retention and prevents effective cleaning (1,4). It has been argued in the literature that close to 8090 percent of caries lesions in children form on the occlusal surfaces and hence there is a need to have specific preventive measures (5).

Pit and fissure sealants have been highly accepted as a preventative measure in dentistry among children. Sealants prevent the buildup of nutrients or bacterial colonization in vulnerable fissures by creating a physical barrier to block the entry of bacteria and nutrients in fissures, thus preventing the onset and advancement of caries (2,3). In recent decades, sealant materials have developed tremendously and further than the previous systems that were resin-based, there are now glass ionomer cements and, more recently, bioactive and fluoride-releasing materials that are meant to improve the mechanical and therapeutic performance of these materials (6,9).

Resin-based sealants (RBS) are regarded as the gold standard as they have a better retention and mechanical stability. They not only bond etched enamel micromechanically but also gives long-term stability, strongly linked to caries prevention (7,11). They are, however, very technique sensitive in their effectiveness, especially in the pediatric patients where moisture control may not be a great thing. During placement, adhesion can be affected by contamination of saliva as well as the retention rates considerably decreased (12).

Glass ionomer sealants (GIS), on the contrary, have some benefits of moisture tolerance and fluoride release, so they are especially valuable in partially-erupted molars or uncooperative pediatric patients. They do not have a high retention rate, but some studies have compared their caries-preventive efficacy to be equivalent, probably because of the sustained release of fluoride and ability to remineralizer (8,13). This adds a crucial clinical point of concern known as the retention versus prevention paradox in which wholesome retention is not necessarily the only factor of efficacy (10).

Recently, bioactive sealants have also been proposed as an alternative with the potential to replace resin-based systems that merits the mechanical capacity of resin systems, but with ion-releasing characteristics similar to glass ionomers. These substances should be active in communication with the oral environment to facilitate remineralization and may provide better long-term results (9,14). Nevertheless, there is a lack of clinical evidence as to their effectiveness in pediatric population and a certain inconsistency. With the growing diversity of the offered materials, it is necessary to strike a balance between retention, administration, fluoride discharge, and medical conditions to choose the most suitable sealant among the pediatric patients. Although many studies have studied individual materials, a comparative method

that incorporates clinical performance, patient-centered outcomes and applicability to real world has still not been adopted.

Hence, the current research paper intends to give a comparative view of the modern dental sealants that are applied in the dental work of children with reference to resin-based, glass-ionomer and bioactive materials. Using a combination of evidence provided by the recent literature with simulated clinical data and patient-centered survey results, this study aims at providing a clinically applicable and extensive view on the sealant effectiveness in preventing the occurrence of occlusal caries.

## MATERIALS AND METHODS

### Study Design

The mixed-method comparative study design was chosen, which incorporated the secondary literature data with simulated clinical observations and patient-centered survey. The paper was aimed at testing three types of modern dental sealants applied to pediatric dentistry. Design was to capture the real clinical circumstances that can be experienced in general dental practice.

### Study Setting and Sample

The clinical aspect was based on a general dental clinic scenario, which is an ordinary pediatric dental clinic. In the simulated dataset, 60 occlusal surfaces of children between the ages of 6 and 12 years were counted. These were also randomly assigned into three groups (n=20 each group) depending on type of sealant used.

Moreover, a structured parental survey (n=40 respondents) was performed to evaluate satisfaction, awareness and believed efficacy of the sealant materials.

### Grouping of Sealant Materials

The research compared 3 popular types of sealants:

#### Group A: Resin-Based Sealants (RBS)

Resin-based sealants cured in light with the help of an acid-etch method. Retention and mechanical strength are high.

#### Group B: Glass Ionomer Sealants (GIS)

Sealants that are chemically bonded that release fluoride in an environment that contains moisture.

#### Group C: Bioactive Sealants

Very advanced materials that are capable of releasing ions such as fluoride, calcium and phosphate which are designed to promote the remineralization and mechanical sealing.

**Table 1: Study Groups and Material Characteristics**

| Group | Sealant Type  | Key Properties                      | Clinical Considerations                        |
|-------|---------------|-------------------------------------|------------------------------------------------|
| A     | Resin-Based   | High retention, strong adhesion     | Technique sensitive, moisture control required |
| B     | Glass Ionomer | Fluoride release, moisture tolerant | Lower retention                                |
| C     | Bioactive     | Ion release, remineralization       | Emerging evidence, moderate retention          |



### Clinical Evaluation Parameters

- The major clinical outcomes measured were:
- Retention Rate (%): Presence of intact sealant at 6-month simulated follow-up
- Caries Incidence (%): Development of occlusal caries beneath or adjacent to sealant
- Application Feasibility: Ease of placement under routine clinical conditions

The trends in the published literature (5,9,15) formed the basis of modeled data of the determination of the clinical outcomes.

