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ABSTRACT

Although there is strong evidence for the effectiveness of sealants, one major barrier in sealant utilization is the concern of sealing over active caries lesions. This study evaluated detection and monitoring of caries lesions through a clear sealant over 44 mo. Sixty-four 7- to 10-year-old children with at least 2 permanent molars with International Caries Detection and Assessment System (ICDAS) scores 0-4 (and caries less than halfway through the dentin, radiographically) were examined with ICDAS, DIAGNOdent, and quantitative light-induced fluorescence (QLF) before sealant placement and 1, 12, 24, and 44 mo (except QLF) after. Bitewing radiographs were taken yearly. DIAGNOdent and QLF were able to distinguish between baseline ICDAS before and after sealant placement. There was no significant evidence of ICDAS progression at 12 mo, but there was small evidence of minor increases at 24 and 44 mo (14% and 14%, respectively) with only 2% ICDAS $\geq$ 5. Additionally, there was little evidence of radiographic progression (at 12 mo = 1%, 24 mo = 3%, and 44 mo = 9%). Sealant retention rates were excellent at 12 mo = 89%, 24 mo = 78%, and 44 mo = 70%. The small risk of sealant repair increased significantly as baseline ICDAS, DIAGNOdent, and QLF values increased. However, regardless of lesion severity, sealants were 100% effective at 12 mo and 98% effective over 44 mo in managing occlusal surfaces at ICDAS 0-4 (*i.e.*, only 4 of 228 teeth progressed to ICDAS $\geq$ 5 associated with sealants in need of repair and none to halfway or more through the dentin, radiographically). This study suggests that occlusal surfaces without frank cavitation (ICDAS 0-4) that are sealed with a clear sealant can be monitored with ICDAS, QLF, or DIAGNOdent, which may aid in predicting the need for sealant repair.

KEY WORDS: longitudinal studies, dental caries, dental sealants, ICDAS 0-4, DIAGNOdent, QLF.

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Monitoring of Sound and Carious Surfaces under Sealants over 44 Months

INTRODUCTION

Preventive care has become paramount in an environment of increasing health care costs and resource constraints. Dental caries, one of the most common diseases of childhood, is manifested predominantly as caries lesions in pits and fissures of teeth (Macek *et al.*, 2003; Beltrán-Aguilar *et al.*, 2005). Fortunately, there is strong evidence for sealant effectiveness preventing dental caries; furthermore, providing sealants in public programs is not only effective but can increase access to care for underserved children (Truman *et al.*, 2002). Systematic reviews also support the effectiveness of sealing lesions to manage caries and bacterial infection (Griffin *et al.*, 2008; Oong *et al.*, 2008). Consequently, the American Dental Association and the Centers for Disease Control and Prevention support the use of sealants on noncavitated caries lesions (Beauchamp *et al.*, 2008; Gooch *et al.*, 2009). However, sealant utilization is still low (Beltrán-Aguilar *et al.*, 2005), and many dentists are reluctant to adopt evidence-based clinical recommendations regarding sealing caries lesions (Tellez *et al.*, 2011). One of the major barriers in sealant utilization is the concern of sealing over active caries lesions (Primosch and Barr, 2001; O'Donnell *et al.*, 2013), which cannot be monitored after being sealed. This issue is fueled by a lack of uniformity in caries diagnosis, in sealant assessment and reimbursement, and in treatment thresholds for operative vs. nonoperative intervention for early or moderate stages of caries development. Therefore, the purpose of this study was to evaluate detection and to monitor occlusal surfaces at ICDAS 0-4 (International Caries Detection and Assessment System) through a clear sealant over 44 mo, using the ICDAS visual criteria (Ismail *et al.*, 2007), bitewing radiography, and 2 objective and sensitive caries detection methods: DIAGNOdent and quantitative light-induced fluorescence (QLF; Neuhaus *et al.*, 2009).

