Exploring four-handed delivery and retention of resin-based sealants

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Expert panels assembled by the American Dental Association (ADA) and the Centers for Disease Control and Prevention, Atlanta, have been reviewing available scientific information about sealant effectiveness to support the generation of evidence-based guidelines for clinical care and school-based sealant programs, respectively. Although the aims and scope of comprehensive clinical care and the more limited school-based sealant programs may vary, information about the impact of specific clinical practices, such as the use of an assistant (that is, the four-handed technique), on sealant retention, effectiveness and costs can inform practitioners' decisions and practices in both settings.

The Association of State and Territorial Dental Directors supports the use of four-handed delivery in school-based programs.[1] In addition, an expert panel convened by the ADA Council on Scientific Affairs considered the topic important enough to address in evidence-based clinical recommendations for sealant use.[2] Although we are unaware of any data describing the frequency of four-handed sealant delivery in clinical settings in the

ABSTRACT

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Background. To date, no trials have been published that examine whether four-handed delivery of dental sealants increases their retention and effectiveness. In the absence of comparative studies, the authors used available data to explore the likelihood that four-handed delivery increased sealant retention.

Methods. The authors examined data regarding the retention of autopolymerized resin-based sealants from studies included in systematic reviews of sealant effectiveness. The explanatory variable of primary interest was the presence of a second operator. To examine the unique contribution of four-handed delivery to sealant retention, the authors used linear regression models.

Results. Eleven of the 36 studies from systematic reviews met explicit criteria and were included in this analysis. The high level of heterogeneity among studies suggested that multivariate analysis was the correct approach. According to the regression model, the presence of a second operator increased retention by 9 percentage points.

Conclusions. For this group of studies, four-handed delivery of autopolymerized sealants was associated with increased sealant retention.

Clinical Implications. Using four-handed delivery to place resin-based sealants may increase retention.

Key Words. Pit-and-fissure sealants; sealant retention; four-handed delivery.

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United States, almost 94 percent of dentists reported in a recent ADA survey of dental practice that they employed a chairside assistant.[3]

A recent systematic review that examined the retention of resin-based pit-and-fissure sealants according to different clinical procedures used during sealant delivery, however, did not address two-handed versus four-handed delivery.[4] In addition, the ADA conducted a Medline search of the literature from 1975 through 2006, which identified no studies that directly compared sealant outcomes associated with two- and four-handed delivery (Julie Frantsve-Hawley, RDH, PhD, ADA Division of Science, director, Research Institute and Center for Evidence-based Dentistry and Helen Ristic, PhD, ADA Division of Science, director, scientific information, oral communication, January 2007). (The search strategy is available from the authors on request.) Theoretical rationale and expert opinion support the use of a trained auxiliary during sealant placement.[5-8] The four-handed technique may improve the quality and efficiency of sealant placement through shortened placement time, improved isolation, reduction in operator fatigue and enhanced patient care.[5,9,10]

The primary objective of this secondary data analysis was to determine whether evidence existed that sealant retention increased with four-handed placement, while controlling for other factors that could affect retention.

While we could find no comparative studies directly estimating improvements in outcomes associated with the use of an assistant, the studies included in systematic reviews of sealant effectiveness offer a potentially rich source of relevant information. These studies have met established rules of study design, conduct and measurement for inclusion in final bodies of evidence. In addition, they usually provide a detailed description of the intervention (for example, the preparation and placement procedures) and outcomes, in addition to the study participants, the time period and the setting.

A multivariate analysis of the association between the outcome in these studies (sealant retention) and four-handed delivery, in addition to other preparation and placement procedures, can provide indirect evidence of possible benefits. In the absence of randomized controlled trials, a multivariate approach can control for the effects of potential confounders measured in the studies, as well as provide estimates of the unique contribution of each procedure (such as four-handed delivery). Because such approaches may not account for all confounders, however, findings provide only indirect evidence of possible benefit. Information about the contribution of selected aspects of the sealant delivery protocol is important for clinical and public health decision making.