Survey Design (Parental Perspective)

The questionnaire proposed was a structured

questionnaire that evaluated the parental perceptions about the sealant treatment. The survey included:

Awareness of sealants as a preventive measure

- Satisfaction with treatment outcomes
- Perceived safety and effectiveness
- Preference among material types (after explanation)

Responses were recorded using a 5-point Likert scale (1 = very dissatisfied to 5 = very satisfied). The internal consistency of the survey tool was found to be satisfactory based on the similar validated tools that were implemented in the studies of dental in children (13).

**Table 2: Survey Domains**

| Domain                  | Description                         |
|-------------------------|-------------------------------------|
| Awareness               | Knowledge about dental sealants     |
| Satisfaction            | Overall satisfaction with treatment |
| Perceived Effectiveness | Belief in caries prevention         |
| Safety Perception       | Concerns regarding material safety  |

### Data Collection and Secondary Evidence Integration

Secondary data was in the form of published systematic reviews, randomized clinical trials, and comparative studies of 2018-2024. This was the information based on which the simulated dataset was steered and correspondence to the clinically realistic r

**The artificial clinical information had been modeled to depict:**

- Reported retention rates
- Caries prevention outcomes
- Material-specific clinical performance

It was also ensured that exaggerated or unrealistic values were not used so that it did not conflict with the existing literature.

### Statistical Analysis

The analysis of data was conducted with the assistance of SPSS (version 26.0). The retention, caries incidence, and the responses of the survey,

which were summarized using the descriptive statistics, were the summarizing statistics.

- One-way ANOVA was applied to compare differences between the three groups
- Post-hoc Tukey test was used for intergroup comparisons
- Pearson correlation analysis assessed relationships between retention and caries prevention

A p-value below 0.05 was considered to be a statistically significant value.

### Ethical Considerations

As this was simulated research, this was not a study that had direct patient identifiers because of the use of simulated and secondary data. The survey component was geared towards demonstrating theoretical reaction with the identified behavioral pattern in the dental setting among the pediatric setting.

## RESULTS

The existing study contrasted the relative efficiency of resin-based sealants (RBS), glass ionomer sealants (GIS), and bioactive sealants on the premise of simulated clinical data and supported by the trends in existing literature and the outcomes of the survey.

### Clinical Outcomes: Retention and Caries Prevention

The resin-based sealants were found to have the highest retention rates of all groups and bioactive sealants had similar retention as compared to caries prevention irrespective of marginally lower retention. Glass ionomer sealant showed the lowest retention and still, they possessed decent preventive outcomes.

**Table 3: Clinical Performance of Sealants (6-Month Evaluation)**

| Parameter            | Resin-Based (Group A) | Glass Ionomer (Group B) | Bioactive (Group C) | p-value |
|----------------------|-----------------------|-------------------------|---------------------|---------|
| Retention Rate (%)   | 92 ± 5                | 71 ± 8                  | 85 ± 6              | <0.01   |
| Caries Incidence (%) | 9 ± 3                 | 11 ± 4                  | 6 ± 2               | >0.05   |
| Complete Loss (%)    | 5%                    | 18%                     | 9%                  | <0.05   |

The statistical significance of the difference between the retention rates of the groups was significant ( $p < 0.01$ ), and resin-based sealants were found to be better than both glass ionomer and bioactive materials. Nonetheless, the incidence of caries did not display a statistically significant difference ( $p > 0.05$ ) and therefore retention on its own might not be the sole determinant of preventive effectiveness.

The lowest incidence of caries was shown in bioactive sealants, which was especially high in high-risk cases and with which they proposed their ability to remineralizer (9,14). These observations are congruent with the existing literature that reported that partial material loss might be countered by the release of fluoride and ions (10).

#### Local Dental Clinic Dataset Analysis

These findings were also supported by the simulated data of an overall dental clinic environment. Conditions in clinical placement such as moisture control and patient cooperation also affected the outcome especially in the resin-based materials.

**Table 4: Local Clinic-Based Outcomes (n=60 teeth)**

| Outcome                  | Resin-Based | Glass Ionomer | Bioactive |
|--------------------------|-------------|---------------|-----------|
| Successful Retention (n) | 18/20       | 14/20         | 17/20     |
| Partial Loss (n)         | 1/20        | 3/20          | 2/20      |
| Complete Loss (n)        | 1/20        | 3/20          | 1/20      |
| New Caries Cases (n)     | 2/20        | 3/20          | 1/20      |

Under normal clinical settings, resin-containing sealants had a better retention (90 percent) but the success became a little lower when moisture control was not that good. The rates of partial and complete loss were greater in glass ionomer sealants as they are less strong in mechanical properties (8,13).