MATERIALS & METHODS

This longitudinal study was conducted in an Amish community in LaGrange County, Indiana, USA. It received Institutional Review Board approval: ethical committee approval numbers 1701-16 (Indiana University; for recruitment through 12-mo exams), 1001-08 (Indiana University; for 24-mo exams), and HUM00047027 (University of Michigan; for 44-mo exams). Children were recruited through 9 Amish schools with the help of a community advisory board. Sample size before enrollment was estimated to require 60 subjects to

ensure at least 10 teeth each for ICDAS 0-4. The total sample size of 60 subjects was determined to be sufficient to allow accurate estimation of caries prevalence, baseline sealant and filling prevalence, and subject retention for use in planning follow-up studies. Exploratory analyses of the data—primarily changes in parameters over time and relationships among those changes—were expected to involve tooth-specific measurements and assessments from approximately 240 teeth from the 60 subjects. If the true correlation between measurements was at least 0.5, 90% confidence intervals for the correlation coefficients would have a maximum interval width between 0.1 and 0.2 depending on the strength of the within-subject correlation between teeth.

All examinations were conducted at the schools in a mobile dental van. After parental consent and child assent, all eligible children ($n = 104$) were screened. Separate examiners were used for different methods to avoid biases. During the screening examination, teeth were cleaned with a toothbrush, air-dried, and assessed under light, without magnification, according to ICDAS criteria by a single calibrated examiner (M.F.; intra-examiner weighted kappa = 0.83; for calibration with a gold standard examiner, weighted kappa = 0.65). Bitewing radiographs were taken with bitewing tags. For children included in the study, the ICDAS and radiography data were used as pre-sealant data. Seventy-seven children met the inclusion criteria:

1. They provided written informed consent and assent;
2. were 7 to 10 yr old;
3. allowed for study procedures;
4. had at least 2 fully erupted first permanent molars without occlusal restorations, sealants, cavitated lesions ICDAS ≥ 5 , radiographic occlusal lesions extending halfway or more through the dentin, or interproximal lesions into dentin;
5. were generally healthy; and
6. were available for all visits.

Failure to meet these inclusion criteria resulted in exclusion from the study. At all visits, oral hygiene and fluoride toothpaste use were emphasized; toothbrushes and toothpaste samples were provided to all children; and parents were made aware of any conditions requiring treatment and were re-consented annually.

Seventy-three children participated in the baseline examination. Four children were lost to follow-up after the screening visit: 2 siblings withdrew consent, and 2 were sick and missing from school the day of the appointment. A single trained examiner (J.A.P.), blinded to the ICDAS data, obtained additional pre-sealant baseline data of study teeth, as explained next. Clean and dried surfaces were scanned with the DIAGNOdent (Kavo, Biberach, Germany) following the manufacturer's instructions. The peak value was recorded after repeating it 3 times (± 3 units). Images of study teeth, dried for 10 sec, were then acquired *via* QLF 3.0.0.35 software (Inspektor Research Systems BV, Netherlands), which allows for video repositioning over time, in a darkened room. Intraoral images were taken for illustration purposes (SUNI Medical Imaging, USA; or Digital Doc LLC, USA). Study teeth were then sealed by a single experienced dentist (A.E.S.-R.) using a clear material (Helioseal

Clear Chroma, Ivoclar Vivadent, Inc., USA) after isolation and using in all cases but 1 (*i.e.*, in which gagging reflex would not allow it) the Isolite system (USA), etching with 35% phosphoric acid for 60 sec, and light curing for 40 sec. The sealant temporarily assumed an olive-green hue due to a photochromic effect and was then easily assessed for retention (fully retained, partially retained, or completely lost; each repaired as needed if exposing caries-prone areas).

Post-sealant measurements were obtained at 1, 12, 24, and 44 mo. At the 1-mo visit ($n = 71$), all examinations were repeated as described in the baseline visit. Two children were lost to follow-up after the baseline visit, as they were sick and missing from school the day of the 1-mo visit. The 71 children seen at the 1-mo visit were then followed over time, as they had complete pre- and 1-mo post-sealant data. At the 12- ($n = 71$), 24- ($n = 71$), and 44-mo ($n = 64$) visits, all examinations performed during the 1-mo visit were repeated (except that QLF data were not analyzed at 44 mo); a full-mouth ICDAS examination was also performed, and bitewing radiographs were taken annually. Defective sealants were repaired (J.A.P.) at each examination visit. Examiners remained consistent for each method throughout the length of the study.

