# Effects of resin luting agents and 1% NaOCl on the marginal fit of indirect composite restorations in primary teeth

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## ABSTRACT

Objective: The purpose of this study was to provide information regarding the marginal adaptation of composite resin onlays in primary teeth previously treated with 1% sodium hypochlorite (NaOCl) (pulp irrigant) using two different resin luting agents. Material and Methods: Forty extracted sound primary molars had their crowns prepared in a standardized machine and were randomly divided into 4 groups (n=10): G1 (1% NaOCl irrigation+EnForce); G2 (EnForce); G3 (1% NaOCl irrigation+Rely X); G4 (Rely X). The onlays were made with Z250 composite resin on plaster models. After luting, the tooth/restoration set was stored in 100% relative humidity at 37ºC for 24 h and finished with Soflex discs. Caries Detector solution was applied at the tooth/restoration interface for 5 s. The specimens were washed and four digital photos of each tooth were then taken. The extents of the gaps were measured with Image Tool 3.0 software. The percentage data were submitted to a Kruskal-Wallis test ($\alpha$=0.05). The Relative Risk test analyzed the chance of a gap presence correlated to each group. Results: There were no statistically significant differences (p>0.05) among the groups. The relative risk test revealed that some groups were more apt to have a presence of gaps than others. Conclusion: Neither the 1% NaOCl treatment nor the resin luting agents caused any alterations in the dental substrate that could have influenced the marginal adaptation of composite onlays in primary teeth.

**Key words:** Composite resins. Prosthesis fitting. Sodium hypochlorite.

## INTRODUCTION

Gap measurement is a reliable method of evaluating the initial quality of resin restorations[1]. The presence of an enamel gap is an important factor that predicts future failures in composite restorations, and this occurs because of the composite resin polymerization shrinkage. Shrinkage leads to the development of higher stresses when the composite is bonded to the cavity walls[16]. Even indirect restorations, which are expected to have minimal polymerization shrinkage due to cement agents, experience this phenomenon[23].

It is extremely important to recognize enamel gap. As the normal stresses at the tooth/composite interface of a restoration increases from the enamel margins towards the internal cavity angle[13], it can lead to discoloration, microleakage and secondary caries[31]. The feature of a linearly measured gap seems to be a lack of adhesion. Alonso, et al.[2] (2004) detected marginal gaps in the dentin/resin interface using a stain composed of red acid and propylene glycol (Caries Detector®). The detected gaps were measured by a digital system that has presented reliable results. The gaps identified by the digital system are easy to carry out and the results are valid when compared to a scanning electronic microscopy analysis of the same gaps[1].

It is widely believed that root-filled teeth are weakened and more susceptible to fracture than vital ones, especially because there is a reduction of the inner cuspal slopes that support the cuspal angles of the coronal tooth structure during endodontic treatment[10,29]. Composite restorations are the best choice for sealing weakened treated teeth, as the micromechanical retention obtained by the resin-dentin interdiffusion zone (hybrid layer) is effective in strengthening the weakened tooth after endodontic therapy[5,19].

Indirect composite restorations have several over direct ones, such as the replacement of natural convexities of teeth, control of proximal contact points[27,28,30] and polishing and finishing possibilities. Because indirect restorations can be done outside the mouth, these factors contribute to improve the treatment of pediatric patients and also decrease the time spent chairside[24,25,27]. Furthermore, a better marginal fit can be obtained, especially in the gingival walls of indirect restorations.

Primary teeth present structural and compositional differences from permanent teeth, such as thinner dentin layer and the lower degrees of mineralization[3]. Secondary dentin secretion and pulpal repair activity decreases with aging in primary teeth. These promote a favorable condition for the carious process to reach the coronary pulp[9]. In these cases, an indirect composite restoration can be a better treatment choice.

Because microorganisms penetrate from a coronal direction and might re-infect the root canal system, a lack of adhesion between the final restoration and tooth structure may reduce the prognosis of an endodontically treated tooth[12]. Thus, the quality of the coronal restoration is a critical factor for the overall prognosis of the tooth after the root canal is filled.

