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Caries risk in formerly sealed teeth

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Almost 70 percent of youth have experienced dental caries by late adolescence.[1] Available data show that children and youth from low-income families (those with an income of less than 200 percent of the federal poverty guidelines) are more than twice as likely to have untreated caries in their permanent teeth as are their higher-income counterparts.[1] Overall, about 90 percent of carious lesions are found in the pits and fissures of permanent posterior teeth,[2] with molars being the most susceptible to caries in comparison with other tooth types.[3]

Researchers have shown that dental sealants delivered in clinical or school settings are highly effective in preventing dental caries, reducing caries in the pits and fissures by 60 percent from two to five years after placement.[4] Sealant effectiveness is linked to sealant retention, and a retained sealant has been shown to be 100 percent effective.[5] Although systematic reviews[4,6] have demonstrated the effectiveness of dental sealants, recent national data indicate that sealant prevalence among children and youth—30 percent[1]—is well below the national Healthy People

A B S T R A C T

Background. The authors examined the risk of caries development in teeth with partially or fully lost sealant (formerly sealed [FS] teeth) relative to the risk in teeth that never have received sealants (never-sealed [NS] teeth).

Methods. The authors searched the population of studies used in five reviews of sealant effectiveness as established in split-mouth design studies involving resin-based sealants with no reapplication of lost sealant. They required included studies to contain sufficient data to estimate the risk of caries in FS teeth relative to that in NS teeth (relative risk [RR] = $\frac{\% \text{ FS developing caries}}{\% \text{ NS developing caries}}$) and its 95 percent confidence interval (CI). To estimate the mean RR by year since sealant placement, they used a weighted bivariate model and tested for heterogeneity using the quantity I^2.

Results. The weighted mean RR was 0.998 (95 percent CI, 0.817-1.220) one year after placement (four studies, 345 tooth pairs) and 0.936 (95 percent CI, 0.896-0.978) at four years (five studies, 1,423 tooth pairs).

Conclusions. Teeth with fully or partially lost sealant were not at a higher risk of developing caries than were teeth that had never been sealed.

Clinical Implications. Inability to provide a retention-check examination to all children participating in school sealant programs because of loss to follow-up should not disqualify a child from receiving sealants.

Key Words. Dental sealants; pit-and-fissure sealants; retention; caries.
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TABLE 1

Description of studies used to determine risk of caries in formerly sealed teeth.

STUDY CHARACTERISTIC	STUDY AUTHOR, YEAR STUDY PUBLISHED, SITE		
	McCune and Colleagues,[13] 1979, Colombia	Mertz-Fairhurst and Colleagues,[14] 1984, United States	Charbeneau and Colleagues,[15] 1977, United States
Subjects			
Age range (years)	6-9	6-8	5-8
Background prevention exposure	CWF*	CWF	NR†
Caries severity threshold	One or more lesions§	One or more lesions	NR
Sealants			
Material¶	RB2	RB1# and RB2	RB2
Tooth type sealed**	M	M	M
Criteria for partial loss	Present on at least one occlusal region	Present on at least one occlusal region	NR
Criteria for full loss	Sealant not present on any occlusal region	Sealant not present on any occlusal region	NR
Complete retention rate (%)††	Y1 = 92, Y2 = 89, Y3 = 88	RB1: Y1 = 84, Y2 = 58, Y3 = 60, Y4.5 = 35 RB2: Y1 = 95, Y2 = 84, Y3 = 80, Y4.5 = 72	Y1.5 = 74, Y4 = 52
Study Quality			
Number of subjects at baseline‡‡	200	382	143
Teeth	636	1,202	458
Sites	NA§§	NA	NR
Dropout rate (%)	Y1 = 14, Y2 = 21, Y3 = 15	Y1 = 21, Y2 = 19, Y3 = 34, Y4 = 42	Y1.5 = 16¶¶, Y4 = 19
Method of measurement of caries progression	VT##	VT	VT
Caries criteria	NR	Catch/softness and evidence of decalcification	Explorer catch and evidence of decalcification
Examiner agreement	Consensus	92%	Consensus

