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Effectiveness of non-operative approaches in active enamel carious lesions: a retrospective longitudinal study

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Abstract: The aim of the study was to investigate the effectiveness of non-invasive and micro-invasive treatments in active enamel carious lesions in high-caries-risk children. Clinical records of children treated in a dental school setting were retrospectively screened for active enamel carious lesions treated non-invasively (topical fluoride applications, oral hygiene instruction, or dietary guidance) or micro-invasively (sealant). The control of active carious lesions was set as the main outcome established by the combination of inactivation and non-progression of the lesions based on Nyvad and ICDAS criteria, respectively. Individual and clinical factors associated with the outcome were analyzed by Poisson regression. The sample consisted of 105 high-caries-risk children with a mean age of 8.3 (± 2.4) years. From a total of 365 active enamel carious lesions, most lesions (84.1%) were active non-cavitated carious lesions (ICDAS scores 1 and 2) and only 15.9% presented localized enamel breakdown (ICDAS score 3). Of these, 72.6% were inactivated and 92.1% did not progress (mean time of 6.5 ± 4.1 months). The prevalence of controlled carious lesions was higher among children older than 6 years (PR:1.43; 95%CI:1.00–2.03; p = 0.04) and in those with better biofilm control (PR:0.99; 95%CI: 0.98–0.99; p = 0.03). Non-operative approaches are effective for controlling active enamel carious lesions. The majority of active enamel carious lesions became inactive and did not progress after treatment. Caries control was associated with older children and better biofilm control.

Keywords: Dental Caries; Tooth, Deciduous; Dentition, Permanent; Tooth Remineralization.

Introduction

Dental caries is one of the most prevalent chronic diseases in children and adolescents worldwide.[1] Epidemiological studies[2,3] have shown a decrease in its prevalence based on the decayed-missing-filled teeth index (DMF-T), which just considers more advanced stage lesions (cavities). The decrease in the disease prevalence has been accompanied by a reduction in the progression rate of the lesions,[4] allowing easier recognition of incipient carious lesions.[5] Lesions at this stage can be arrested, preserving the tooth surface integrity.[6] Due to this scenario, caries detection systems based on visual inspection have been proposed to detect all stages of carious lesions[7] from the first clinical signs of the disease to extensive cavitated dentin lesions. Evaluation of the caries activity status in association with other clinical and radiographic diagnostic parameters is essential for choosing the best treatment option.[6]

A cohort study showed the progression of active carious lesions in preschool children was 50% more frequent than that of inactive lesions,[8] regardless of their severity (enamel or dentin lesions). Moreover, sound surfaces and initial lesions in children already presenting cavities are more likely to progress to more severe conditions.[9] In this sense, inactive (arrested) carious lesions do not require any treatment, but should be monitored, while active non-cavitated and cavitated carious lesions in enamel should be managed non-invasively or micro-invasively.[10] Non-invasive strategies involve dietary and biofilm control, as well as the use of fluorides for controlling mineral balance. Sealants can be used as a micro-invasive treatment for enamel carious lesions.[10] Such measures include managing the etiologic factors based on individual caries risk.

Most conservative strategies for tooth structure remineralization have shown benefits by decreasing the progression of non-cavitated lesions. However, evidence is limited regarding the effectiveness of these methods for treating incipient carious lesions in high-caries-risk children.[11] In addition, there is no clear evidence of whether tooth- or patient-related risk factors may influence the success of non-invasive or micro-invasive approaches for controlling initial carious lesions. Therefore, the aim of this retrospective longitudinal study was to evaluate the effectiveness of non-invasive and micro-invasive treatments in active enamel carious lesions of high-caries-risk children and the factors associated with caries control.

Methodology

Ethical aspects

The local Research Ethics Committee approved the research protocol (no. 20791119.7.0000.5347). Parents or guardians signed a written informed consent for the data collection. The patients' personal information was kept confidential. The present observational study conforms to the "Strengthening the Reporting of Observational studies in Epidemiology" (STROBE) statement.

