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ORIGINAL ARTICLE

Comparison of a resin-based sealant with a nano-filled flowable resin composite on sealing performance of marginal defects in resin composites restorations: a 36-months clinical evaluation

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Abstract

Objectives Our goal was to evaluate the clinical behavior of resin-based composite (RBC) restorations with sealed marginal defects using nano-filled flowable RBCs (FRS) compared with resin-based sealant (RBS); this work used marginal adaptation, marginal staining, and secondary caries according to the World Dental Federation (FDI) criteria.

Materials and methods This was a prospective, randomized, double-blind, controlled trial. Fifty-four patients who met the inclusion criteria (older than 18 years old; with high cariogenic risk determined by Cariogram software; and restorations with marginal defects, 3 and 4 according to FDI criteria) were randomly divided into three groups. There were three defective RBC restorations per patient and were repaired ($n=162$). The groups were RBS—marginal sealing using a resin-based sealant (Clinpro Sealant, 3 M ESPE, MN, USA) plus adhesive (Single Bond Universal, 3 M ESPE, MN, USA); FRS—sealing using flowable resin (Filtek Flow Z350XT, 3 M ESPE, MN, USA) plus adhesive (Single Bond Universal, 3 M ESPE, MN, USA); and control—no repair treatment. All procedures were performed under complete isolation. Evaluations were evaluated at 1-week post treatment (baseline) as well as at 18 and 36 months after treatment regarding marginal adaptation, marginal staining, and secondary caries according to FDI criteria. The data were analyzed using the Wilcoxon test ($\alpha=0.05$) to compare the differences in each treatment group at different evaluation times.

Results Marginal adaptation of micro-repaired RBC restorations were seen in patients with a high risk of caries using flowable resin composite or resin-based sealants. There were differences ($P<0.001$) when baseline was compared at 18 and 36 months. Marginal staining showed differences when baseline was compared to 18 months ($P<0.001$) and 36 months ($P=0.001$) for both treatments. Secondary caries parameters for RBS treatment showed differences when baseline was compared to 36 months ($P=0.025$) and when 18 months was compared to 36 months ($P=0.046$).

Conclusions Micro-repair of RBC restorations resulted in clinical deterioration of marginal adaptation and marginal staining. Nano-filled flowable resin composites were sealed on defective restorations; 3 and 4 FDI marginal defects have better clinical performance to prevent secondary caries than resin-based sealants after 36 months.

Clinical relevance Micro-repair with RBS does not seem to be an effective treatment to prevent secondary caries.

Keywords Repair · Sealant · Flowable RBC

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Introduction

The longevity of restorations mainly depends on the marginal integrity between restorative materials and dental tissue [1, 2]. Repairing marginal defects offers a conservative alternative and can reduce the loss of dental tissue and costs versus total replacement of restoration that increases preparation size and pulpal proximity, thus preventing a more aggressive approach in the future. Therefore, some marginal defects can be sealed to increase the longevity of restorations [3].

The preventive role of pits and fissure sealants (PFSs) using resin-based sealants (RBSs) is well described in the literature [1, 2]. There is some evidence about PFSs reducing the incidence of caries lesions in 76% of healthy occlusal faces versus no preventive treatment during a follow-up period of 3 years [1]. Moreover, RBS procedures offer a fast and minimally invasive treatment for RBC restorations with marginal defects. This is also a less complicated procedure for dentists versus total replacement of the restoration [4]. Importantly, when the RBS fails, it does not necessarily imply the immediate development of secondary caries; the treatment can also be repeated.

Several studies have proposed that flowable resin composites used as a sealant (FRS) may have similar resistance and sealing properties as RBSs or even better results due to their better wear resistance [5–7]. More filler particles in flowable resin composites reduces the porosity in restorations and provides better wear resistance than conventional RBS [7]. Conventional RBSs have a better flowability than flowable resin composites. This allows deeper penetration into the fissure and thus better retention [8]. In contrast, flowable resin composites have a significantly higher viscosity than RBSs, thus resulting in less deep penetration; their use seems better suited to minimally invasive interventions [9].