* CWF: Community water fluoridation.
† NR: Not reported.
‡ FMR: Fluoride mouthrinse delivered fortnightly.
§ Lesion: Untreated or treated caries.
¶ RB1: Ultraviolet light–polymerized resin-based sealant. RB2: Autopolymerized resin-based sealant.
\# Assumed ultraviolet light–polymerized resin-based sealant (RB1) because majority of lost sealants were RB1.
** M: Permanent molar. PM: Permanent premolar.
†† Y1: Year 1. Y1.5: Year 1.5. Y2: Year 2. Y3: Year 3. Y4: Year 4. Y4.5: Year 4.5.
‡‡ Note that these numbers are for all subjects.
§§ NA: Not applicable—for example, analysis was done at the tooth level so site-level data are not applicable.
¶¶ Estimated for teeth versus subjects.
\## VT: Visual/tactile.

(continued on next page)

2010[7] target of 50 percent. Disparities exist according to income, with children from lower-income families about one-half as likely to have received a sealant as their counterparts from higher-income families.[1]

School programs providing dental sealants are an important intervention to increase children's receipt of sealants. On the basis of strong evidence of effectiveness, the independent, nongovernmental Task Force on Community Preven-

tive Services[8]—a volunteer body of public health

ABBREVIATION KEY. **CDC:** Centers for Disease Control and Prevention. **CWF:** Community water fluoridation. **FMR:** Fluoride mouthrinse. **FS:** Formerly sealed. **M:** Permanent molar. **NA:** Not applicable. **NR:** Not reported. **NS:** Never sealed. **PM:** Permanent premolar. **RB1:** Ultraviolet light–polymerized resin-based sealant. **RB2:** Autopolymerized resin-based sealant. **VT:** Visual/tactile. **Y1**: Year 1. **Y1.5**: Year 1.5. **Y2:** Year 2. **Y3:** Year 3. **Y4:** Year 4. **Y4.5:** Year 4.5.

STUDY AUTHOR, YEAR STUDY PUBLISHED, SITE			
Going and Colleagues,[29] 1977, United States	**Horowitz and Colleagues,[32] 1976, United States**	**Leake and Martinello,[49] 1976, Canada**	**Thylstrup and Poulsen,[22] 1976, Denmark**
10-14	5-14	5-7	7
None	None	NR	FMR[‡]
NR	NR	NR	NR
RB1	RB1	RB1	RB2
M and PM	M	M	M
Slight to severe loss of material	Part but not all of pit or fissure was not covered with sealant	Sealant can be demonstrated as present on some occlusal grooves and fissures	Part but not all of pit or fissure was not covered with sealant
Total loss of material	Entirely missing	Sealant cannot be demonstrated over any of the occlusal grooves and fissures	Entirely missing
Y1 = 81, Y2 = 69, Y3 = 56, Y4 = 50	Y4 = 50	Y4 = 20	Y1 = 73, Y2 = 60
84	429	518	217
479	NR	2,072	NR
NA	NR	NA	NR
Y1 = 5, Y2 = 16, Y3 = 18, Y4 = 18	Y4 = 37.5	Y4 = 19	Y1 = 12, Y2 = 12.0
VT	VT	VT and radiographic	VT
Explorer catch/penetration or visually evident lesion	Explorer catch and evidence of decalcification	Fissure definitely resists the withdrawal or supports the point of explorer	Definite pull required to remove explorer
Consensus	NR	One examiner	One examiner

and prevention experts whose members are appointed by the director of the Centers for Disease Control and Prevention (CDC), Atlanta—issued a strong recommendation that school-based sealant programs be part of a comprehensive community strategy to prevent dental caries. The task force also acknowledged that these programs typically deliver services to children unlikely to receive them otherwise (such as children from lower-income families). School-based sealant programs also have the potential to link students with treatment services in the community.

One potential barrier to delivering sealants is the concern that a tooth with a partially lost sealant may be at a higher risk of developing caries than it would be if it never had been sealed. The theoretical rationale is that food particles could become trapped under a partially retained sealant, thus increasing the availability of nutrients for cariogenic bacteria. Because

school-based programs typically deliver sealants to children who are more likely to move during or between school years than are higher-income children,[9] follow-up examinations for all children receiving sealants may not be possible. This concern about risks associated with sealant loss led a CDC-sponsored Expert Work Group that was developing guidelines for school-based sealant programs to request an analysis of relevant clinical studies. We were charged with carrying out this analysis. Therefore, the objective of our research was to determine if the risk of developing caries in a formerly sealed (FS) tooth with fully or partially lost sealant exceeds the risk in a never-sealed (NS) tooth.