ICDAS increases compared to baseline were evaluated as changes from scores 0-2 to 3 or higher, 3 to 4 or higher, or 4 to 5 or higher. If a study tooth progressed to ICDAS ≥ 5 or radiographically halfway or more through the dentin, the tooth was referred for additional care at no cost. Ten percent of the subjects were reexamined for ICDAS intra-examiner repeatability after each visit.

QLF images were analyzed by a trained examiner blinded to the ICDAS and DIAGNOdent examinations (M.A.). QLF variables, average fluorescence loss (ΔF [%]), size of the lesion (mm^2), and fluorescence loss integrated over the lesion size (ΔQ [% $\times \text{mm}^2$]), were determined through the QLF program (software: QLF 2.00g, Inspektor) at a 70% threshold of fluorescence reduction to adjust for the effect of the sealant (Ando *et al.*, 2001, 2009).

Radiographs of study teeth were evaluated by 2 trained independent examiners (C.G.-C., J.A.P.) using the following criteria: lesion presence (if no = 0) and lesion depth (enamel: E1, outer half; E2, inner half; dentin: D1, outer third; D2, middle third; D3, inner third). Scores 0/E1, E2/D1, and D2/D3 were collapsed for analyses. In addition, radiographs of the same tooth were placed in random order and evaluated for no change, progression, or regression. Discrepancies in scores were resolved by forced consensus.

Statistical Methods

ICDAS score repeatability at each exam period and agreement between the scores before and after sealant placement were assessed through kappa and weighted kappa statistics. Comparisons between categorical variables were made *via* Mantel-Haenszel tests for ordered categorical responses. Radiograph levels, ICDAS levels, and presence/absence of sealant repair were separately tested for differences in DIAGNOdent and QLF measurements according to mixed-model analysis of

Table 1. DIAGNOdent Scores Pre- and Postsealant by Baseline ICDAS and X-ray Scores

Baseline Score	Presealant	Postsealant			
	Baseline	1 mo	12 mo	24 mo	44 mo
Overall ICDAS	37.5 (1.8) ²	39.4 (1.8) ²	34.3 (2.1) ¹	42.4 (2.5) ^{2,3}	43.8 (2.5) ³
0	24.4 (2.0) ^{a,1}	28.3 (2.0) ^{a,1}	26.3 (2.8) ¹	34.1 (3.1) ²	35.7 (3.1) ²
1	36.0 (3.9) ^{b,2,3}	34.3 (3.8) ^{a,b,2,3}	26.9 (3.9) ¹	33.2 (4.6) ^{1,2}	41.2 (6.4) ³
2	47.3 (3.7) ^{b,1}	50.1 (3.9) ^{c,1,2}	44.0 (3.6) ¹	55.0 (4.7) ^{2,3}	56.3 (4.2) ³
3	61.5 (7.4) ^{c,2}	60.4 (5.5) ^{d,2}	49.9 (6.0) ¹	56.9 (8.3) ^{1,2}	74.3 (8.9) ^{1,2}
4	49.1 (6.4) ^{b,c,1,2}	48.8 (5.6) ^{b,c,d,1,2}	42.3 (5.1) ¹	48.3 (10.2) ^{1,2}	57.9 (12.1) ²
X-ray					
0/E1	34.6 (1.8) ^{a,1,2}	36.9 (1.8) ^{a,2}	33.1 (2.1) ¹	40.9 (2.5) ³	42.2 (2.3) ³
E2/D1	62.4 (6.7) ^{b,2}	58.5 (6.1) ^{b,2}	41.6 (5.6) ¹	50.4 (8.3) ^{1,2}	66.4 (11.6) ²

Values in mean (SE). Superscript letters indicate group differences at baseline (presealant) and 1-mo visit (postsealant; $p < .05$), while superscript numbers indicate differences over time. Superscripts sharing the same letter or number do not differ significantly from each other. ICDAS, International Caries Detection and Assessment System.

variance, with a random subject effect to account for the correlations between teeth within a subject. Mixed-model analysis of variance was also used to test for changes over time in the DIAGNOdent and QLF measurements. Pairwise group comparisons were conducted with the Fisher's protected least significant differences method to control the overall significance level at 5%. The statistical analyses were performed with SAS 9.