The primary objective of this secondary data analysis was to determine whether evidence existed that sealant retention increased with four-handed placement, while controlling for other factors that could affect retention. We chose retention instead of effectiveness as the outcome of interest, because retention would be affected less by differences in caries risk among the sample populations of multiple studies. In addition, the effectiveness of resin-based sealants is highly associated with retention, because these sealants act by providing a physical barrier that prevents microorganisms and food particles from collecting in pits and fissures.[11]

METHODS

Definitions. We defined four-handed delivery as the placement of sealants by a primary operator with a second person present to provide assistance. Similarly, we defined two-handed delivery as the placement of sealants by a single operator. We used World Bank designations to classify countries where the studies were conducted as "high" income or "not high" income (a combination of low income, lower middle income and upper middle income).[12]

Inclusion criteria. We searched Medline and the Cochrane Library for systematic reviews of sealant effectiveness that were published in English between 1990 and 2005. Four systematic reviews,[13-16] which included 36 unique studies, met these inclusion criteria.[17-52] One reviewer (S.K.G.) screened these studies, and she excluded 25[28-52] for the following reasons: the study was not published in English[52]; the study design was not a prospective cohort or randomized controlled trial[46]; the study did not apply second- or third-generation sealant material[28,30,32-40,42,45,49,50]; subjects were not between 5 and 10 years of age [48]; the study contained insufficient information to estimate both the percentage of sealants that

were retained fully on permanent first molars according to year since placement and the standard errors (SEs) for these estimates[29,41,47,51]; mechanical preparation, such as enameloplasty or fissureotomy, was performed before sealant placement[44]; or lost or fractured sealant material was repaired or reapplied.[31,43]

Data abstraction. The same reviewer (S.K.G.) abstracted the studies meeting the inclusion criteria. The abstraction form included the following factors hypothesized to be associated with sealant retention:

- two- or four-handed delivery;
- years since placement (for example, one, two or three);
- tooth-surface cleaning method (toothbrush or handpiece);
- isolation by cotton rolls or a rubber dam;
- type of suction;
- use of acid-etching and/or a bonding agent;
- type of primary operator (dentist or nondentist);
- income level of the country (high or not high).

We included the last factor to explore the assumption that greater access to and utilization of dental services, as well as differences in dental systems in higher-income countries, would increase the detection of incipient caries in sealed teeth. We contacted the authors of the studies to verify information about the conduct of the study if adequate detail was not provided in published reports.

Quality assessment. Because we selected studies from published systematic reviews that had explicit quality criteria for inclusion, we did not reassess all aspects of individual study quality but did document two selected quality aspects: number of primary operators and whether operators received training before delivering sealants to study subjects. It is important to remember that, to our knowledge, there are no comparative studies of sealant outcomes for two- versus four-handed placement and, thus, some commonly used criteria to determine study quality such as random allocation would not necessarily apply.

Outcome measure and data adjustment. Our outcome measure was retention at each annual follow-up examination of sealants that were placed on occlusal surfaces of first permanent molars. We defined retention as the presence of a sealant that completely covered the pits and fissures of the tooth. We used the following formula to calculate the SE of the retention rate:

$$SE = \sqrt{\frac{\text{retention} \times (1 - \text{retention})}{n}}$$

where "n" represents the number of teeth initially sealed.

Because teeth in the same subject may be correlated with each other, conducting the analysis at the tooth level may have underestimated SEs. If a study provided only site-level retention data (for example, examiners reported multiple sites on individual teeth, such as buccolingual pits and mesiodistal occlusal pits), we used the reported retention rate but calculated the SE using the reported number of teeth instead of tooth sites. This adjustment resulted in higher SEs for studies using tooth sites as the unit of analysis.

Analysis. We calculated the summary-weighted retention rate separately for the studies that used two-and four-handed delivery for each of the three years after sealant placement. We weighted the studies by the reciprocal of their squared SE. To determine whether it was reasonable to pool the studies to attain a summary estimate of retention according to the presence or absence of a second operator for each of the three years, we examined whether the confidence intervals on the forest plots[53] overlapped for studies using two-handed delivery and for those using four-handed delivery.