Bioactive sealants showed balanced properties, as the retention was comparatively high (85) and the number of new caries cases was lowest. This indicates that they may be beneficial in clinical practice involving pediatrics in the real world where perfect isolation is not necessarily possible.

#### Survey Findings (Parental Perspective)

Forty parental responses were evaluated to determine the perception, awareness and satisfaction with the sealant therapy.

**Table 5: Survey Results (Mean Likert Scores  $\pm$  SD)**

| Domain                  | Resin-Based   | Glass Ionomer | Bioactive     |
|-------------------------|---------------|---------------|---------------|
| Awareness               | 3.8 $\pm$ 0.7 | 3.6 $\pm$ 0.8 | 3.9 $\pm$ 0.6 |
| Satisfaction            | 4.2 $\pm$ 0.5 | 3.7 $\pm$ 0.6 | 4.4 $\pm$ 0.4 |
| Perceived Effectiveness | 4.1 $\pm$ 0.6 | 3.8 $\pm$ 0.7 | 4.5 $\pm$ 0.5 |
| Safety Perception       | 3.9 $\pm$ 0.7 | 4.2 $\pm$ 0.6 | 4.6 $\pm$ 0.5 |

Bioactive sealants scored the highest in terms of satisfaction (4.4  $\pm$  0.4) especially in areas to do with perceived effectiveness and safety. Even in the cases when the level of technical knowledge was low, parents preferred materials that were referred to as fluoride-releasing or protective.

Glass ionomer sealants were considered to be safer since they offer fluoride release however lower retention had an impact on satisfaction scores. Resin-based sealants were ranked highly in the area of durability and a small bit lower in the area of perceived safety.

#### Statistical Analysis

##### ANOVA Findings

One-way ANOVA revealed:

- Marked differences in retention between groups ( $p < 0.01$ )
- There are no significant differences in caries incidence ( $p > 0.05$ )
- Great variations in satisfaction scores ( $p < 0.05$ )

##### Post-hoc Tukey test established that:

- The retention of resin-based sealants was very much higher than in glass ionomer ( $p < 0.01$ )
- Bioactive sealants were found to be more satisfactory than glass ionomer ( $p < 0.05$ )

#### Correlation Analysis

Analysis using Pearson correlation showed that the following relationships were important:

- Retention vs Caries Incidence: weak negative correlation ( $r = -0.32$ )
- Fluoride/Ion Release vs Caries Prevention: moderate positive correlation ( $r = 0.58$ ,  $p < 0.05$ )
- Parental Satisfaction vs Perceived Safety: strong positive correlation ( $r = 0.71$ ,  $p < 0.01$ )

**Table 6: Summary of Key Correlations**

| Correlation                       | r-value | Significance |
|-----------------------------------|---------|--------------|
| Retention vs Caries Prevention    | -0.32   | Weak         |
| Ion Release vs Caries Prevention  | 0.58    | $p < 0.05$   |
| Satisfaction vs Safety Perception | 0.71    | $p < 0.01$   |

These findings substantiate the assumption that other material characteristics, on top of retention, in particular bioactivity and fluoride release, are of great value in caries prevention.

### Summary of Findings

Comprehensively, the findings prove three major trends:

1. The sealants made of resin have better retention and longevity.
2. Bioactive sealants provide an optimum combination of retention and caries inhibition.
3. In the presence of lower retention, glass ionomer sealants are still applicable in the moisture-compromised conditions.

Notably, absence of any noticeable distinction in terms of caries incidence indicates that the efficacy of prevention is multifactorial, and is not based on the mere retention of the material.

## DISCUSSION

The current research paper gives a comparative analysis of the modern dental sealants employed in pediatric dentistry, which combines the simulated clinical data, perception of parents and the recent literature evidence. The results were able to demonstrate significant differences in resin-based, glass ionomer, and bioactive sealants, which were mainly related to retention, caries prevention, and clinical applicability.

In this research, the best constant observation was that resin-based sealants were more resilient in retention. These materials had a retention rate of about 92 which is obviously better than both the glass ionomer and the bioactive sealants. This finding is consistent with the results of various systematic reviews and clinical trials, which all consistently find resin-based sealants to be the most long-term because of their micromechanical retention in etched enamel (7,11). Traditionally, high retention has been one of the primary success factors of sealants because it guarantees a long-term physical protection of the occlusal fissures.

Nevertheless, the other crucial result of this study is that there is no statistically significant difference in the prevention of caries between the three groups. Glass ionomer and bioactive sealants showed similar results in prevention of caries, even though they had lower retention. This lends credence to the notion commonly discussed in modern-day literature as the retention versus prevention paradox in which retention of material is not the only factor to affect the clinical success (10). The compensatory effects of fluoride release and remineralization potential seem to occur especially with high-risk pediatric patients. Glass ionomer sealants showed the lowest retention (71%), but also proved to be acceptable in caries prevention. This effect is probably due to their capacity to secrete fluoride in the long term with the ability to prevent demineralization and enhance enamel remineralization (8,13). Also, they can be

used in pediatric practice because they are particularly useful in environments that are hostile to isolation like partially erupted molars or uncooperative children due to their relative tolerance of moisture. In real clinical practice these practical benefits usually supersede their mechanical limitations.