In relation to retention, RBS treatment can prevent occlusal cavities, but there is still concern about sealant detachment. Jafarzadeh et al. [10] reported a similar success rate among RBS and FRS. Similar results were also observed in the systematic review of Taneja and Singh [6] where they concluded that RBS and FRS show similar retention rates. Microinfiltration using an adhesive protocol (applying an adhesive layer between the sealant and the teeth surface) has been shown to reduce the shrinkage stress produced during polymerization of the resin composite, thus limiting the space between the RBS and the tooth surface. According to Meller et al. [11], there is a higher microinfiltration of sealants used without an additional adhesive protocol. However, the actual differences among retention and success rate of RBS and FRS as alternative treatments to replacement are still unclear.

Thus, to determine clinical outcome and advantages between RBS and FRS treatments to repair RBCs, this study evaluated the clinical performance of resin composite restorations with marginal defects sealed with nano-filled flowable resin composites. These were compared to a resin-based sealant while assessing marginal adaptation, marginal staining, and secondary caries by FDI criteria. The null hypothesis was that no difference would be found in marginal adaptation, marginal staining, and secondary caries by FDI criteria between RBS- and FRS-based treatments.

Materials and methods

This randomized clinical study was carried out under the CONSORT recommendations and under the ethical principles of the Helsinki convention [12, 13]. All patients consented to their participation in writing in a document reviewed and approved by the local scientific ethical committee for research in humans (Ethical approval number 2017/10).

Fifty-four patients—volunteers from the Restorative Dentistry Clinic at the School of Dentistry—were included. They had at least three occlusal (class I) restorations with marginal defects according to stage 3 and 4 marginal adaptation criteria of the World Dental Federation (FDI) [14]. They had a high cariogenic risk according to cariograms [15] and had no previous marginal sealing of restorations. This study was approved by our ethics committee, and all patients signed an informed consent. Restorations were randomly assigned to two groups: RBS—marginal sealing with resin composite sealant + adhesive and FRS—marginal sealing with flowable resin composite + adhesive. A third control group had restorations that corresponded with clinically acceptable scores by FDI criteria. Clinical evaluations were performed at 1 week (baseline) and 36 months after intervention. For marginal adaptation, marginal staining and secondary caries lesions were assessed according to the FDI criteria [14]. The CONSORT diagram is depicted in Fig. 1, and characteristics of teeth with Cclass I resin composites are described in Table 1.

Calibration methodology

The marginal adaptation parameter was assessed using a dental explorer with two sharp points of 150 µm and 250 µm (Deppeler, Geneva, Switzerland). Marginal staining and secondary caries lesion were visually assessed. Evaluators were calibrated with FDI criteria by examining 30 extracted teeth with different direct restorations of amalgams (only for calibration proposes) or resin composites eight times once per week. A final revision