Study design, characteristics, and participants

This is a university-based retrospective longitudinal study developed at the Children and Youth Dental Clinic, School of Dentistry, Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Brazil. Porto Alegre has a human development index (HDI) of 0.805. The fluoride concentration in public water supplies is 0.8 milligrams of fluoride per liter. The convenience sample consisted of all clinical records (census) from patients who had active enamel carious lesions – International Caries Detection and Assessment System (ICDAS) scores 1, 2, and 3 in permanent or primary teeth, characterized by roughened and whitish/yellowish opaque enamel surface with loss of luster according to the NYVAD criteria.[12]

Carious lesions were assigned to one of the following groups: no intervention, non-invasive treatment, or micro-invasive treatment. No intervention was considered when the carious lesions did not receive any type of treatment (non-invasive or micro-invasive). Non-invasive treatment was considered when the carious lesions received topical fluoride applications (1.23% APF gel), oral hygiene instruction, or dietary guidance. The topical fluoride applications were instructed to be performed weekly in three appointments, after dental prophylaxis, during toothbrushing of all erupted teeth (approximately for 4 minutes). The oral hygiene instruction was carried out by showing the child and caregiver, with the aid of a mirror, the sites with plaque, followed by a demonstration of brushing (toothbrush, fluoridated toothpaste, and dental floss). The child (or adult) then performed the brushing supervised by the professional. Adaptations of the brushing technique were introduced according to the patient's age and specific clinical condition (*e.g.*, tooth eruption, interproximal contacts, and areas of difficult access). Dietary guidance was given verbally, based on the initial assessment of a food diary, and aimed to guide the family nucleus to reduce sucrose consumption and make better food choices. Re-assessment of the dental plaque control and changes in eating habits were carried out in non-invasive treatment appointments. Micro-invasive treatment was considered when the carious lesions received sealant application.

Most of the children (aged 3–12 years) who attended the public dental school clinic for one year (2017–2018) were from low socioeconomic status households. Only records with complete data were included. The caries detection and treatment procedures were performed by undergraduate dental students (4th year) and postdoctoral students receiving specialty training in pediatric dentistry, supervised by experienced specialists in pediatric dentistry. The dental students underwent training prior to detecting carious lesions based on the ICDAS. This activity consisted of conventional theoretical lecture, activity with image projection, and hands-on activity with extracted teeth.

Dental care involved initial examinations and subsequent elaboration of an individual treatment plan according to the sequence of specific priorities of each case. All participants underwent treatment in weekly dental appointments. Appointments focused on oral hygiene guidance were directed at instructing the children and their family members on how to remove biofilm with the aid of a toothbrush, fluoridated toothpaste, and dental floss. No micro-invasive or invasive treatments were performed in these appointments. A new clinical examination of the dental surfaces was performed at the end of treatment to assess treatment impact on carious lesions control.

Data collection

Three trained researchers (ASA, DPG, and MMS) collected the following individual and clinical characteristics from patients' records: age, sex, tooth type (primary or permanent), tooth location (anterior or posterior), tooth surface (palatal/buccal, occlusal, or proximal), treatment (no treatment, non-invasive, micro-invasive), number of topical fluoride applications (≤ 3 or > 3), oral hygiene instruction (yes or no), dietary guidance (yes or no), the activity status and severity of the carious lesion in the first and last appointments, the total number of appointments, and visible plaque index (yes or no). The visible plaque index (VPI) was used to evaluate the patients' oral hygiene routine. The presence of biofilm was evaluated through visual inspection of the tooth surfaces, using relative isolation, illumination, and drying of the tooth surfaces. The VPI was calculated by dividing the number of tooth surfaces by the number of surfaces with visible plaque.[13] The dates of the first and last dental examinations were considered to calculate the mean time for change in the dental caries profile.

Outcome parameters

The control of active carious lesions was set as the main outcome, and it was established by the combination of inactivation and non-progression of the lesions (Nyvad and ICDAS criteria, respectively). Initial and final lesion status and the time between the first and last examinations were registered to evaluate the outcome. Inactivation of enamel carious lesions (ICDAS scores 1, 2, and 3) were considered if, in the last appointment, they were classified as inactive according to the Nyvad criteria[12] or sealed[14] (without adjacent lesions). We considered non-progression of carious enamel lesions when enamel lesions (ICDAS scores 1, 2, and 3) at baseline remained in the same category (ICDAS scores 1, 2, and 3) in the last appointment or when enamel lesions (ICDAS scores 1 and 2) at baseline turned into lesions with ICDAS score 0 in the last appointment.

Statistical analyses

Data analyses were performed using STATA 20.0 software (Stata Corp., College Station, USA). The descriptive analysis provided a distribution summary according to the independent variables. Poisson regression was used to investigate the association of the independent variables with the outcome. The prevalence ratio and the respective 95% confidence intervals (PR; 95%CI) were obtained. Dependency of the variables for the same patient was considered (one patient could contribute with more than one tooth/lesion for the analysis). A backward stepwise procedure was used to select covariates in the fitting model. Only those variables presenting P-values < 0.20 were included in the final model. A significance level of 5% was considered for all analyses.