We used weighted linear regression models to examine the effect of four-handed delivery alone (model 1) and in the presence of other hypothesized factors (model 2) on sealant retention for each year since placement. All explanatory factors were represented in the regression model as dichotomous independent variables, where "1" indicates the presence of the factor and "0" indicates the absence of the factor. We excluded hypothesized factors that were present in only one study, because the variable might have reflected other unique aspects of a single study. We considered explanatory variables to be significant if the *P* value for the coefficient was less than or equal to .05.

Because we had several possible combinations of explanatory variables and a small sample of studies, we constructed a tree diagram to determine for which combinations of variables we had studies. We also compared the explanatory power of model 1 (that is, how much total variation was

TABLE 1

Characteristics of included studies.

CHARACTERISTIC	STUDY AUTHOR, YEAR STUDY BEGAN, SITE					
	McCune and Colleagues[17] 1975 (Medellin, Columbia)	Mertz-Fairhurst and Colleagues[18] 1974 (Augusta, Ga.)	Charbeneau and Dennison[19] 1973 (Chelsea, Mich.)	Erdogan and Alaçam[20] 1982 (Ankara, Turkey)	Houpt and Shey[21] 1976 (Jersey City, N.J.)*	Hunter[22] (Year Not Reported (New Zealand)
Sealant Placement						
Operators trained	NR‡	Yes	NR	NR	NR	Yes
No. of primary operators	Two	Six	Two	One	Two	NR
Isolation	CR¶, low-volume suction	CR, triple air-water syringe or central suction	Teeth isolated with dry-angle absorbent wafer and saliva ejector	CR, suction and low-volume saliva ejector	CR, low-volume suction	Air-water syringe, low-volume suction
Children's Age (Years)**	6-8	6-8	6-8	8-10	6-10	5-8
Follow-up						
No. of children at first follow-up	173	155	126††	59	186	509
No. of teeth at first follow-up	275	239	202	118	186	509
No. of tooth sites at first follow-up	NA	NA	NA	NA	NA	NA
Study weight at first follow-up	3,574	4,679	1,226	668	2,494	2,215

* Fourth-year retention calculated with site data.
† Retention calculated with site data.
‡ NR: Not reported.
§ The authors used findings for second operator only because retention rates for first operator were much lower than those reported in other studies.
¶ CR: Cotton rolls.
# NA: Not applicable.
** Unless otherwise specified.
†† Estimate based on the reported number of tooth pairs per child.
‡‡ Estimate based on the number of tooth pairs per child at the second-year follow-up examination.
§§ The authors assumed one sealed tooth per child.

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explained by the model as measured by the adjusted R^2) with that of model 2. We also reran the regression without the weights to determine whether the results still held when we weighted all of the studies equally.

RESULTS

We included 11 studies in the final body of evidence (Table 1). Eight studies used four-handed delivery (representing 1,189 children and 1,944 teeth), while three used two-handed delivery (representing 885 children and 1,000 teeth). In nine studies, the operator performed prophylaxis using a handpiece (with pumice or prophylaxis paste) before placing the sealant. In two studies, the operator cleaned the tooth surfaces with a toothbrush and toothpaste. In six studies, dentists were the primary operators. Seven studies were conducted in high-income countries. Most studies began between 1973 and 1995. Four of the seven studies conducted in high-income countries began between 1973 and 1976. Of the remaining three studies, two likely began in 1977. The four studies published in countries with not-high incomes began between 1975 and 1995.

We found little or no variation for several factors. All studies used cotton rolls and/or high- or low-volume suction to isolate the surface; acid-

TABLE 1 (CONTINUED)

STUDY AUTHOR, YEAR STUDY BEGAN, SITE				
Poulsen and Colleagues[23] 1995 (Damascus, Syria)	**Gibson and Colleagues[24] (Year Not Reported) (Vancouver, British Columbia)**	**Rock and Bradnock[25] (Year Not Reported) (Birmingham, England)**	**Thylstrup and Poulsen[26] 1974 (Hillerod, Denmark)†**	**Vrbic[27] 1979 (Slovenia)**
Yes	NR	NR	NR	NR
Two	One	One§	One	Six
NA#	CR, suction	CR, air-water syringe and high-volume aspirator	CR, low- and high-volume suction	Low-volume suction
7	Second-graders	6-7	7	Kindergarten
121	246‡‡	65	190	244
121§§	393	130	305	373
NA	NA	NR	451	NA
1,696	4,217	686	1,562	5,068

etching before sealant placement; and autopolymerized resin-based sealants applied to the occlusal surfaces of permanent first molars in both arches.