MATERIALS AND METHODS

Inclusion criteria and identification and selection of studies. We searched MEDLINE and the Cochrane Library for systematic reviews of sealant effectiveness that were published in English from 1990 through 2005. Five systematic reviews,[4,6,10-12] which included 37 unique studies,[13-49] met these inclusion criteria. Two reviewers (S.K.G. and S.O.G.) screened these studies. They excluded 30 of the studies for the following reasons: publication in language other than English,[47] adult rather than child or youth subjects,[34] absence of concurrent comparison group that had not received sealants,[19,25,37,40,42,43,46] intervention not involving placement of resin-based sealants on permanent posterior teeth with no reapplication,[26,27,35,38,39,44,48] absence of description of caries status by retention status[17,18,20,21,23,28,30,31,33,41] and absence of a split-mouth design.[16,24,36,45]

Data abstraction and quality assessment. The same two reviewers independently abstracted data from the included studies. If there was disagreement on a specific item on the abstraction form, both reviewers re-examined the relevant portion of the study and reached consensus on the appropriate value. Because included studies were randomized controlled split-mouth trials and selected from among published systematic reviews that included explicit quality criteria for inclusion, we did not assign a quality score. However, we collected information on selected aspects of study quality (Table 1, page 416), including loss to follow-up and validity (caries assessment method) and reliability (examiner agreement) of caries status determination. Because studies involved randomized controlled trials with a split-mouth design, we determined it to be unlikely that initial assembly and maintenance of comparable groups was an issue. We also should note that it is difficult to blind examiners as to whether a sealant was placed or not placed unless the sealant was removed before follow-up, a scenario that is not typical in most sealant studies.

Outcome and risk measures. Our outcome measure was whether a tooth, when assessed at each annual follow-up examination, had developed caries. We compared the risk of developing caries in an FS tooth relative to that in an NS tooth, where relative risk $(RR) = \frac{\% \text{ FS developing caries}}{\% \text{ NS developing caries}}$. FS teeth included teeth that had fully or partially lost sealant material. We also estimated the 95 percent confidence interval (CI) for the RR reported in each study by assuming that paired teeth were independent (further information about estimation of the variance is available as supplemental data to the online version of this article, found at "http://jada.ada.org"). We also collected data on the percentage of FS teeth on which the sealants were partially lost.

Synthesis of findings. To estimate the mean RR, we used a weighted bivariate model in which we weighted each study by the reciprocal of its squared standard error. We also calculated the median RR across studies. To determine if the weighted bivariate analysis was heterogeneous, we calculated the quantity I^2.[50]

RESULTS

Characteristics of studies. We included seven studies in the final body of evidence (Table 1). The publication date of the last report from each study ranged from 1976 to 1984.[13-15,22,29,32,49] Three studies involved the use of ultraviolet light–polymerized resin-based sealant, which we designated "RB1"[29, 32,49]; three involved the use of autopolymerized resin-based sealant, which we designated "RB2"[13,15,22]; and one involved the use of both RB1 and RB2.[14] RB1 sealants have lower retention rates than do RB2 sealants, as evidenced by results from the latter study,[14] in which about 70 percent of teeth classified as FS had received RB1 at the first two follow-up examinations. Researchers in all but one study[29]

> Our outcome measure was whether a tooth, when assessed at each annual follow-up examination, had developed caries.

reported data for permanent molars only.

Subjects' ages ranged from 5 through 14 years. In three studies, investigators reported that subjects were exposed to fluoride via community water systems or mouthrinse program participation,[13,14,22] two studies reported no fluoride exposure[29,32] and two studies did not report background fluoride exposure.[15,49] Caries incidence among NS teeth at the first-year follow-up examination ranged from 24 to 47 percent. Researchers in all studies used visual or tactile methods or both to assess caries; however, those in one study also used radiographs.[49] For studies with more than one examiner, reported agreement among examiners (one study did not report agreement[32]) was greater than 90 percent. Loss to follow-up ranged from 5 to 21 percent for the five studies in which researchers conducted their first follow-up examination one to 1.5 years after placement[13-15,22, 29] and from 19 to 37.5 percent for the two studies in which investigators conducted their follow-up examinations four years after placement.[32,49]