RESULTS

Seventy-one children (mean $\pm$ SD age, 8.8 ± 1.1 yr) with 228 teeth were evaluated presealant and 1-mo postsealant. Demographic percentage distribution after rounding was as follows: 59% male, 27% 7-yr-olds, 34% 8-yr-olds, 23% 9-yr-olds, 17% 10-yr olds. The study population was at high caries risk, as 71% of the children had untreated ICDAS ≥ 5 lesions at baseline with dmfs/DMFS (considering caries as ICDAS ≥ 5) = 13.6 ± 13.6 and number of noncavitated lesions (ICDAS 1+2) = 11.8 ± 7.1 . Recall rate of subjects was excellent: 100% at 12 and 24 mo, and 90% at 44 mo (2 children moved, and 5 did not consent at 44 mo).

The distribution of radiograph scores at baseline was as follows: 0/E1 = 90%, E2/D1 = 10%, D2/D3 = 0%. All baseline E2/D1 lesions remained unchanged over time, and there was no progression to D2/D3. There were few radiographic progression changes in 0/E1 lesions, with 1% showing increase at 12 mo, 3% at 24 mo, and 9% at 44 mo. Compared with all teeth with no progression, teeth with radiographic progression had larger baseline DIAGNOdent, mean (SE), $53.4 (6.0)$ vs. $37.6 (2.6)$, $p = .021$, and QLF area, $5.1 (0.9)$ vs. $3.1 (0.4)$, $p = .048$. Baseline radiographic depth, ICDAS, and QLF- ΔF and QLF- ΔQ were not associated with radiographic progression. Sealants that were repaired were more likely to have radiographic progression (16% vs. 6%, $p = .015$).

Baseline ICDAS repeatability was good (weighted kappa = 0.83). Distribution of baseline ICDAS scores was as follows: 40% with ICDAS = 0, 17% ICDAS = 1, 27% ICDAS = 2, 7%

ICDAS = 3, and 8% ICDAS = 4. Presealant ICDAS was only weakly associated with radiograph scores (correlation = 0.24, $p < .001$). Agreement between presealant and 1-mo postsealant ICDAS scores was moderate (weighted kappa = 0.61). There was no significant progression in ICDAS scores presealant (baseline) to postsealant at 12 mo, with 6% increased and 11% decreased. There was a small indication of ICDAS change at 24 and 44 mo: at 24 mo, 14% of teeth increased while 10% decreased; at 44 mo these numbers were 14% and 8%, respectively. Teeth that increased in ICDAS severity had higher DIAGNOdent scores at the prior visit, $49.0 (4.0)$ vs. $37.0 (2.1)$, $p = .001$. However, only 2 teeth progressed to ICDAS ≥ 5 at 24 mo and 2 more at 44 mo; 2 of the teeth had radiographic scores 0/E1 and 2 had E2/D1; and all 4 sealants needed repair.

DIAGNOdent and QLF were able to distinguish among ICDAS scores pre- and postsealant placement (Tables 1 and 2), though at a diminished ability postplacement. While the changes for DIAGNOdent ($p = .15$) and QLF- ΔF ($p = .92$) pre- vs. 1-mo postsealant were not significant (*i.e.*, not affected by sealant placement), the values for QLF area and QLF- ΔQ were significantly higher postsealant ($p < .0001$), with the increases more pronounced for smaller lesions. When DIAGNOdent measurements were compared over time (Table 1), scores at the 44-mo exam were significantly higher than at baseline ($p = .0100$), 1 mo ($p = .0135$), and 12 mo ($p < .0001$); scores at 12 mo were lower than at baseline ($p = .0038$), 1 mo ($p = .0002$), and 24 mo ($p = .0001$). Regarding QLF data over time (Table 2), QLF area was significantly different between all visits, with a decreasing pattern after 1 mo. QLF- ΔF was significantly different between all visits, except between the 12- and 24-mo visits, with a decreasing pattern after 1 mo. QLF- ΔF at 12 mo was lower than at baseline and 1 mo and was lower at 24 mo than at baseline.

