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Projecting the economic impact of silver diamine fluoride on caries treatment expenditures and outcomes in young U.S. children

Ben Johhnson, PhD[1]; Nicoleta Serban, PhD[1]; Paul M. Griffin, PhD[2]; Scott L. Tomar, DMD, MPH[3]

1 School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, GA, USA
2 Regenstrief Center for Healthcare Engineering, Purdue University, West Lafayette, IN, USA
3 Department of Community Dentistry and Behavioral Science, College of Dentistry, University of Florida, Gainesville, FL, USA

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Correspondence
Nicoleta Serban, PhD, School of Industrial and Systems Engineering, Georgia Institute of Technology, 755 Ferst Dr NW, Atlanta, GA 30332. Tel.: 404-385-7255; e-mail: nserban@isye.gatech.edu. Ben Johhnson and Nicoleta Serban are with the School of Industrial and Systems Engineering, Georgia Institute of Technology. Paul Griffin is with the Regenstrief Center for Healthcare Engineering, Purdue University. Scott L. Tomar is with the Department of Community Dentistry and Behavioral Science, College of Dentistry, University of Florida.

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Abstract

Objective: To quantify the economic impact of using silver diamine fluoride (SDF) to arrest the progression of dental caries in Medicaid-enrolled children (aged 1–5 years) relative to the standard restorative treatment from the Medicaid programs' perspective.
Methods: We used Monte Carlo simulation to estimate averted restorative visits and associated expenditures for varying SDF effectiveness and intervention penetration levels. We compared the current standard of care for treating caries to applying SDF. We estimated expenditures from the 2010–2012 Medicaid Analytic Extract files for seven US states and the incremental cost effectiveness ratio for SDF application on averted restorative visits.
Results: Across the seven states, averted restorative visits ranged from 2,049 (Vermont) to 60,542 (North Carolina), assuming an SDF penetration level of 50%. Averted per-restorative visit costs ranged from $100 to $350 per-visit. There were higher averted per-restorative visit costs in nonmetropolitan counties than metropolitan counties.
Conclusions: Providing SDF as a caries management strategy can reduce Medicaid program dental care expenditures by averting expensive caries treatment options. It could also prevent stressful restorative procedures. State Medicaid programs should consider reimbursing for SDF to arrest the progression of dental caries in young children.

Introduction

More than 36% of US children aged 2–8 years had experienced dental caries in their primary teeth in 2012 (1). Furthermore, significant disparities exist for untreated dental caries for this population (2). For example, non-Hispanic black children aged 2–8 years had more than double the prevalence of untreated decay (20.5%) compared to their non-Hispanic white counterparts (10.1%) (1). A contributing factor to oral health disparities is the limited access to dental care for children in low-income families even when they are eligible for public insurance (3,4).

Untreated tooth decay in young children can lead to pain, infections, and expensive emergency department (ED) visits and/or hospitalizations. In 2010, 0.65% of pediatric hospitalizations were due to nontraumatic dental conditions (5). In 2011, $68 million in Medicaid payments were made for preventable dental conditions in operating rooms or ambulatory surgery centers, with 98% of those cases related to dental caries and 71% for children aged 1–5 years (6). Arresting and preventing caries can thus not only reduce severe oral health outcomes, but also reduce the associated costs.

Silver diamine fluoride (SDF) has an antimicrobial effect on cariogenic biofilms and can slow down the demineralization of dentin (7–9). The silver in SDF attacks harmful bacteria while the fluoride promotes remineralization of the tooth (10). Although there is not yet consensus on the appropriate number or frequency of applications, recent systematic reviews show that the application of 38% SDF can arrest caries in the primary teeth of young children, potentially eliminating the need for any restorative treatments until they are replaced by their permanent teeth (11–13). Furthermore, SDF can reduce the use of general anesthesia or sedation in very young children, either by eliminating the need for the restorative care, or postponing the potentially stressful dental procedures until the child is old enough to receive more standard restorative care options. Pediatricians in 49 states have been applying topical fluoride varnish on the teeth of young children to prevent caries (14), and potentially could begin using SDF for Medicaid-enrolled children with active caries lesions, particularly, those who have limited access to dental care.

This study explored the cost-effectiveness from Medicaid programs' perspective of using SDF to arrest the progression of dental caries in Medicaid-enrolled children (aged 1–5 years) relative to standard restorative treatment. We evaluated two outcomes: caries-related visits and the associated expenditure. We also computed the incremental cost effectiveness ratio of SDF application visit costs on averted restorative visits. We based the age group selection on the high cost and the adverse outcomes due to anesthesia of restoring caries in very young children (15–17). Medicaid dental expenditures were estimated by assuming caries was treated with the status quo treatment of a restoration or treated with SDF. We also examined the impact of varying the percentage of children receiving SDF application and of the estimated SDF effectiveness on outcomes.