Results

A total of 386 (59.8%) out of 645 clinical records had initial carious lesions. However, 281 (72.8%) records were excluded from the study because of incomplete data. Thus, 105 (27.2%) dental records were included in the analysis.

The mean age of the children was 8.3 years (± 2.4), presenting a mean DMFT of 6.2 (± 4.4), with the decayed component corresponding to 75.1% of the index. A total of 365 active enamel carious lesions in 105 patients (48 female and 57 male) were included in the analysis. The mean prevalence of incipient carious lesions per child was 3.5 (± 2.5). The mean time between the first and last clinical evaluation was 6.5 (± 4.1) months.

The characteristics of the active carious enamel lesions according to the independent variables are shown in Table 1. Among the initial carious lesions, 43.3% occurred in primary teeth and 56.7% in permanent teeth. The majority of the lesions (83.0%) were in posterior teeth, and first permanent molars and second primary molars were the most affected teeth. Most lesions were active non-cavitated carious lesions (ICDAS scores 1 and 2) and only 15.9% presented localized enamel breakdown (ICDAS score 3). Most non-cavitated enamel carious lesions were located on buccal/lingual (49.5%) and occlusal (32.9%) surfaces, while cavitated enamel carious lesions were located on occlusal (53.4%) and buccal/lingual (39.7%) surfaces, respectively.

The flowchart of the implemented treatment and the characteristics of the enamel carious lesions after treatment are shown in Figure. Non-invasive treatment was scheduled in 75.9% of cases, 12.9% of the lesions received micro-invasive treatment, and 11.2% received neither non-invasive nor micro-invasive treatment. Fifty-one (48.6%) patients had appointments focused on oral hygiene instruction, with an average of 2.0 (±1.13) appointments.

Table 1. Characteristics of the active enamel carious lesion at baseline (n = 365).

Variables	Initial Carious Lesions	
	Non-cavitated enamel carious lesions (scores 1 and 2 of the ICDAS*)	Cavitated enamel carious lesions (score 3 of the ICDAS*)
	n (%)	n (%)
Visible Plaque Index (VPI) site		
Yes	123 (40.1)	20 (34.5)
No	184 (59.9)	38 (65.5)
Dental surface		
Buccal/Lingual	152 (49.5)	23 (39.7)
Occlusal	101 (32.9)	31 (53.4)
Mesial	49 (16)	4 (6.9)
Distal	5 (1.6)	-
Treatment		
No treatment	35 (11.4)	6 (10.3)
Non-invasive treatment	253 (82.4)	24 (41.4)
Micro-invasive	19 (6.2)	28 (48.3)

*ICDAS: International Caries Detection and Assessment System.

The characteristics of enamel carious lesions after treatments are shown in Table 2. Considering the active enamel carious lesions (ICDAS scores 1 and 2) at baseline, 32.6% became inactive carious lesions (ICDAS scores 1 and 2), 35.5% were classified as sound (ICDAS score 0), 22.1% remained active (ICDAS scores 1 and 2), and only 2.6% were sealed. It was noted that 92.8% of these lesions did not progress. Considering the active cavitated enamel carious lesions (ICDAS score 3) on the first examination, 37.9% received sealant, 29.3% became inactive carious lesions (ICDAS score 3), 20.7% remained active, and 87.9% did not progress.

Table 3 shows the unadjusted and adjusted prevalence ratio of variables that may influence carious lesion control (inactivation and non-progression). VPI (PR: 0.99; 95%CI: 0.98–0.99;