Several features interact cumulatively to influence the tooth gap at the interface between cavity walls and composite restorations. Sodium hypochlorite (NaOCl) irrigation during endodontic therapy could affect the ability to create a high-quality adhesion of restorative materials to the pulp chamber wall[14,20]. According to Morris, et al.[22] (2001), The oxidizing action of NaOCl probably leads to the oxidation of some components in the dentin matrix that may compromise the process of initiation due to polymerization of the resin system. Borges, et al.[6] (2008) showed that 1% NaOCl modified the inorganic molecular content. Insufficient polymerization of the adhesive system, for example, could lead to gaps at the tooth/restoration interface.

Resin luting agents present different adhesive systems that mostly vary with regard to solvent component[30]. Acetone and ethanol solvents require moisturized dentin during the adhesion procedure, but it is not specified in some instructions for use. Dentin overdrying can lead to the collapse of the collagen fibril network, affecting negatively dentin adhesion[12].

Even in indirect restorations, there are signs that marginal defects occur despite the use of luting agents[21,28]. Particularly in primary teeth, there is no study evaluating the presence of gaps in cavities prepared in endodontically treated teeth. Root canal filling in primary teeth has been done with several filler pastes that do not set, such as zinc oxide and eugenol. Therefore, it is more dangerous if contamination occurs in primary teeth when compared to filling materials used in permanent teeth[15,17].

The hypotheses of the present study are: (1) treatment with 1% NaOCl can increase the enamel gaps of composite onlays in primary teeth and (2) there is a difference between the two resin luting agents tested, which require adhesive systems with different solvents and manufacturers' instructions.

## MATERIAL AND METHODS

This study was approved by the Research Ethics Committee of FOP/UNICAMP (approval No. 108/2003) according to the Brazilian Resolution of the National Commission for Ethics in Research.

Forty freshly extracted primary molars were cleaned with pumice/water slurry and stored frozen for no more than 2 months until use in the experiment. Subsequently, the teeth were equally divided into 4 groups (n=10) according to the treatment: G1 (1% NaOCl irrigation+EnForce); G2 (EnForce); G3 (1% NaOCl irrigation+Rely X); G4 (Rely X). The commercial brands, compositions, manufacturers and batches of the materials used in this study are shown in Figure 1. Each group was comprised of 5 mandibular first molars, 2 maxillary first molars, 2 maxillary second molars and 1 mandibular second molar.

Each tooth was embedded in polystyrene resin (Piraglass Ltda., Piracicaba, SP, Brazil) using a PVC cylinder (21 mm diameter and 25 mm high) as mold. The sound crown was positioned 1 mm below the cementoenamel junction.

The teeth were prepared in a machine to standardize certain areas of the cavities (Figure 2). Diamond tapered burs with a 6-degree inclination (KG Sorensen Ind. e Com. Ltda., Barueri, SP, Brazil), especially designed for this experiment, were used. The burs were replaced after every fifth preparation. The onlay preparations had the following characteristics:

*Occlusal box*: the isthmus width was approximately half of the buccolingual distance

| Materials | Composition* | Manufacturer - Batch No. |
|---|---|---|
| 1%NaOCl | | Proderma Pharmacy Ltda, Piracicaba, SP, Brazil |
| Filtek Z250 (C4) | Bis-GMA; Bis-EMA; UDMA zirconium/silica filler (82 w%) | 3M/ESPE, St. Paul, MN, USA – 2KX |
| EnForce (A2) | Bis-GMA; TEGDMA dimethacrylate monomers; filler (67 w%) | Dentsply, Petrópolis, RJ, Brazil – 55612†, 54925‡ |
| Cond ac 37 | 37% Phosphoric acid | FGM, Joinville, SC, Brazil – 101103 |
| Prime & Bond 2.1 | UDMA; PENTA; toluene and dimethyl aminobenzoate, cetylamine hydrofluoride, acetone, photoinitiators | Dentsply, Petrópolis, RJ, Brazil – 55684 |
| Rely X Luting (A3) | Bis-GMA; TEGDMA zirconia/silica filler (67.5 w%) dimethacrylate monomers | 3M/ESPE, St. Paul, MN, USA – CXCY |
| Single Bond | HEMA; Bis-GMA; dimethacrylates; methacrylates; polyacrylic acid and poly-itaconic copolymers ethanol; water; photoinitiators | 3M/ESPE, St. Paul, MN, USA – 3HW |