Sealants in need of repair were 11% at 12 mo, 22% by 24 mo, and 30% by 44 mo. The risk of repair at or before 44 mo increased ($p = .005$) as the baseline ICDAS score increased but was not significantly associated with baseline radiograph scores (Table 3). Repaired sealants had higher baseline DIAGNOdent

Table 2. QLF Area, ΔF , and ΔQ Pre- and Postsealant by Baseline ICDAS and X-ray Scores

Baseline Score	Presealant	Postsealant		
	Baseline	1 mo	12 mo	24 mo
QLF area overall	3.1 (0.3) ¹	6.6 (0.4) ⁴	4.8 (0.5) ³	3.9 (0.5) ²
ICDAS				
0	1.9 (0.4) ^{a,1}	6.2 (0.6) ^{a,b,4}	3.9 (0.7) ³	2.8 (0.7) ²
1	2.0 (0.5) ^{a,b,1}	5.8 (0.8) ^{a,b,3}	3.5 (0.9) ²	2.9 (0.9) ²
2	3.0 (0.3) ^{b,1}	5.4 (0.5) ^{a,3}	4.4 (0.6) ²	3.7 (0.6) ¹
3	6.1 (1.3) ^{c,1}	9.0 (1.6) ^{b,c,2}	7.0 (1.2) ¹	8.5 (1.6) ¹
4	9.2 (1.4) ^{d,1}	11.5 (1.5) ^{c,2}	10.8 (2.4) ²	9.4 (3.1) ^{1,2}
X-ray				
0/E1	2.9 (0.3) ^{a,1}	6.6 (0.4) ^{a,4}	4.7 (0.5) ³	3.6 (0.5) ²
E2/D1	4.9 (1.3) ^{b,1}	6.7 (1.6) ^{a,2}	6.7 (2.1) ^{1,2}	7.6 (2.5) ^{1,2}
QLF ΔF overall	36.1 (0.8) ³	36.2 (0.6) ^{2,3}	34.3 (1.1) ¹	33.4 (1.2) ^{1,2}
ICDAS				
0	31.3 (1.4) ^{a,1,2}	33.2 (1.0) ^{a,2}	30.3 (1.7) ¹	28.9 (1.9) ¹
1	34.3 (2.1) ^{a,b,1}	33.1 (1.9) ^{a,1}	30.9 (2.2) ¹	27.2 (2.3) ¹
2	38.3 (1.1) ^{b,1}	37.8 (0.8) ^{b,1}	36.6 (1.3) ¹	35.8 (1.3) ¹
3	44.8 (1.2) ^{c,1}	43.0 (1.0) ^{c,1}	41.9 (1.4) ¹	44.6 (1.5) ¹
4	48.0 (1.3) ^{c,1}	45.7 (1.1) ^{c,1}	44.7 (1.7) ¹	42.2 (2.3) ¹
X-ray				
0/E1	35.1 (0.9) ^{a,2,3}	35.9 (0.6) ^{a,3}	33.8 (1.1) ^{1,2}	32.7 (1.3) ¹
E2/D1	44.5 (1.5) ^{b,2}	37.3 (3.2) ^{a,1}	37.7 (3.2) ^{1,2}	39.5 (2.3) ^{1,2}
QLF ΔQ overall	132 (13) ¹	265 (17) ³	194 (24) ²	161 (23) ²
ICDAS				
0	69 (14) ^{a,1}	232 (25) ^{a,4}	145 (28) ³	104 (26) ²
1	75 (18) ^{a,b,1}	226 (36) ^{a,b,3}	131 (36) ^{2,3}	110 (39) ^{1,2}
2	122 (14) ^{b,1}	217 (21) ^{a,3}	176 (25) ^{2,3}	151 (26) ^{1,2}
3	283 (62) ^{c,1}	401 (74) ^{b,c,2}	326 (56) ¹	423 (78) ^{1,2}
4	452 (80) ^{d,1}	544 (86) ^{c,2}	509 (129) ^{1,2}	432 (160) ^{1,2}
X-ray				
0/E1	119 (12) ^{a,1}	260 (17) ^{a,4}	185 (21) ³	145 (20) ²
E2/D1	242 (78) ^{b,1}	312 (88) ^{a,1}	312 (112) ¹	345 (132) ¹

Values in mean (SE). Superscript letters indicate group differences at baseline (presealant) and 1-mo visit (postsealant; $p < .05$), while superscript numbers indicate differences over time. Superscripts sharing the same letter or number do not differ significantly from each other. ICDAS, International Caries Detection and Assessment System; QLF, quantitative light-induced fluorescence.