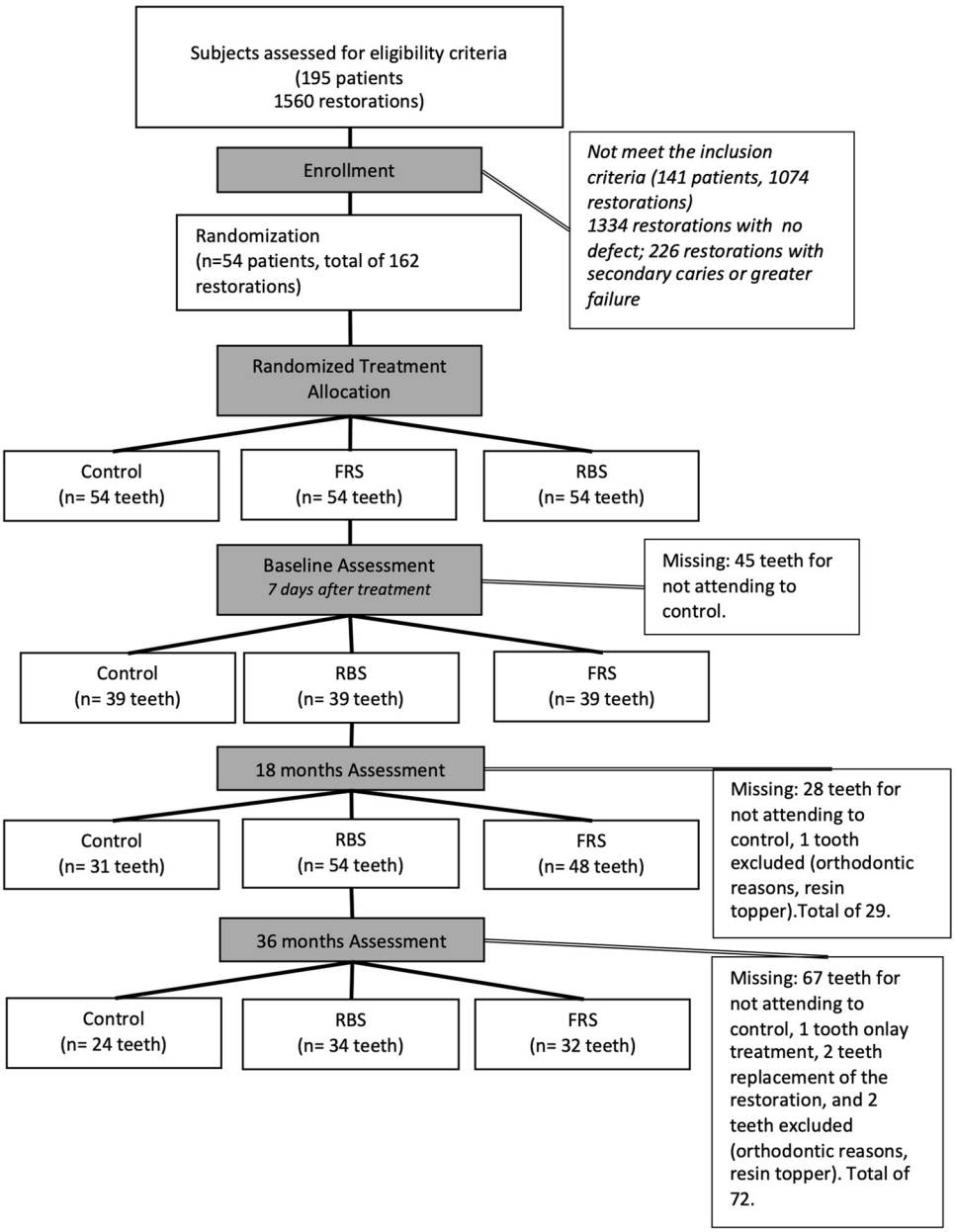

Fig. 1 The CONSORT diagram

of the results and discussion was performed with each corresponding calibrator. Calibration ended when the kappa value was better than 0.8. This ensured a standardized evaluation of restorations during the study.

Table 1 Characterization of teeth with class I resin composite included in the study

Treatment	Number of teeth	Molars	Premolars	Maxillary	Mandibular
RBS	63	58	5	42	21
FRS	60	54	6	23	37
Control	39	36	3	7	32
Total	162	148	14	72	90

RBS, resin-based sealant, *FRS*, flowable resin sealant

Marginal sealing

The patient's restorations were polished using aluminum oxide polishing disks with complete series (Sof-Lex. 3 M ESPE, MN, USA) and finishing polishing tips (Diacomp, Brasseler, GA, USA). Each sealed restoration received a random identification. Tabulation and data analyses were conducted using Microsoft Excel software (Microsoft 365, Microsoft Corporation; Redmond, WA, USA).

Cariogram Risk Assessment Software (Malmö, Sweden) was used to assess the parameters for cariogenic risk analysis including experience of caries, co-morbid diseases, dietary content, frequency of eating, plaque quantity, exposure to fluoride, salivary secretion, buffering capacity, and clinical judgment.

Clinical intervention of the groups and control group

After randomization for intervention using "RAND" function of a software spreadsheet program (Excel, Microsoft 365, Microsoft Corporation; Redmond, WA, USA), all restorations were cleaned with a hard brush and water at low speed. The repair procedures were performed under complete isolation using a rubber dam and saliva ejector to remove excess water. After isolation, the surface to be repaired was conditioned with 35% orthophosphoric acid etch (Condac etch; Joinville, SC, Brazil) for 15 s. The teeth were rinsed with water for 30 s and dried with compressed air using a triple syringe for 15 s. The application of an adhesive (Single Bond Universal, 3 M ESPE, St. Paul, MN, USA) was performed using a brush (Microbrush international, Grafton, WI, USA) for 20 s. The tooth was then allowed to dry for 5 s to evaporate the remaining solvent; photopolymerization was performed for 10 s using light curing (Led Elipar, 3 M ESPE, St. Paul, MN, USA).