* Material compositions according to the manufacturers' technical profile.
† Matized paste
‡ Catalyzed past

**Figure 1-** Description of materials used in this study

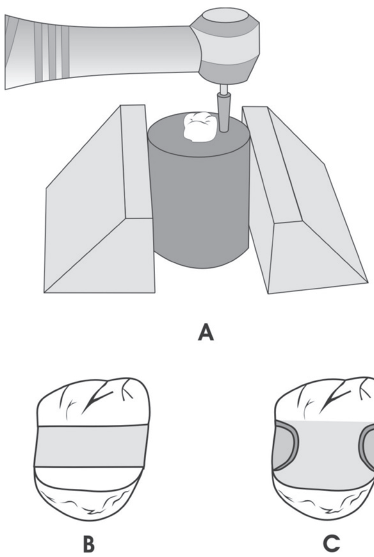


**Figure 2-** Sequence of tooth cavity preparation using a high-speed handpiece perpendicularly adjusted to the oclusal surface of teeth. A: Tooth positioned into a machine in order to standardize the cavity dimensions of each tooth until cusp grinding step. B: Occlusal box was made beginning with grinding in a slot shape. C: The proximal boxes were made in the machine followed by additional manual grinding of the largest cusp

without any beveling of the occlusal cavosurface margin. The depth ranged according to the anatomy of the teeth. For first molars, the depth of pulpal wall was 2.0 mm below the tallest cusp. For second molars, the depth of pulpal wall was 2.5 mm below the tallest cusp.

*Proximal box*: the depth was determined according to the remaining distance of each tooth with the polystyrene resin base due to the variation in cervical-occlusal heights. The inner angles of the prepared teeth were rounded.

All teeth underwent additional reduction of the largest cusp: distolingual cusps of the mandibular first molars, palatal cusp of the maxillary first molars, distolingual cusps of the mandibular second molars and mesiopalatal cusps of the maxillary second molars.

The treatment with 1% NaOCl in G1 and G3 was carried out to simulate irrigation during the root canal therapy. Each tooth was placed in a plastic container while the solution was simultaneously flushed out through a disposable pipette for 30 min and with the Multi-Sonic-s ultrasound (Gnatus, Ribeirão Preto, SP, Brazil). This was done to simulate an irrigation section using ultrasound.

Impressions of the preparations were taken with heavy and light addition silicone (Express; 3M/ESPE, St. Paul, MN, USA), and the casts were poured in plaster (Herostone; Vigodent, Rio de Janeiro, RJ, Brazil). Next, the casts were isolated with Isolant Gel (KG Sorensen Ind. Com. Ltda., Barueri, SP, Brazil) and the indirect restorations (onlays) were made with Z-250 composite resin (3M/ESPE; shade C4), using an incremental technique beginning with the proximal box followed by the occlusal box. Each increment was light-activated for 40 s using an Elipar Trilight curing unit (ESPE).

The bonding procedure on tooth surface was done according to the manufacturer's instructions, which consisted of 37% phosphoric acid etching followed application of Prime Bond 2.1 or Single

Bond for the luting agents En Force or Rely-X (Figure 1), respectively. The resin luting agents were inserted on the inner surfaces of the onlays being cleaned with phosphoric acid for 20 s. The onlays were fixed by finger pressure to simulate a clinical situation, and excess cement was removed with a cutting instrument. Then, each surface (buccal, lingual, mesial, and distal) was light-activated for 40 s. Finally, the restoration/tooth set was stored in 100% relative humidity at 37ºC for 24 h followed by a finishing procedure using Soflex discs (3M/ESPE). The tooth preparations, the composite onlays and the bonding procedures were done by the same operator.