For studies in which researchers reported sealant loss at the tooth level versus the site level,[13-15,29,49] the mean percentage of FS teeth accounted for by partially lost sealants was at least 60 percent, up to and including three years after placement (Table 2). The mean percentage of FS teeth accounted for by partially lost sealants declined over time, and there did not appear to be a difference according to generation of sealant material. Two studies reported retention at the site level (pit and fissure; data not shown)[22,32]; in one of them,[22] the proportion of FS teeth accounted for by partially lost sealants was 27 percent one year after placement and 32 percent two years after placement, and in the other study,[32] it was 32 percent four years after placement.

The RR one year after placement (four studies,[14,15,22,29] 345 tooth pairs) ranged from 0.828 to 1.118 (Table 3, page 421). The weighted mean RR was 0.998 (95 percent CI, 0.817-1.220) and the median value was 0.941 (data not shown). For later years, the RR ranged from 0.467 to 1.186 with a weighted mean of 0.912 (95 percent CI, 0.793-1.048) at two years (four studies,[13,14,22,29] 481 tooth pairs), from 0.761 to 1.111 with a weighted

mean of 0.901 (95 percent CI, 0.789-1.029) at three years (three studies,[13,14,29] 332 tooth pairs) and from 0.693 to 1.083 with a weighted mean of 0.936 (95 percent CI, 0.896-0.978) at four years (five studies,[14,15,29,32,49] 1,423 tooth pairs) (Table 3). The median RR was less than 1 for all years since sealant placement. In year 1, the I^2 statistic was negative, indicating that heterogeneity was not present. The I^2 statistic was always higher than 66 percent for later years, indicating that there were systematic differences among studies.

DISCUSSION

Our findings indicate that individual teeth with partial or complete loss of sealant are not at a higher risk of developing caries than they would be if they never had received sealants. The caries rate in FS teeth is less than or equal to the rate in NS teeth. The weighted mean RR was less than 1 for all four years after sealant placement, and the median RR also was less than 1 for all years after placement. Additionally, partially retained sealants accounted for the majority of FS teeth in most studies in which investigators collected data at the tooth level. In all but one study,[49] the RR of caries for FS teeth with partially lost sealants versus NS teeth was lower than the RR of caries for FS teeth with either partially or fully lost sealants versus NS teeth. In the remaining study, by Leake and Martinello,[49] the RR of caries for FS teeth with partially lost sealants was the same as the RR of caries for FS teeth with either partially or fully lost sealants in comparison with teeth that never had received sealants. These findings suggest that heightened concern about partially lost sealants trapping food and thus increasing the risk of caries development may be unfounded.

Theoretically, it is possible that partially retained sealants may offer some protection,[51] especially if a specific tooth site remains sealed. Indeed, in one study included in our analysis, Horowitz and colleagues[32] found that sealant effectiveness increased with the extent of retention. One possible explanation as to why our review did not find an association is that the unit of observation (tooth) used in most studies was not sufficiently sensitive to detect a difference. For example, let us assume that all teeth without sealants develop caries and that 10 teeth, each

> **Our findings suggest that heightened concern about partially lost sealants trapping food and thus increasing the risk of caries development may be unfounded.**

TABLE 2

Formerly sealed teeth: percentage partially retained, according to sealant material and interval since placement.*		
STUDY	**SEALANT MATERIAL,† BY INTERVAL SINCE PLACEMENT**	**SEALANTS PARTIALLY RETAINED (%)**
One Year		
Going and colleagues[29]	RB1	87
Mertz-Fairhurst and colleagues[14]	RB1	64
MEAN	NA‡	**76**
Mertz-Fairhurst and colleagues[14]	RB2	46
McCune and colleagues[13]	RB2	70
Charbeneau and colleagues[15]	RB2	74
MEAN	NA	**63**
Two Years		
Mertz-Fairhurst and colleagues[14]	RB1	57
Going and colleagues[29]	RB1	73
MEAN	NA	**65**
McCune and colleagues[13]	RB2	64
Mertz-Fairhurst and colleagues[14]	RB2	65
Charbeneau and colleagues[15]	RB2	61
MEAN	NA	**60**
Three Years		
Mertz-Fairhurst and colleagues[14]	RB1	52
Going and colleagues[29]	RB1	70
MEAN	NA	**61**
McCune and colleagues[13]	RB2	68
Mertz-Fairhurst and colleagues[14]	RB2	53
Charbeneau and colleagues[15]	RB2	59
MEAN	NA	**60**
Four Years		
Mertz-Fairhurst and colleagues[14]	RB1	33
Going and colleagues[29]	RB1	56
Leake and Martinello[49]§	RB1	2
MEAN	NA	**30**
Mertz-Fairhurst and colleagues[14]	RB2	49
Charbeneau and colleagues[15]	RB2	53
MEAN	NA	**51**