Retention rates. Summary retention rates for one, two and three years after placement were 89.0 percent (range, 73.4 to 94.6 percent), 81.2 percent (range, 59.5 to 88.9 percent) and 73.9 percent (range, 60.1 to 87.5 percent), respectively. Retention appeared to vary significantly according to study for both two- and four-handed studies (Figure). Summary retention rates for studies using four-handed delivery—equaling 89.8 percent after one year, 83.0 percent after two years and 83.0 percent after three years—were higher than summary retention rates for studies using two-handed delivery (equaling 84.8 percent after one year, 72.4 percent after two years and 67.9 percent after three years) (data not shown). For the regression model that included four-handed delivery and the time since sealant placement as explanatory variables (model 1 in Table 2 (page 287); 28 observations), the adjusted R^2 was 42 percent and the coefficient for four-handed delivery approached significance ($P = .055$).

Explanatory variables. Stratifying studies according to four explanatory variables (four-handed delivery, surface cleaning via handpiece prophylaxis, dentist as the primary operator and country income) revealed several combinations of these variables for which there were no studies (Table 3, page 287). The included studies provided data for seven of the 16 possible combinations of explanatory variables. Because there were no studies in lower-income countries that used two-handed delivery and, thus, would add no direct information about the impact of four-handed delivery, we ran the regression model for all of the studies and for studies that were conducted in a high-income country. These seven studies conducted in high-income countries provided 18 observations of sealant retention over three years since placement; three studies used two-handed delivery and four studies used four-handed

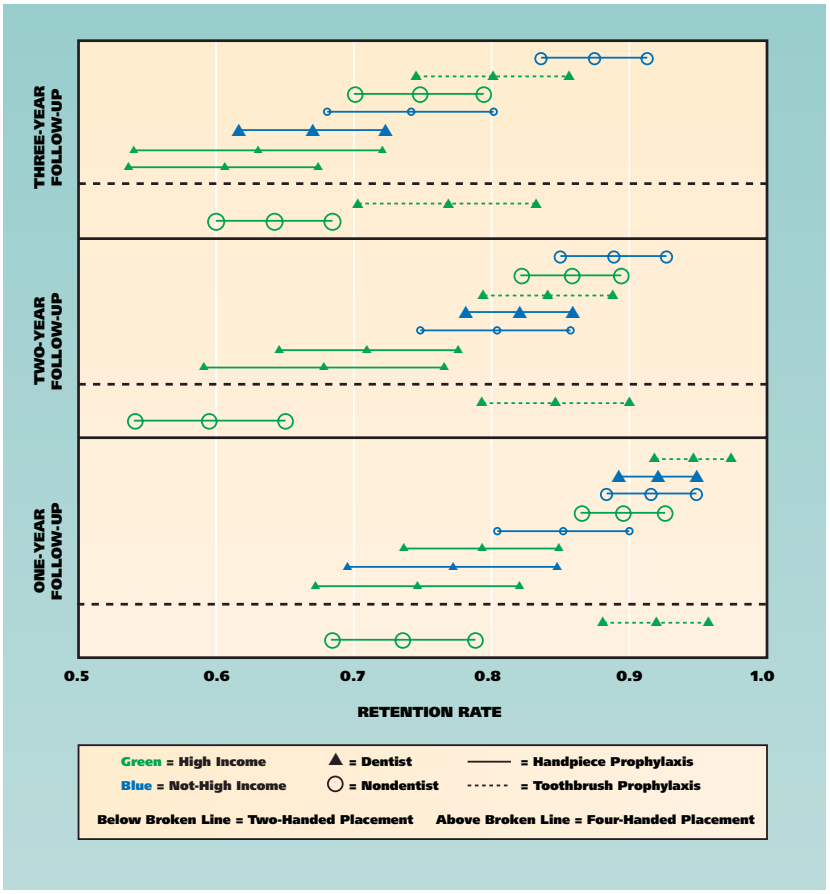

Figure. Forest plots showing sealant retention (95 percent confidence interval) in studies involving two- and four-handed delivery, for each year after placement.

delivery (Table 3). Five of these seven studies used a handpiece prophylaxis, all with prophylaxis paste.