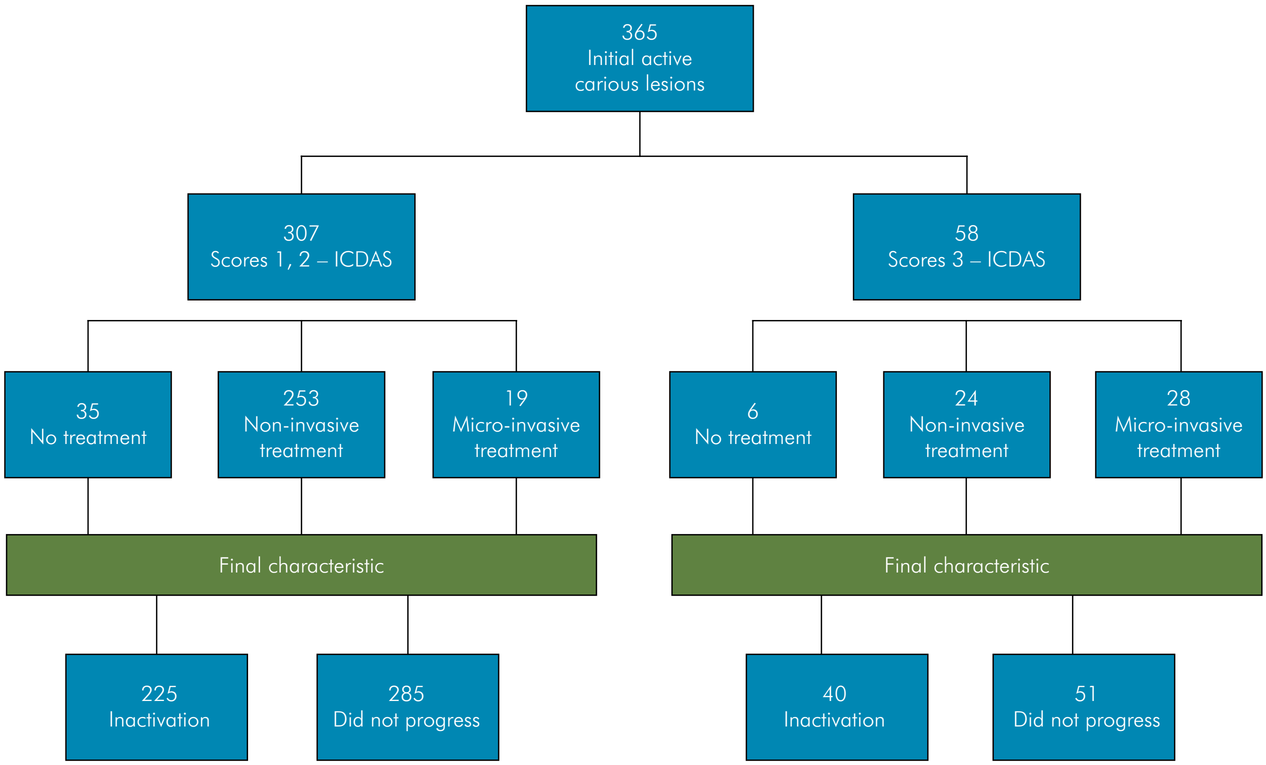

Figure. Flowchart of the implemented treatment and the characteristics of the enamel carious lesions after treatment.

Table 2. Characteristics of the enamel carious lesions post-treatment (n = 365 lesions).

Variables	Final characteristic of the lesions (ICDAS*)									Lesion inactivation		Lesion progression	
	Score 0	Scores 1–2		Score 3		Score 4	Score 5		Sealant	Yes	No	Yes	No
		Active	Inactive	Active	Inactive	Active	Active	Inactive					
Initial carious lesions													
Active non-cavitated enamel carious lesions (scores 1 and 2 of the ICDAS)	109 (35.5)	68	100	6	8	3	5		8	225	82	22	285
n (%)		(22.1)	(32.6)	-2	(2.6)	-1	(1.6)		(2.6)	(73.3)	(26.7)	(7.2)	(92.8)
Active cavitated enamel carious lesions (score 3 of the ICDAS)	-	-	-	12	17	-	6	1	22	40	18	7	51
n (%)				(20.7)	(29.3)		(10.4)	(1.7)	(37.9)	-69	-31	(12.1)	(87.9)

*ICDAS: International Caries Detection and Assessment System.

p < 0.01) and > 3 fluoride topical applications (PR: 0.75; 95%CI:0.58–0.96; p = 0.02) were associated with a higher prevalence of controlled carious lesions in the unadjusted analysis. Moreover, the prevalence of controlled lesions was 50% higher among children older than 6 years (PR:1.50; 95%CI:1.06–2.11;

Table 3. Poisson regression analysis for carious lesion control (outcome), according to individual and treatment/tooth-related variables.