* Thylstrup and Poulsen[22] and Horowitz and colleagues[32] not included because these studies collected retention data at the site level versus the tooth level. Percentage of formerly sealed teeth accounted for by partially retained sealant was 32 percent and 27 percent for years 1 and 2, respectively, in Thylstrup and 32 percent in Horowitz.
† RB1: Ultraviolet (UV) light–polymerized resin-based sealant. RB2: Autopolymerized resin-based sealant.
‡ NA: Not applicable.
§ Sealant loss rate is higher than in the other studies. Clinicians reported difficulty in adapting to field equipment. Variation in the intensity of the UV light from the polymerization unit also was reported. This unit was one of the first manufactured to meet Canadian electrical standards; the investigators tried to compensate by increasing sealant exposure to UV light from 30 to 45 seconds.

with two sites, are sealed while their contralateral teeth remain unsealed. If one site on each tooth lost its sealant while the other site remained sealed, then the RR calculated at the tooth level would be 100 percent/100 percent = 1, while the RR at the site level would be 50 percent/100 percent = 0.5. In the two studies that used site as the unit of measurement, both[22,32] had an RR of less than 1. However, only one study[22] did not include 1 in the 95 percent CI.

We compared the caries in FS teeth with that in NS teeth at the individual tooth level. It is important to note, however, that at the community level, the relevant question is not a direct comparison of caries rates in FS and NS teeth but rather a comparison of the caries rate in the group with sealed teeth (FS teeth plus fully retained sealants) versus the caries rate in the group with NS teeth. It must be remembered that the caries rate in the group with sealed teeth is based on the sealant loss rate and the caries rate in teeth that lost sealants (that is, FS teeth).

TABLE 3

Risk of caries development in formerly sealed (FS) teeth and never-sealed (NS) teeth for each interval since sealant placement.

STUDY, ACCORDING TO INTERVAL SINCE SEALANT PLACEMENT	NO. OF TOOTH PAIRS	CARIOUS FS TEETH	CARIOUS NS TEETH	RR*	95% CI†
One Year					
Mertz-Fairhurst and colleagues[14]	50	12	14	0.857	0.441-1.666
Charbeneau and colleagues[15‡]	88	42	41	1.024	0.749-1.401
Going and colleagues[29§]	87	38	34	1.118	0.784-1.401
Thylstrup and Poulsen[22¶]	120	24	29	0.828	0.513-1.335
WEIGHTED MEAN	**345**	Not applicable (NA)	NA	**0.998**	**0.817-1.220**
Two Years					
McCune and colleagues[13#]	28	7	15	0.467	0.225-0.967
Mertz-Fairhurst and colleagues[14]	146	74	63	1.186	0.928-1.516
Going and colleagues[29]	124	62	75	0.827	0.659-1.037
Thylstrup and Poulsen[22]	183	61	73	0.836	0.637-1.096
WEIGHTED MEAN	**481**	NA	NA	**0.912**	**0.793-1.048**
Three Years					
McCune and colleagues[13]	34	21	22	0.955	0.664-1.372
Mertz-Fairhurst and colleagues[14]	122	66	73	1.111	0.893-1.382
Going and colleagues[29]	176	86	113	0.761	0.631-0.918
WEIGHTED MEAN	**332**	NA	NA	**0.901**	**0.789-1.029**
Four Years					
Mertz-Fairhurst and colleagues[14]**	162	117	126	1.083	0.955-1.229
Charbeneau and colleagues[15]	190	135	139	0.971	0.857-1.101
Going and colleagues[29]	195	106	130	0.815	0.893-0.959
Horowitz and colleagues[32††]	205	97	140	0.693	0.583-0.823
Leake and Martinello[49‡‡]	671	514	543	0.947	0.895-1.001
WEIGHTED MEAN	**1,423**	NA	NA	**0.936**	**0.896-0.978**