When we included all of the studies, the adjusted R^2 was 0.69, and when we excluded the studies from countries that were not high-income (model 2 in Table 2), the adjusted R^2 was 0.81. Four-handed delivery increased sealant retention by a statistically significant 9 percentage points in model 2. Sealant retention decreased with the following factors: years since placement, study conducted in a high-income country, prophylaxis performed with a handpiece before sealant placement, and having a dentist as the primary operator. Rerunning the regression models without the weights did not change the direction or significance of the association between the factors and sealant retention.

DISCUSSION

The findings of this multivariate analysis indicate that, in comparison with two-handed delivery, four-handed delivery increased sealant retention by about 9 percentage points. It is important to note that we identified this positive association only when the variation in other selected factors (that is, time since sealant placement, provider type and surface cleaning method) was controlled across the studies. In contrast, the simple sealant retention rates in an individual study reflect multiple factors, and, thus, retention rates of more than 90 percent at one year for sealants placed in a study with two-handed delivery[21] or less than 80 percent in a study with four-handed delivery[20,25] can be expected.

The forest plots suggest that significant heterogeneity existed among studies even after we stratified them according to the presence of a second operator. This likely reflects the multiple factors that can affect retention and thus indicated that the multivariate analysis, which controlled for the effects of some of these factors, was the appropriate approach. The high R^2—ranging from 69 to 81 percent—for the final regression models indicates that these models included important variables affecting sealant retention in this group of studies.

The findings for some of the other variables in the model also were consistent with the initial hypotheses. First, sealant retention decreased over time. Three years after placement, about 15 percent of the sealants were completely or partially lost. In addition, sealants were less likely to be retained over time in high-income countries. As described above, greater use of dental services in these countries may have increased the probability of detecting caries in sealed teeth.

Unexpected findings. Certain findings of our analysis were unexpected. We found that handpiece prophylaxis was associated with a reduction in sealant retention of about 20 percentage points when compared with toothbrush prophylaxis. Of the nine studies in the regression analysis that reported the use of a handpiece prophylaxis, five used prophylaxis paste, three used pumice and one did not specify. It is possible that some prophylaxis pastes marketed in the 1970s and 1980s may have contained oils or other substances that

TABLE 2

Coefficients associated with sealant retention ($P < .05$) in fixed-effects weighted least-squares regression models.

VARIABLE	COEFFICIENT (STANDARD ERROR)			
	All Studies		High-Income Studies	
	Model 1	Model 2	Model 1	Model 2
Intercept*	0.83 (0.04)	1.01 (0.05)	0.84 (0.04)	0.98 (0.04)
Two Years Since Placement	–0.08 (0.03)	–0.07 (0.02)	–0.09 (-0.05)	–0.08 (0.03)
Three Years Since Placement	–0.14 (0.04)	–0.14 (0.03)	–0.16 (0.05)	–0.14 (0.03)
Four-Handed Delivery	NA†	0.09 (0.03)	0.04 (0.02)	0.10 (0.03)
High-Income Country	NA	–0.07 (0.03)	NA	NA
Handpiece Prophylaxis	NA	–0.16 (0.03)	NA	–0.20 (0.04)
Dentist Delivered Sealants	NA	–0.07 (0.03)	NA	–0.04 (0.04)
Adjusted R^2	0.42	0.69	0.41	0.81

* One-year retention for studies using two-handed delivery and a toothbrush prophylaxis. None of the included studies had all of the characteristics.
† NA: Not applicable.

TABLE 3

Studies stratified according to four factors hypothesized to be associated with sealant retention.