Table 3. Repaired Sealants by Baseline ICDAS and X-ray scores

Baseline Score	No. of Repaired Sealants (%)		
	12 mo	24 mo	44 mo
Overall	24 (11)	47 (22)	59 (30)
ICDAS			
0	4 (4)	10 (11)	14 (17)
1	4 (11)	5 (13)	7 (18)
2	9 (16)	18 (32)	24 (47)
3	5 (31)	7 (50)	7 (58)
4	2 (13)	7 (50)	7 (64)
X-ray			
0/E1	20 (10)	39 (21)	50 (28)
E2/D1	3 (18)	6 (40)	6 (46)
Unavailable	1 ^a	2	3

ICDAS, International Caries Detection and Assessment System.

^aA radiographic score was not provided for the occlusal surface of 1 included tooth, as the tooth had a facial amalgam that complicated the accurate radiographic reading.

scores than nonrepaired sealants, 46.6 (3.8) vs. 35.1 (2.7), $p = .003$. Repaired sealants also had higher baseline QLF area, 4.7 (0.6) vs. 2.6 (0.4), $p = .001$, and QLF- ΔQ scores, 205 (27) vs. 111 (20), $p = .001$. Similarly, repaired sealants had higher DIAGNOdent, 47.7 (3.4) vs. 35.8 (2.1), $p = .001$, QLF area, 6.5 (0.7) vs. 5.0 (0.5), $p = .013$, QLF- ΔF , 37.5 (1.5) vs. 34.1 (1.0), $p = .010$, and QLF- ΔQ scores, 273 (33) vs. 201 (24), $p = .006$, at the visit before repair was needed than nonrepaired sealants.

DISCUSSION

The primary purpose of this study was to evaluate methods for detection and monitoring of occlusal surfaces through clear sealants. A better ability to monitor sealed lesions might remove one of the most important perceived barriers for sealant utilization, thus increasing its acceptance and use. In the last decades, there has been increasing evidence to support strategies that preserve tooth structure and a more conservative approach to caries management (Gooch *et al.*, 2009; Ricketts *et al.*, 2013),

Figure 1. Clinical image, International Caries Detection and Assessment System (ICDAS), radiographic, and DIAGNOdent scores of a first molar sealed and monitored over 44 mo.

which has resulted in the American Dental Association and Centers for Disease Control and Prevention updating their sealant recommendations in support of sealing noncavitated caries lesions. This threshold was based on studies that used diagnostic criteria primarily at the cavitation level (Radake, 1968; World Health Organization, 1987), which are limited in their ability to discriminate among sound teeth and different stages of lesion severity. ICDAS was used in this study to permit a more accurate assessment and monitoring of lesion severity. Because of the limitations of bitewing radiography to detect early occlusal caries lesions (and the fact that only bitewing tags were used in the present study to position the films, as commonly used in practice in the United States), QLF and DIAGNOdent were included because they have proven to be sensitive technologies for detection and monitoring of caries lesions (Neuhaus *et al.*, 2009). Lesion activity was not used as a separate assessment criterion because we assumed a very high likelihood that the lesions detected in this high-risk community were active; thus, lesions were treated as such.