After storage, Caries Detector® (Kuraray Co., Osaka, Japan) was applied on the restoration margins for 5 s, followed by rinsing in tap water gentle air drying[1]. Two black dots were drawn 2 mm apart with a pen using a digital caliper rule to calibrate the measurement used in the Image Tool 3.0 software (University of Texas, Health Science Center at San Antonio, TX, USA). Two dots were drawn on each of the buccal, mesial, distal and lingual surfaces. Then, with a Mavica FD 97 camera (Sony Corp., Tokyo, Japan), digital color photographs were taken of each tooth surface (buccal, lingual/palatal, mesial and distal) from a fixed distance, at equal magnification and with equal light levels.

Each digital photograph (×40 magnification) of each surface was then evaluated in the Image Tool software. The two black dots drawn on the tooth surfaces were used to calibrate the spatial measurements. The command "calibrate spatial measurements" in the Image Tool Software (Figure 3A) was used to transform the measurements into mm. A line was drawn to join the two black dots after the conversion into mm, and the number 2 was written into a specific box that required an exact measurement value used as reference (Figure 3B). Afterwards, each measurement was automatically converted into mm. This procedure was repeated for each photograph.

The "distance command" was used and a line was drawn on the restoration margins (Figure 3C). Next, a line was drawn on all tooth/restoration margins, and the sum of those four surface lengths was determined as the total length of the tooth/restoration interface. The same procedure was carried out on the stained areas considered to show the presence of gaps, and the sum of the stained area lengths of each tooth was considered as the