Variables	Unadjusted PR* (95% CI**)	p-value****	Adjusted PR* (95% CI**)	p-value***
Sex				
Male	1.00	0.15	1.00	0.33
Female	1.19 (0.93–1.53)		1.13 (0.87–1.46)	
Age (years)				
≤ 6	1.00	0.02	1.00	0.04
> 6	1.50 (1.06–2.11)		1.43 (1.00–2.03)	
Initial carious lesion				
Active enamel non-cavitated	1.00	0.31	-	-
Active enamel cavitated	0.82 (0.57–1.19)			
Dentition				
Primary	1.00	0.64	-	-
Permanent	1.06 (0.82–1.36)			
Tooth location				
Anterior teeth	1.00	0.69	-	-
Posterior teeth	1.06 (0.76–1.49)			
Tooth surface		0.73		
Palatal/buccal surfaces	1.00	0.34	-	-
Occlusal surfaces	1.04 (0.79–1.38)			
Proximal surfaces	1.18 (0.83–1.66)			
Visible Plaque Index (follow up)	0.99 (0.98–0.99)	< 0.01	0.99 (0.98–0.99)	0.03
Dmf-t index****	0.97 (0.95–1.00)	0.11	1.00 (0.97–1.03)	0.90
Treatment				
Non-invasive treatment	1.00	0.80	-	-
Micro-invasive treatment	0.95 (0.65–1.38)			
Number of topical fluoride applications				
≤ 3 applications	1.00	0.02	1.00	0.18
> 3 applications	0.75 (0.58–0.96)		0.83 (0.63–1.08)	
Oral hygiene instruction				
Yes	1.00	0.27	-	-
No	0.82 (0.58–1.16)			

*Prevalence ratio; **Confidence interval; ***p-value based on Poisson Regression; ****DMFT decayed, missing, or filled permanent teeth.

p = 0.02). The final adjusted model demonstrated the prevalence of controlled lesions remained high among older children (PR: 1.43; 95%CI:1.00–2.03; p= 0.04). Moreover, a higher prevalence of non-controlled lesions after treatment was associated with a higher VPI (PR: 0.99; 95%CI:0.98–0.99; p = 0.03).

Discussion

This study investigated the effectiveness of non-invasive and micro-invasive treatments in active enamel carious lesions in high-caries-risk children, in addition to factors associated with caries control (inactivation and non-progression). Data on the effectiveness of these treatments applied to incipient carious lesions in high-caries-risk children are still scarce. To the best of our knowledge, this study is the first investigation performed in a high-caries-risk population from low socioeconomic status households, representing the worst scenario for the control of caries disease activity. The majority of the carious lesions became inactive (72.6%) and did not progress (92.1%) after a mean time of 6.5 (± 4.1) months of non-operative treatment.

When caries disease is present, clinicians deal with the challenge of determining the appropriate approach to stop the consequences of the cariogenic process through arrest or reversal of carious lesions.[15] Patient-level interventions aim to reestablish mineralization balance. These interventions require adequate patient adherence for success and include, but are not limited to, diet counseling[16] and oral hygiene instructions.[17] Lesion-level interventions include non-restorative treatment (non-invasive treatment such as professional topical fluoride application and micro-invasive treatment such as sealants).

There is moderately certain evidence for recommending the use of sealants *plus* 5% NaF varnish, sealants alone, 5% NaF varnish alone, or 1.23% APF gel to arrest or reverse non-cavitated carious lesions on occlusal surfaces of primary and permanent teeth.[15] The use of 5% NaF varnish, resin infiltrate, or sealants can be indicated to arrest or reverse non-cavitated carious lesions on approximal surfaces of primary and permanent teeth.[15] There is also moderate to low-certainty evidence to recommend the use of 1.23% APF gel or 5% NaF varnish to control non-cavitated carious lesions on facial or lingual surfaces of primary and permanent teeth.[15]

Most active enamel carious lesions in our study received non-invasive treatment (topical fluoride applications with 1.23% APF gel, oral hygiene instruction, or dietary guidance), irrespective of the location of the carious lesions, or type of tooth (primary or permanent). It is important to note that the topical application of fluoride gel was performed in the entire mouth, through brushing. In this way, subclinical lesions are also benefited. Although there is no consensus regarding an application protocol of fluoride gel,[18] 3 to 4 applications at weekly intervals were used in most cases,[19] as this (associated with biofilm control) seems to be more adequate for treating incipient carious lesions in clinical practice.

Few carious lesions were sealed, and most of them presented localized enamel breakdown (ICDAS score 3). This may be explained because the use of sealants was proposed as a secondary approach for controlling initial carious lesions after an attempt to control the etiologic factors through oral hygiene instruction and dietary guidance.