Group I was sealed with flowable resin composite with nanofiller. A nanoparticle flowable composite resin (Filtek Flow Z350XT, 3 M ESPE, St. Paul, MN, USA) was applied to marginal defects with an instrument for calcium hydroxide cement application (PICH, Hu Friedy Mfg. Co Inc., Chicago, IL, USA). The flowable resin was photoactivated for 20 s (Led Elipar, 3 M ESPE, St Paul, MN, USA) according to the manufacturer's instructions. Group II was sealed using dental pits and fissure sealant (Clinpro Sealant, 3 M ESPE, St Paul, MN, USA; PICH, Hu Friedy Mfg. Co Inc., Chicago, IL, USA) and photoactivated for 20 s Elipar LED, 3 M ESPE, St Paul, MN, USA) according to the manufacturer's instructions. Occlusion was checked and controlled with an articulate paper (200-µm Bausch Articulating Papers, Nashua, NH, USA) and adjustments were performed with a No. 3 bur (SSWhite, Lakewood, NJ, USA) at high speed using water cooling in both groups. Group III was the control and included restorations clinically acceptable by FDI criteria; no treatment was performed.

The clinical status of each restoration was compared according to FDI criteria for marginal adaptation, marginal staining, and secondary caries lesions. Pictures from each tooth were taken to keep procedures and restorations registered for medical data. This was a double-blind study, and the professional who performed the micro-repairment was not the same who performed the evaluation. This helped avoid awareness of the treatment; none of the patients were aware of the treatment they received.

Performance analysis of treated groups

We compared baseline (1 week after treatment), 18 months, and 36 months results to assess treatment performance. According to this approach, two situations describing performance of restorations were determined: 1. Clinical status maintained with no changes between baseline and 18- and 36-month assessment and 2. clinical deterioration with at least one initial parameter affected.

To compare results with previous studies, we used the homologate Ryge criteria also known as the Modified United States Public Health Service Evaluation (USPHS). This led to FDI criteria for marginal adaptation and marginal staining. The alpha value corresponded to 1 or 2 FDI criteria; the Bravo value was 3 or 4 FDI criteria; and Charlie was the 5 FDI criteria. The equivalence criteria are shown in Tables 2, 3, and 4.

Table 2 Marginal adaptation category and homologation for Ryge and FDI criteria used in the study

Ryge/modified USPHS score		FDI score	
Alpha	Restoration completely adapted to the tooth. No visible gap. No explorer catch at the margins or in any direction	1 or 2	Harmonious outline, no gaps, no white or discolored lines or marginal gap (< 150 µm), white lines. Small marginal fracture removable by polishing
Bravo	Explorer catch. There is no visible evidence of a gap into which the explorer could penetrate	3 or 4	< 250 µm not removable. Several small marginal fractures. Major irregularities, ditching or flashes, steps or 250 µm, may result in exposure of dentine or base. Severe ditching or marginal fractures. Larger irregularities or steps (repair necessary
Charlie	Explorer penetrates into a deep gap that exposes dentin or base	5	Restoration (total or partial) is loose but in situ. Generalized major gaps or irregularities

USPHS, United States Public Health Service Evaluation; *FDI,* Federeation Dentaire Internactionale

Table 3 Marginal discoloration or staining category and homologation for Ryge and FDI criteria used in the study

Ryge/modified USPHS score		FDI score	
Alpha	No discoloration along the cavosuperficial margin	1 or 2	No marginal staining or minor marginal staining easily removable by polishing
Bravo	< 50% of the cavosuperficial margin affected by stain	3 or 4	Moderate staining not noticeable from speaking distance, also present on other teeth or pronounced marginal staining, major intervention necessary
Charlie	> 50% of the cavosuperficial margin affected by stain	5	Deep marginal staining, not accessible for intervention (replacement necessary)

USPHS, United States Public Health Service Evaluation; *FDI*, Federeation Dentaire Internactionale

Table 4 Secondary caries category and homologation for Ryge and FDI criteria used in the study

Ryge/modified USPHS score		FDI score	
Alpha	Absent	1	No secondary or primary caries
Charlie	Present	2	Small and localized. Demineralization área
		3	Larger areas of demineralization. Only preventive measures necessary
		4	12.4. Caries with cavitation and suspected undermining caries. Localized and accessible can be repaired.*not mandatory
		5	Deep secondary caries or exposed dentine that is not accessible for repair of restoration

USPHS, United States Public Health Service Evaluation; *FDI*, Federeation Dentaire Internactionale

Statistical analysis

Descriptive analyses were first performed. A non-normal distribution was determined, and thus non-parametric analysis was performed. The clinical status of each restoration according to FDI criteria for marginal adaptation, marginal staining, and secondary caries lesion was compared at baseline, 18, and 36 months via a Wilcoxon test. SPSS 7.0 software (SPSS Inc. Chicago, IL, USA) was used to perform the test with a 0.05 significance level.