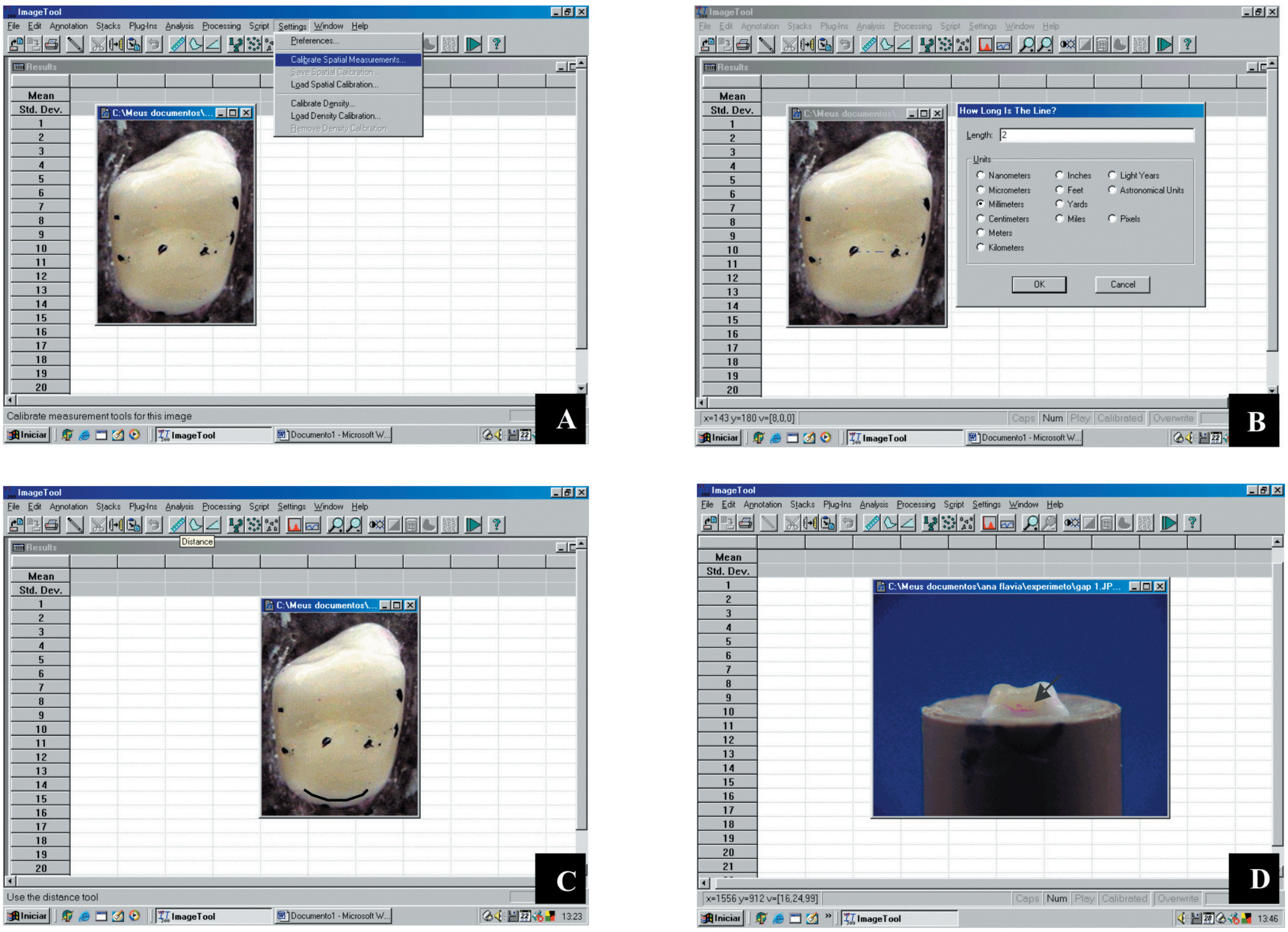


**Figure 3-** Sequence of gap measurements. A and B: Calibration of measurements to mm. C: Measurement of marginal restoration. D: Gap presence detected by staining area (black arrow)

total gap length (Figure 3D).

A blinded, calibrated examiner measured all marginal gaps after obtaining reliable gap lengths using 25% of the total sample. The statistical correlation results (Pearson's correlation test) showed a 96% confidence. The gaps at the tooth/restoration margins were determined. The data from each specimen were transformed into gap percentages in relation to the total margin using the equations: $Gap\% = \frac{dl}{Tl} \times 100$, where dl is the stained length and Tl is the total margin length. The gap percentages were subjected to a Kruskal Wallis test at 5% significance level. Moreover, the Relative Risk test was used to analyze the possibility of a gap presence. According to Kleinbaum, et al.[16] (1986), this test involves the division of the number of specimens with gaps by the number of specimens without gaps.

## RESULTS

The gap percentage medians and quartiles of the groups are displayed in Figure 4. The Relative Risks of gap presence of the groups are shown in Table 1.

There were no significant differences (p>0.05) in the gap percentages observed for the evaluated groups (Figure 4). The bars represent the quartiles and the vertical lines represent the median values for each group. It can be observed that G3 (1% NaOCl irrigation+Rely X) and G4 (Rely X) had first quartile values (25%) coinciding with zero, while G2 showed the longest distance to zero. These findings indicate groups with a higher and lower quantity of the specimens without a gap presence, respectively. G1 (1% NaOCl irrigation+EnForce) can be thought to have an intermediate chance of having gaps compared to the other groups. G3 (1% NaOCl +Rely X) had its median and quartile values coinciding with zero, which means that this group did not present any specimens with gaps.

The Relative Risk test did not show statistically significant differences among the correlated groups (p>0.05), although we may consider the tendency of some groups to present fewer gaps than others from a numerical perspective. Forty percent of the marginal gap presence was found in the G1 and G2 samples, 20% in the G4 samples, and 0% of the G3 samples (Table 1). However, the likelihood of gap occurrence was the same for both G1 and G2. The value was 2.64 times higher for G2 than G4 and thus 0.38 times higher when G4 was compared to G2.

An additional inspection was carried out in the sites that had greater frequencies of marginal gaps. This examination revealed that among specimens of each group with gap presence, 100% of the samples showed a marginal gap in the cervical wall.