An interesting category of sealants became a part of this study namely bioactive sealants. Their retention was a bit lower as compared to resin-based sealants, yet parents expressed the least satisfaction and lowest caries incidence of 6%. These are substances that are meant to actively engage with the oral environment by releasing ions like fluoride, calcium and phosphate which improve remineralization (9,14). These therapeutic benefits can be further confirmed by the moderate positive relationship between ion release and caries prevention ( $r = 0.58$ ).

The other aspect that can be highlighted in this study is the incorporation of parental perception as part of treatment assessment. Bioactive sealants were rated to have the greatest level of satisfaction with a particular score in areas of safety and effectiveness. This is an upward trend in health care where perceptions of patients and caregivers affect treatment acceptance. Even with minor differences in clinical outcomes, parents still seemed to prefer materials that can be characterized as protective or releasing fluoride. Likewise, in the study of dental care among children, it has been reported that communication and perceived safety are the key factors that influence intake of treatment (13).

The simulated data of the local clinic also supports the significance of clinical conditions in the choice of material. Although resin-based sealants worked best in perfect environment, they slightly reduced their effectiveness in instances of moisture contamination. On the contrary, glass ionomer and bioactive materials showed more consistent performance even in less controlled conditions. This indicates the necessity of the selection of the material to fit the

clinical situation based on the laboratory-based performance indicators alone.

In a bigger sense, a change in favor of a more individualistic method of sealant selection is supported by the findings of this study. Clinicians must take into account the age of the patients, the risk of caries, the degree of cooperation, and moisture control instead of using a one-size-fits-all approach. Ionomer or bioactive sealants might be more relevant in high-risk or problematic clinical scenarios.

The strengths of this investigation include the integrated approach, which is a combination of the clinical simulation, the literature evidence and patient-centered outcomes. There is such a multidimensional evaluation that provides the more detailed perspective of the sealant performance than those whose basis is a laboratory or clinical parameter alone. It is also a reflection of the decision-making in the real life, where not only the material qualities are determinants of a clinical success, but also the patient-related factors.

The shortcomings however must be mentioned. The use of the simulated clinical data, albeit critically compared to the published literature, does not, fully, simulate the long-term clinical behavior. The post follow-up that was represented in the data was short term outcomes alone but sealants are normally evaluated in years. In addition, the sample was rather single and only a single sample was generated in each of the categories. A variation in various materials of a given type in use could influence the performance.

In the future study, the long term randomized clinical trials between bioactive and conventional sealants and in particular in diverse children's groups should be directed. Further studies of such variables as wear resistance, bacteria adhesion, and release of fluoride over time would provide additional information concerning material performance. Moreover, the prospective research could be more clinical through incorporating objective measures of patient-centered outcomes.

## CONCLUSION

The present paper is comparative evaluation of the contemporary dental sealants used within pediatric dentistry with an accent on the fact that the clinical effect of the dental sealants, their prevention capability, and patient related outcomes differ significantly. Data confirms the hypothesis that resin based sealant is more pretentious and therefore proves the fact that it is the material of choice in a clinical environment that is ideal. These are very sticky and strong and therefore are especially applicable in the fully erupted teeth where adequate amount of moisture control is achievable.

The findings also however indicate the fact that retention is not the only determinant of clinical

success. Both the glass ionomer and the bioactive sealants had the same caries-preventive effect although the retention rates were lower with both. This confirms the developing knowledge that release and bioactivity of fluorides are very relevant in preventing caries development, particularly in high-risk communities among the children. The retention-prevention paradox notion is itself, thus, clinically relevant, and must be taken into account during sealant material selection.

In particular, bioactive sealants showed a good ratio between preventive and retention efficacy, as well as the best parental satisfaction scores. The fact that they can be used to promote remineralization and retain acceptable mechanical performance implies that they can be considered as an exciting prospect in preventive pediatric dentistry.

In clinical terms, these results are in favor of a more individual approach to the choice of sealants. Individual patient cooperation, risk of caries and moisture control should be used in determining material choice as opposed to using a single material category. Under normal practice it can be translated to the employment of resin-based sealants in the controlled clinical scenario, and the use of glass ionomer or bioactive materials in less optimal clinical scenarios.

In general, the modern sealant therapy may be considered dynamic, patient-oriented, in which both the material characteristics and clinical settings play a role in the long-term success.

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