Results

At 18 months, 46 of 54 patients initially enrolled remained (85.2%); 34 of the 54 patients initially enrolled were present at 36 months (63%). Of the 162 restorations repaired at baseline, 133 restorations (82.1%) were assessed at 18 months and 90 restorations (55.6%) at 36 months. Evaluations are grouped according to FDI clinical parameters (Table 5).

Marginal adaptation

Marginal adaptation parameters were evaluated at 18 months: 61% of the RBS group had 1 or 2 FDI criteria; 60% had FRS restorations rated 1 or 2 on the FDI criteria. At 36 months, 74% of the RBS group had 1 or 2 FDI criteria while 59% had FRS restorations rated 1 or 2 on the FDI criteria. Baseline was compared to 18 months for each treatment group using the Wilcoxon test: Significant differences were detected for RBS with a P-value < 0.001 and for FRS with a P-value < 0.001. Significant differences were detected for RBS with a P-value < 0.001 between baseline and 36 months from each treatment groups using the Wilcoxon test. The FRS P-value was also < 0.001. No differences were detected when an 18-month assessment was compared to 36 months of assessment for RBS and FRS groups. The correspondence of FDI criteria to Ryge criteria for this parameter is shown in Table 2.

Marginal staining

At 18 months of follow-up, the marginal staining parameter showed 1 or 2 FDI criteria values in 92% of restorations treated with RBS while 1 or 2 FDI criteria values were detected in 94% of restorations treated with FRS. At 36 months of follow-up, the marginal staining parameter showed 1 or 2 FDI criteria values in 94% of restorations treated with RBS while 1 or 2 FDI criteria values were detected in 97% of restorations treated with FRS. Correspondence of the FDI criteria to the Ryge criteria for this parameter is shown in Table 3.

Baseline and 18 months were compared for each treatment group using the Wilcoxon test. Significant differences were detected for RBS (P < 0.001) and for FRS (P < 0.001). Significant differences were detected for RBS (P < 0.001), and for FRS (P < 0.001) between baseline and 36 months after treatment using the Wilcoxon test. No differences

Table 5 Percentage (%) and number (*n*) of restorations with FDI value for marginal staining, marginal adaptation, and secondary caries parameters at baseline; and after 18 and 36 months follow-up, according to treatment groups

Category	Score FDI Criteria	Baseline						18 months						36 months					
		Control		RBS		FRS		Control		RBS		FRS		Control		RBS		FRS	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Marginal Adaptation	1 or 2	0	0	***63***	***100***	**60**	**100**	18	58	**33**	**61**	**29**	**60**	15	63	**25**	**74**	**19**	**59**
	3 or 4	39	100	***0***	***0***	**0**	**0**	13	42	**21**	**39**	**19**	**40**	9	38	**9**	**26**	**13**	**41**
Marginal Staining	1 or 2	38	97	***63***	***100***	***60***	***100***	29	91	***49***	***92***	***45***	***94***	23	96	***32***	***94***	***31***	***97***
	3 or 4	1	3	***0***	***0***	***0***	***0***	3	9	***4***	***8***	***3***	***6***	1	4	***2***	***6***	***1***	***3***
Secondary Caries	1	39	100	**63**	**100**	60	100	31	97	**50**	**93**	48	100	20	83	**31**	**91**	31	97
	2	0	0	**0**	**0**	0	0	1	3	**4**	**7**	0	0	3	13	**3**	**9**	1	3
	3 or 4	0	0	**0**	**0**	0	0	0	0	**0**	**0**	0	0	1	4	**0**	**0**	0	0

FDI, Federeation Dentaire Internactionale; *RBS*, resin-based sealant, *FRS*, flowable resin sealant. Bold letters and colored cells showing significant differences by Wilcoxon test comparisons: RBS treatment for marginal adaptation: baseline and 18 months ($P<0.001$) and baseline and 36 months ($P=0.001$); and FRS for marginal adaptation: baseline and 18 months ($P<0.001$) and baseline and 36 months ($P=0.001$). RBS treatment for marginal staining: baseline and 18 months ($P<0.001$) and baseline and 36 months ($P=0.001$); and FRS for marginal staining: baseline and 18 months ($P<0.001$) and baseline and 36 months ($P=0.001$). RBS treatment for secondary caries: baseline and 36 months ($P=0.025$) and 18 months and 36 months ($P=0.046$)

were detected when 18 months assessment was compared to 36 months assessment for RBS and FRS groups.