HIGH-INCOME COUNTRY							
Handpiece Prophylaxis				No Handpiece Prophylaxis			
Dentist operator		Nondentist operator		Dentist operator		Nondentist operator	
Four-Handed	Two-Handed	Four-Handed	Two-Handed	Four-Handed	Two-Handed	Four-Handed	Two-Handed
Charbeneau and Dennison[19]	NA*	Gibson and colleagues[24]	Hunter[22]	Mertz-Fairhurst and colleagues[18]	Houpt and Shey[21]	NA	NA
Rock and Bradnock[25]	NA	NA	Thylstrup and Poulsen[26]	NA	NA	NA	NA
NOT-HIGH-INCOME COUNTRY							
Handpiece Prophylaxis				No Handpiece Prophylaxis			
Dentist operator		Nondentist operator		Dentist operator		Nondentist operator	
Four-Handed	Two-Handed	Four-Handed	Two-Handed	Four-Handed	Two-Handed	Four-Handed	Two-Handed
Erdogan and Alaçam[20]	NA	McCune and colleagues[17]	NA	NA	NA	NA	NA
Vrbic[27]	NA	Poulsen and colleagues[23]	NA	NA	NA	NA	NA

* Not applicable.

interfered with bonding. In addition, prophylaxis paste, along with pumice, may have been difficult to remove completely from the enamel surface before etching. In 1998, a study comparing toothbrush prophylaxis (with no toothpaste) with handpiece prophylaxis (with prophylaxis paste) reported similar rates of sealant retention—all greater than 97 percent—after one year.[54]

Another unexpected finding was the association between having a dentist as the primary

operator and lower sealant retention rates. The prevalence of sealant placement in the United States through the early 1990s, however, was less than 20 percent. This suggests that many operators likely had limited experience with sealant materials and/or placement techniques. The studies in which dentists were the primary operators may have been less likely to provide training in sealant placement than the studies in which the primary operators were nondentists for two possible reasons.

First, the investigators may have assumed that training was unnecessary because dentists generally have exceptional familiarity with restorative materials and techniques; moreover, even as early as the 1970s and 1980s, they were increasingly using resin-based composite materials. During that time, however, placement of resin-based composite materials generally was limited to restorations on smooth surfaces (that is, Class III, IV and V) with prepared margins. In the absence of training, some of the dentist operators and auxiliaries may not have appreciated fully the meticulousness and attention to detail that are required for successful sealant placement on pit-and-fissure surfaces.

Second, the opportunity cost of training time, as measured by foregone wages, would be higher for dentists than for nondentists. We cannot test this hypothesis because only three of the studies in this analysis specifically described the use of training before sealant placement. In the one study in which the dentists were trained, the retention rate was high, ranging from 95 percent at one year to 80 percent at three years after a one-time placement of sealants.[18]

Study limitations. This study and its underlying methodology have limitations. First, our comparison of the subgroups was observational. In the absence of random assignment in studies that were designed to directly compare sealant placement outcomes according to two- and four-handed delivery, the association between retention and an explanatory variable might have been due to another omitted causal variable, commonly known as confounding. Confounding may have been mitigated, however, because we used a multivariate analysis that attempted to control for key factors that are relevant to sealant retention.

Second, we did not have studies for all of the possible combinations of study factors, and there were, at most, two studies for any combination of factors. However, although the findings cannot be considered to be definitive because of potential confounding and the limited number of studies, the R^2 value suggests that, for this group of studies, the factors included in the model had good predictive power.

Third, our findings may be subject to recall bias because we contacted authors to obtain additional information if adequate data were not included in their report. For example, only five of the 11 studies reported the main explanatory variable—number of operators—in the original report.

Finally, our search universe was limited to studies included in systematic reviews of sealant effectiveness, and only one reviewer screened these studies. For this exploratory analysis, we chose a less resource-intensive method to identify and screen potential studies. In the absence of published comparative 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 the current analysis, because the universe of studies was determined by authors of the original systematic reviews. Inclusion and exclusion criteria in this analysis were objective and were specified before we screened available studies. Findings may be useful in developing hypotheses and directing resources for further research.

CONCLUSIONS

For this group of 11 studies, four-handed delivery was associated with higher retention of resin-based sealants. Although these descriptive findings cannot be generalized to all settings, they justify allocating resources to studies that directly compare sealant placement outcomes using two- and four-handed delivery. ■

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