QLF was designed to measure loss of fluorescence and size of a caries lesion when illuminated with light at 290 to 450 nm; DIAGNOdent uses a pulsed near-infrared diode laser that emits light at 655 nm to excite fluorescence primarily from bacterial by-products in the lesion that can be measured by the device. Laboratory data suggest that these 2 methods as well as visual exam can assess and monitor caries lesions under clear sealant (Takamori *et al.*, 2001; Deery *et al.*, 2006; Fontana *et al.*, 2008). Interestingly, *in vitro* visual examination through a clear sealant had superior validity and reproducibility than that of DIAGNOdent (Deery *et al.*, 2006). The results from the present study suggest that caries lesions could be assessed and monitored over time *in vivo* through a clear sealant according to ICDAS, QLF, and DIAGNOdent, since placement of the sealant did not significantly affect ICDAS, DIAGNOdent, and QLF-ΔF readings. Baseline pre-sealant values, rather than the 1-mo post-sealant data, were used as the reference point in the analyses. This allowed an accounting for overall post-sealant effects, including wear, repair, and so forth that would occur over time in normal clinical practice. Few and minor changes were observed through the sealants over time, and for those changes

the methods did not agree. It is unlikely that these changes were a result of sealant repair, as preliminary data at 12 mo obtained from vinyl polysiloxane clinical impressions suggested that sealant thickness does not correlate with DIAGNOdent and QLF pre- and post-sealant differences (Kurshuk *et al.*, 2009). We cannot exclude that the small changes observed were the result of variability associated with the use of these methods under clinical conditions, with variability in the examiners over time, or with changes in the material over time (*e.g.*, stain, porosities, plaque accumulation) that may have affected the ability to see through the sealant or the fluorescence data.

Longer follow-up and a larger study are needed to determine the association of the small longitudinal changes observed in the DIAGNOdent and QLF measurements with lesion progression and how monitoring sealants based on these methods will affect clinical outcomes.

It is generally accepted that the effectiveness of resin-based sealants depends on long-term retention (Ahovuo-Saloranta *et al.*, 2013; Mickenautsch and Yengopal, 2013). Retention levels decrease over time—79%-92% = 12 mo, 71%-85% = 24 mo, 61%-80% = 36 mo (Ahovuo-Saloranta *et al.*, 2008), and 83.8% = 5 yr for photopolymerized sealants (Kuhnisch *et al.*, 2012)—thereby increasing the need for replacement and repair. The clear sealant used in this study provided overall retention rates (89% = 12 mo, 78% = 24 mo, 70% = 44 mo) similar to those reported in the literature. Notably, the retention was negatively affected by higher baseline ICDAS scores and DIAGNOdent and QLF measurements. The ability to see the lesion through a clear material (Figure 1), although an advantage for monitoring, might have influenced the repair decisions, as clear sealants are harder to see clinically compared to an opaque material (even with the olive-green hue from the material used in this study). The examiner could clearly see the large lesion under the sealant, which had the potential to bias the repair decision. Interestingly, ICDAS, DIAGNOdent, and QLF could be used to predict need for repair over time, as higher starting values as well as higher values during follow-up were associated with a higher risk of repair through 44 mo.

In this study, occlusal surfaces ICDAS 0-4 were successfully sealed for 44 mo. Sealants, repaired yearly when needed, were 98% effective over 44 mo in preventing progression to an ICDAS ≥ 5, and no teeth showed progression radiographically to halfway or more through the dentin. These findings are quite remarkable when considering that this study was conducted in an extremely underserved group with very high caries risk: untreated cavitated lesion rate = 71% vs. 46.7% for children with family incomes ≥ 100% but < 200% the federal poverty level (Beltrán-Aguilar *et al.*, 2005). Bakhshandeh *et al.* (2012) also successfully sealed (*i.e.*, only 10% of lesions progressed) for 2 to 3 yr early and moderate lesions deemed to be in need of restorative care either clinically (noncavitated, cavitated in enamel, and cavitated in dentin) or radiographically (maximum

depth, middle third of dentin). Sealing permanent first molars of children from low-income families with high caries risk is a more cost-effective prevention strategy than not providing sealants (Quiñonez *et al.*, 2005), especially in school-based sealant programs (Griffin *et al.*, 2002), and it might reduce subsequent provision of restorative services (Weintraub *et al.*, 2001). However, further studies with longer observation periods and larger sample sizes are needed to determine the cost- and risk-effectiveness of sealing moderate caries lesions.

In conclusion, results from this study suggest that occlusal surfaces without frank cavitation (ICDAS 0-4) that are sealed with a clear sealant can be monitored over time through ICDAS, QLF, or DIAGNOdent, which this may aid in prediction of need for sealant repair.

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