Secondary caries lesions

Secondary caries parameter was maintained in 93% of restorations treated with RBS at 18 months in one FDI value; 7% had two FDI criteria. In the control group, 97% of restorations had a constant FDI criteria, and 3% showed two FDI criteria. At 36 months after treatment, secondary caries parameters were maintained in 91% of restorations treated with RBS over one FDI value. In the control group, 83% of restorations kept one value for the FDI criteria, 13% had two FDI criteria, and 4% showed three or four FDI criteria. Correspondence FDI criteria to Ryge criteria for this parameter is depicted in Table 4.

No significant differences were detected when comparing baseline with 18 months of assessment using the Wilcoxon test for all groups. Only RBS showed differences upon comparing baseline to 36 months ($P=0.025$) or 18 months to 36 months ($P=0.046$).

Discussion

Multiple studies have established secondary caries as the main reason to replace restorations [16]. The literature shows many factors that can influence the formation of a secondary caries such as a marginal gap formation, the size of marginal gap, chemical environment, tooth-restoration interphase longevity, bacterial penetration extension, and mechanical load [17]. Therefore, it is necessary to control those factors to keep dental restorations in good conditions for as long as possible.

Minimally invasive dentistry adopts a preventive philosophy called minimal intervention in both restoration and replacement; it always uses a conservative approach [18]. Here, to repair defective restorations with the least amount of tissue loss, minimally invasive treatments have emerged as a first option; sealing the restoration is a popular option [5]. Since preventive effect of PFSs was proven in 1980s, several studies have quantified the clinical longevity of several sealing materials including RBS and FRS. Here, three or four defective FDI criteria with RBCs leads to high caries risk patients. These patients were repaired using RBS or FRS treatment; marginal adaptation, marginal staining, and secondary caries parameters were assessed. The control group retained its clinical behavior for all parameters assessed while RBS showed a higher detriment regarding secondary caries parameters after 36 months of follow-up. Marginal staining and marginal adaptation parameter deteriorated at 18 months for RBS and FRS versus baseline, but it remained similar when compared to 36 months of assessment. The null hypothesis that no difference would be found regarding marginal adaptation, marginal staining, and secondary caries FDI criteria between RBS- and FRS-repairing treatments was rejected for the secondary caries parameter.

The Ryge parameters [19] have been widely used to categorize the clinical status of restorations. Current restorative materials have improved clinical performance, and changes over time are not easily detected due to the limited sensitivity of this criterion in short-term clinical research.

Many scientific methodologies have emerged to categorize this condition. Some restorations require greater rigor of evaluation at the level of diagnosis and classification at the clinical status of restorations. The FDI criteria were presented as a solution to the dilemma of limited sensitivity, thus incorporating new categories for the evaluation of restorations. This approach can help standardize and allow greater precision in treatment diagnoses both in research and in clinical practice. The high sensitivity to small changes contrasts with the Ryge criteria, which is distinguished by covering a wide range of classifications that cannot detect small variations [14]. Considering FDI criteria advantages—and to compare results with other studies—a homologation between Ryge criteria and FDI criteria was established for the clinical parameters assessed during the trial.