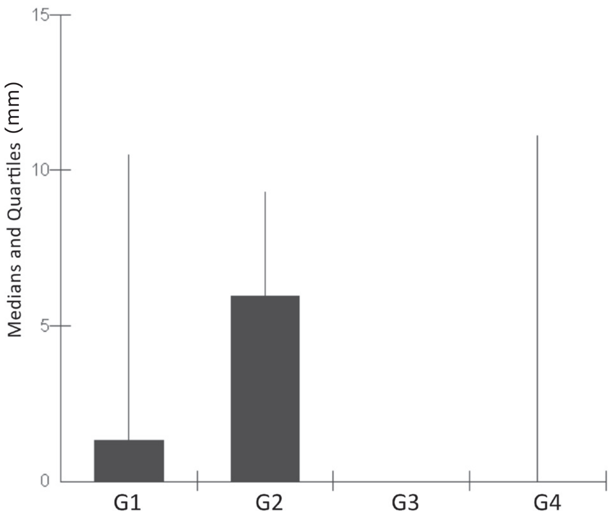


**Figure 4-** Medians and quartiles (25% and 75%) according to the experimental groups

**Table 1-** Relative Risk found in the groups confronts

| *RR | G1 | G2 | G3 | G4 |
|---|---|---|---|---|
| G1 | -- | rr=1 | rr=0 | -- |
| G2 | rr=1 | -- | -- | rr=0.38 |
| G3 | rr=0 | -- | -- | -- |
| G4 | -- | rr=2.64 | rr=0 | -- |

*rr=Relative Risk

## DISCUSSION

The first hypothesis of this study, that the groups that received treatment with 1% NaOCl would not show more enamel gaps compared to untreated groups, was rejected. The second hypothesis was also not validated. Although the two adhesive system techniques have different manufacturers' instructions and solvents, the presence of interfacial gaps in the two resin luting agents was statistically similar.

There was no significant difference related to the length of the gap present in the enamel margins of the restorations in all groups. There was also no significant interaction between the substrate treatment and the resin luting agent. The percentage of gaps found in this study was lower compared to the results of other studies[7,24-26], especially considering that gaps were measured from the total margin lengths of the samples. Although the gap percentages were low, they are still unfavorable percentages representing the first signs of a future clinical failure of the restoration.

It is very important to identify the initial gaps in indirect composite restorations of primary teeth because these are predictors of future composite failures, which start from the margins[13,14]. Braun, et al.[8] (2001) showed a correlation between marginal deterioration and long-term failures. Moreover, the loss of integrity of restorations placed in endodontically treated teeth is more frequently responsible for unsuccessful endodontic treatment than failures in endodontic therapy *per se*. For this reason, the success of root-filled teeth restored with direct or indirect composite resins depends on a high-quality bond of the material to the dental structure.

The magnitude of the generated stress is the main cause of the initial gaps that form in the composite restorations. This is influenced by three main factors: tooth cavity preparation, material composition, and technique. The interplay among these factors determines the exact manifestation of the shrinkage for a given restoration[15].

First, cavity preparation influences the amount of the gap margin. It has been shown that indirect composites better fit onlays with single cusp coverage and wide occlusal isthmus than those with double cusp coverage and wide isthmus[13]. Second, monomer composition, filler content, degree of conversion and the resulting polymer crosslinking of resin luting agents are all closely related to the amount of polymerization shrinkage[22]. Both EnForce and Rely X have Bis-GMA molecules as the main monomer, which has a high viscosity that is minimized by the high percentage of diluent monomers (TEGDMA). However, this causes significant polymerization shrinkage.