* RR: Relative risk.
† CI: Confidence interval.
‡ Actual period was 1.5 years.
§ RR for partially lost sealants was 1.06, 0.78, 0.75 and 0.72 for one, two, three and four years after placement, respectively.
¶ RR for partially lost sealants was 0.2 and 0.5 for one and two years after placement, respectively.
\# RR for partially lost sealants was 0 and 0.71 for two and three years after placement, respectively.
** Actual period was 4.5 years.
†† RR for partially lost sealants was 0.1.
‡‡ RR for partially lost sealants was 1.0.

Researchers conducting a systematic review that included only studies in which lost sealants were not reapplied found that sealants reduced caries by more than 70 percent.[10] This finding indicates that the sealant loss rate multiplied by the caries rate in the group with FS teeth is less than the caries rate in the group with NS teeth or, equivalently, that the benefits of delivering sealants to children for whom follow-up cannot be ensured exceed the potential risks. Additionally, the findings of our study indicate that at the individual tooth level, the risk of caries development in FS teeth does not exceed that in NS teeth.

Because current guidance recommends sealant placement only when there is a risk of caries development[52] and because sealant effectiveness is linked directly to retention,[5] the maximum protection against caries can be achieved when a sealant is fully retained. Our findings do not suggest that practitioners can be any less careful in their sealant-application technique or in the evaluation or maintenance of sealants after placement in clinical practice. Our findings, however, do suggest that a child should not be deprived of the benefits of a sealant even when follow-up care cannot be ensured.

If we consider Cochrane inclusion/exclusion criteria for study design[6] as the gold standard, then the overall quality of studies included in this review was good. Of the four studies included in this review that were not in the Cochrane review,[6] three[22,29,49] were randomized controlled

trials and had dropout rates meeting the Cochrane criteria. Of these three studies, two were excluded from the Cochrane review because they did not meet the intervention criteria of RB2 sealant material,[29,49] and one was excluded because the children in the study participated in a biweekly mouthrinse program.[22] One additional study had a four-year dropout rate of 37.5 percent.[32] The Cochrane review excluded studies with three-year dropout rates exceeding 30 percent and did not specify a threshold for four years after sealant placement.

One limitation of this analysis was the finding of heterogeneity for pooled results two to four years after sealant placement. The presence of heterogeneity suggests that there were significant differences between studies. These differences may not be as important in this study, in which our primary purpose was to determine if the preponderance of evidence indicated that FS teeth were at greater risk of developing caries than were NS teeth. We were not trying to obtain a precise point estimate of effect. For four[13, 22,32,49] of the seven studies included in this review, the point estimate of the RR for each year since sealant placement was always less than 1. In only one[14] of the remaining three studies was the RR consistently above 1, and in that study the highest point estimate of the RR was 1.186.

Finally, we limited our search to studies included in systematic reviews of sealant effectiveness. For this analysis, we chose a less resource-intensive method to identify and screen potential studies. This approach is attractive because it provides an efficient method of collecting data from well-conducted studies. The studies included in systematic reviews have met rules of study design, conduct and measurement. In addition, we minimized bias in selecting studies for this analysis because the authors of the original systematic reviews determined the universe of studies. Inclusion and exclusion criteria in this analysis were explicit, and we specified them before screening available studies.

All but one[14] of the studies included in this analysis were published in the 1970s, when flouride exposure was lower. Furthermore, in some of the studies we included,[14,29,32,49] researchers used a generation of sealant material (RB1) that no longer is commercially available in the United States. It is unlikely, however, that these factors influenced our findings. Among this group of studies, the RR did not appear to vary according to background fluoride exposure or generation of sealant material.

CONCLUSION

The values for both the weighted mean and the median RR suggest that FS teeth with fully or partially lost sealant were not at a higher risk of developing caries than were NS teeth. Thus, the inability to provide a retention examination to all children participating in school-based sealant programs because of potential loss to follow-up should not exclude any child from having access to the well-documented caries-preventive benefit of a retained sealant. ∎

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