Fernández et al. reported minimally invasive treatments in defective restorations. Their Ryge alpha rates in marginal adaptation were 50% to 60% of resin composite sealant treatment at 4 years of follow-up [20]. Martín et al. also studied minimally invasive treatments in defective restorations for 5 years. About 60% of the alpha rates in marginal adaptation were detected after 3 years [4]. Fernández et al. and Moncada et al. reported marginally sealed defective restorations. They showed Ryge alpha rates in marginal adaptation in about a 70% of restorations [21, 22]. These results are close to the rates reported here: 61% of restorations treated with RBS and 60% of restorations treated with FRS were rated with 1 or 2 FDI criteria at 18 months follow -up. At 36 months of follow-up, 74% of restorations treated with RBS and 59% of restorations treated with FRS were had one or two FDI criteria, which is similar to RBS and FRS regarding marginal adaptation. Marginal defects are one of the main causes of failure of restorations; they facilitate bacterial deposition, and these gaps have developed secondary caries lesions when greater than 250 µm or when located in difficult access zones for biofilm remotion [23] or when corresponding to microinfiltration of restoration margins. These situations favor colonization to restoration margins [24]. The origin of microinfiltration has been related to multiple factors such as polymerization shrinkage, adhesive materials, thermic changes during eating, mechanical stress, polishing, and heating. These can all influence the wear of the tooth-restoration interphase [17]. It has been suggested that marginal defects greater than 250 µm should be repaired, thus supporting sealing of marginal defects with 3 or 4 values for FDI criteria equivalents to a bravo Ryge criteria. However, there are no established protocols about minimal or maximum dimensions; localization and extension of the gap can indicate sealing. Here, control groups maintained their marginal adaptation parameter after 18 months while RBS and FRS did not offer a clear advantage in long-term assessment.

Regarding marginal staining, Martín et al. detected between 55 and 60% of restorations with alpha after 3 years follow-up [4]. Fernández et al. reported about 40% to 50% of restorations with an alpha value [21]. On the other hand, Moncada et al. found about 80% to 90% of restorations with an alpha value at 2 years from treatment [25]. This study showed values of 92% in RBS with values of 1 or 2 in the FDI criteria; there were 94% in treatments using FRS with 1 or 2 FDI criteria values, which is closer to Moncada et al. than Fernández et al. and Martin et al. [4, 20, 21]. Marginal staining can be recognized as a change in color along the restoration margin. Importantly, a change in color or opacity around the margin of a restorations is not a necessary predictor of the future development of a secondary caries. Such changes should be carefully evaluated to minimize invasive interventions and control procedures [14].

We noted 100% of alpha values [5] for the secondary caries parameter similar to RBS at 18 months of control, where 100% of restorations treated had one or two FDI values. However, RBS showed 9% of secondary caries, which is significantly different from baseline and 18 months of control assessment. This represents a higher detriment of repair than FBS. Microinfiltration can occur at the teeth-sealant interface; increased microinfiltration has been associated with greater fissures due to polymerization stress regenerated by polymerization shrinkage at the interphase [26]. While RBS and FRS have similar microinfiltration rates in vitro [27], using sealant with adhesive systems offers better mechanical behavior and is less harmful to the teeth-sealant interphase, thus reducing marginal microinfiltration. Early studies have confirmed a higher retention rate of flowable resin composites when they are used with an adhesive during an acid-etching protocol [21]. The adhesive protocol was used for both RBS and FRS treatments, and better behavior regarding secondary caries parameters for FBS can be explained by the remarkable differences between mechanical properties of flowable resin composite given its high nanofiller load.

This study included high cariogenic risk patients, which have been demonstrated to negatively affect longevity and survival rates restorations [28, 29]. Other investigations such as Fernández et al. and Estay et al. have considered only low to medium cariogenic risk patients [21, 30]. This study showed a better approach to repairing longevity considering adverse patient characteristics.

The limitations of this study can be related to the period of follow-up time. The period could be brief and could substantially evaluate differences between RBS and FRS. Future studies could evaluate differences over a longer term. Stronger differences between FRS and RBS and control group might be assessed, but it is important to note that a longer follow-up period makes it more difficult to maintain more patients in the control. Of course, there are multiple factors that could affect the retention and longevity of

restorations not considered in this study such as the socioeconomic level of the patient [31], bruxism, and parafunctional habits [29]. Future studies may propose to determine the results attributable to *materials* than to individual characteristics of the patients.

The FRS had better clinical behavior than RBS at 36 months in terms of secondary caries, but the relevance of this finding is not clinically clear at the time of choosing the material to seal a defective restoration. These data support using RFS treatment. The data on control groups at 36 months encourage us to reflect on whether micro-repair is a good alternative to increase the longevity of restorations.

Conclusions

Micro-repair of RBCs restorations resulted in clinical deterioration of marginal adaptation and marginal staining. Nanofilled flowable resin composite sealing strategies can seal defective restorations with 3 and 4 FDI margins. This leads to better clinical performance and can prevent secondary caries better than RBS at 36 months.

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Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval This study was approved by the CEC (Institutional Human Scientific Committee) protocol number 13/10.

Informed consent All participants were freely invited, and those who accepted signed an informed consent approved and stamped by the local ethics committee.

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