It is important to note that most lesions were restricted to smooth surfaces. Carious lesions on less susceptible surfaces (smooth surfaces) can be reduced by a higher proportion than lesions on more susceptible surfaces (occlusal surfaces), irrespective of the topical fluoride application. It is easier to maintain biofilm control on smooth surfaces due to their anatomical characteristics.[20]

Water fluoridation and fluoride toothpastes (1,000 ppm F) promote sufficiently high concentrations of fluoride in the oral environment, having an impact on the reduction of the number of carious lesions and of their severity in primary and permanent teeth.[21-23] In our study, 48.6% of the children had appointments exclusively focused on oral hygiene counseling. It is known that biofilm control itself is an effective way to arrest enamel carious lesions[24] because it promotes mechanical abrasion of the enamel surface and clinically leads to a change in the appearance of white spots, from chalky and rough (active) to bright and smooth (inactive).[25] Therefore, the regression of lesions could result mainly from surface abrasion and not from repair (remineralization) of enamel mineral loss. It has already been stated in the scientific literature that initial lesions can be arrested without professional intervention.[26] This may explain why 35.5% of the non-cavitated enamel carious lesions (ICDAS 1 and 2) were clinically classified as sound (ICDAS score 0) after treatment. Moreover, some patients received neither non-invasive nor micro-invasive treatment. It is important to emphasize that most of the children seen at the outpatient clinic have pain and diverse invasive treatment needs (operative dentistry, endodontic treatment, extraction), which influences treatment planning. Therefore, the priority of initial treatment is to manage pain, to remove infectious focus, and to control extensive dentin carious lesions, which could justify the fact that some children have not yet received non-invasive or micro-invasive treatment for enamel carious lesions.

The prevalence of controlled enamel carious lesions was higher among children older than 6 years (PR: 1.43; 95%CI: 1.00–2.03; p = 0.04). A previous study[27] has demonstrated that ages between 8 and 12 years were associated with a lower probability of active carious lesions. An association between biofilm control and age has been shown, in which older children may perform better mechanical biofilm removal than younger children.[28] Moreover, it is well known that the eruption stage (first permanent molars) may influence the development and arrest of active lesions. The period following the onset of tooth eruption proves to be the one with the highest risk for the development of carious lesions and may be related to the fact that older children have a higher prevalence of lesion inactivation.[29] Infraocclusion immediately after tooth eruption favors biofilm accumulation and hinders access for biofilm removal. Thus, fully erupted teeth present a masticatory function, which allows for relative cleaning and easy access of the toothbrush to the occlusal surface.[30] Unfortunately, as the present study is based on retrospective data of a convenience sample, information on the stage of tooth eruption was not available in the clinical records. However, in an indirect analysis, using the age of children (5–7 years) as a parameter for the chronology of eruption of permanent molars, a greater tendency towards inactivation was observed for those molars in occlusion (89 of 130 – 68.5%), as compared to erupting ones (11 of 21 – 52.4%).

The results also demonstrated the prevalence of non-controlled lesions (lesions which remained active and progressed) increased as the percentage of VPI increased (PR: 0.99; 95%CI:0.98–0.99; p = 0.03). It is well established in the scientific literature that dental biofilm is a marker for oral health patterns. A birth cohort study demonstrated lifetime exposure to dental biofilm might be a risk factor for cumulative dental diseases such as caries, periodontal disease, and tooth loss.[31]

The mean time between the first and last appointments (treatment length) was 6.5 (± 4.1) months, which is relatively short to note progression, considering the dynamic and slowly progressing nature of caries disease. A cohort study[9] reported incipient carious lesions have a low frequency of progression, but these lesions are more likely to progress to more severe conditions in children with cavitated dentin lesions.

The short time for assessing the progression of carious lesions may be the main limitation of this study; however, even under these challenging conditions, it was possible to assess the inactivation of lesions, regardless of their location. Another variable that can be listed as a limitation of the study is the lack of calibration of the examiners (dental students), despite their previous training with practical activities and the verification of the examinations by professionals with experience in cariology and child treatment. It has been shown the assessment of the activity status of the lesion had lower reliability values than did the detection of its severity,[32] regardless of clinical experience.

Still, observational studies can come closer to the clinical reality, whereas uncontrolled settings may provide external validity. The findings of this study should be interpreted with caution because of the study design and the characteristics of the sampled population.

Conclusions

Irrespective of the community profile, the majority of the active carious lesions became inactive and did not progress after non-operative treatments. Biofilm control is key to promoting caries arrest; therefore, prevention education and early intervention/ anticipatory guidance are essential.

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