Furthermore, the higher the elastic modulus, the higher the polymerization stress[24]. As such, the bifunctional monomers Bis-GMA/TEGDMA result in a large number of double bonds *per* a given unit of weight. They create a high degree of crosslinking and produce a very rigid polymeric network, which contributes to an increase in the elastic modulus of the resulting material. The similarity in the compositions of the two resin luting agent suggests the same behavior related to polymerization shrinkage and their close gap percentages, although the adhesive systems present different solvents in their composition and manufacturers' instructions[30]. The instructions for Prime Bond 2.1, used before the application of En Force, did not include details regarding how wet the dentin should be kept before primer application. This lack of information regarding proper techniques may influence the result of a restoration. If acetone is used as the solvent and if the dentin is excessively dried, the exposed collagen network may collapse via etching. Conversely, it was verified that both adhesive systems (Single Bond and Prime Bond 2.1), when used together with their resin luting agents, failed to influence enamel gap formation in composite onlays, regardless of the lack of moisture when Prime Bond 2.1 bond was used.

Finally, when the onlays were restored, they were fixed during light-activation using finger pressure and no other force, which was designed to simulate a clinical situation. Dietschi, et al.[10] (1993) showed that even if thick enamel margins were available to maintain the marginal integrity, the internal bond to the dentin surface would be disrupted when the position of the inlay relative to the tooth was rigidly maintained during resin cement polymerization. The authors stated that the decrease in the dentin leakage depended on the likelihood of the indirect restoration and/or tooth to deform during cement polymerization.

In this study, the margin of the restoration was placed in enamel, although most of the bonding areas were in dentin. Ozturk and Ozer[23] (2004) stated that during endodontic treatment, the dentin in the pulp chamber is not affected by mechanical instrumentation, whereas root dentin is. Consequently, NaOCl action on dentin surface is considered regular. Marshall, et al.[19] (2001) observed that 6.5% NaOCl used for 30 min produced porosities and a large numbers of channels in the mineralized dentin. No changes were found in the elasticity modulus and hardness of dentin. In this study, because NaOCl was used at low concentrations, the slight morphological alterations in the dentin and the enamel may not be associated with changes in the mechanical properties. Thus, in this study, there was no difference among the groups regarding the degree of marginal adaptation.

It may be observed that all groups showed a majority of restorations without any marginal gaps. The possibility of marginal gap occurrence was 2.64 times higher for G2 (EnForce) when compared to G4 (Rely-X). G1 and G2 showed the same number of specimens with gaps, indicating a relative risk of 1. Finally, G3 (NaOCl+Rely-X) did not present any specimen with gaps; compared to G1 and G4, its relative risk was 0 (Table 1). An interesting point was that no G3 restoration presented gaps. Considering that G3 received the NaOCl treatment, it can be numerically shown that the resin luting agent Rely-X presents the best performance if a tooth had been previously treated with an endodontic procedure.

These data are relevant because they show that even though there were no differences concerning the gap percentage means among the groups, there were certain groups with a higher chance of having unsuccessful specimens in their marginal adaptation. This represents the individual restorations. The identification of the degree of success in the marginal adaptation is as important as the recognition of unsuccessful restorations, although the absence of an initial failure does not necessarily assure the long-term success of the restoration.

Among the sites with marginal gaps, the highest gap incidence occurred at the cervical margins of restorations regardless of the group, as observed by Soares, et al.[31] (2003). This occurs because marginal gap formation may be determined by the polymerization shrinkage of resin luting agents. In addition, at the cervical margins of primary teeth, the enamel is usually thin, aprismatic and less receptive to bonding than other enamel areas[18]. Thus, when the luting composite is polymerized, it shrinks toward the superior bond margins and away from the weaker margins at the cervical wall[4].

Endodontically treated primary teeth require additional attention because failure at the composite/tooth interface may be more significant than even a deteriorated restoration. Because primary tooth roots are filled with pastes like zinc oxide and eugenol or calcium hydroxide, they are may result in infection and a failure in pulpal therapy[15,17].

## CONCLUSIONS

Within the limitations of this study, treatment with 1% NaOCl did not influence the early marginal adaptation; both resin luting agents caused similar degrees of marginal gap formation. The substrate treatment (1% NaOCl) and the use of Rely-X were associated with a higher likelihood of restorations without any initial marginal gaps.

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