We compared the results across seven states selected to contrast states in southeast and northeast of the United States because of differences in their in oral health policies and in their Medicaid programs (18). While there are many states in these two regions, we considered only those states with good quality expenditure data acquired from the 2010–2012 Medicaid Analytic eXtract (MAX) claims files. The results of the analysis will help to determine if SDF would be a cost-effective caries management strategy for Medicaid-enrolled children.

Methods

Study population

The study population consisted of children, aged 1–5 years, enrolled in Medicaid, with a caries-related dental visit. We define caries-related visits consisting of all claims with a restorative dental care code, including amalgam restoration, fillings, crowns, pulpotomy or/and pulpal debridement, for one patient within the same day of care (see Appendix A). Although teeth may be extracted due to dental caries, we did not include extractions in our analyses for several reasons: (a) extraction of a tooth in this age group results in a qualitative difference in clinical outcomes when compared with SDF or any restorative approach. With tooth extraction, the patient may be without a functional tooth for a period of up to several years, which can affect speech and other oral functions; (b) extraction of some teeth such as lower deciduous molars may cause crowding in the permanent dentition and subsequent orthodontic problems unless space maintainers are placed, but often they are not. We did not attempt to model the costs of space maintenance or orthodontic treatment.

All cost parameters of the decision and simulation models described below are based on the study population, the Medicaid-enrolled child population aged 1–5 years.

Decision model

We developed a model that estimated caries-related visits when a restoration was placed (restorative visit) and per-restorative-visit expenditure from the Medicaid payer perspective (Figure 1). The model had a three-year analytic horizon.

We compared expenditure under the current standard of care for treating caries (placing restoration) to the alternative care of applying SDF. For the SDF care, we assumed that if SDF were effective, there would be no need for a

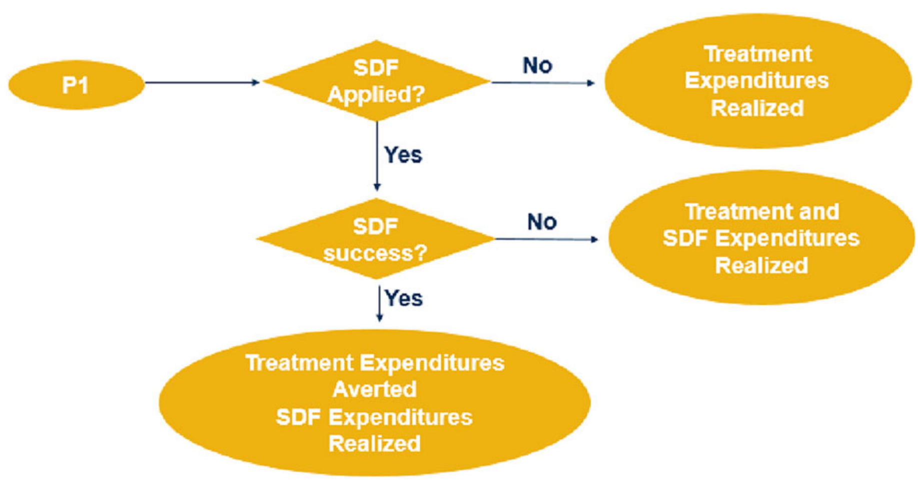

Figure 1 Diagram of the simulation model. [Color figure can be viewed at wileyonlinelibrary.com]

restorative visit and if ineffective, a restorative visit would be provided. Expenditure under the current standard of care included restoration and associated sedation costs together (C_{SC}). Realized expenditure under the SDF care accounted for the probability that SDF was applied, (Pr_{SDF}) the cost of SDF (C_{SDF}) and the effectiveness of SDF (PF_{SDF}). Realized expenditure under SDF was computed as:

$$Pr_{SDF}{}^{*}C_{SDF} + C_{SC}{}^{*}(1 - Pr_{SDF} + 1 - PF_{SDF}).$$

Averted treatment expenditure from using SDF instead of the standard of care was computed as:

$$C_{SC}{}^{*}(1 - PF_{SDF}).$$

Restorative visits and expenditure under the current standard of care and under SDF were estimated for all children in the study population and separately for children living in metropolitan and nonmetropolitan areas. We used Rural Urban Continuum Codes (RUCC) to classify counties as being metropolitan or nonmetropolitan (19). RUCC codes contain nine levels; counties with codes 1–3 were classified as metropolitan while counties with codes 4–9 were classified as nonmetropolitan. In addition, we estimated SDF costs for three different levels of SDF penetration (pr_{SDF})—25%, 50%, and 75%. If penetration were 0 then expenditure would equal C_{CS}.

We also estimated the incremental cost effectiveness ratio (ICER) by state, defined as the ratio of the cost of SDF application over the averted restorative visits.

Model parameters and assumptions

Expenditure for restorative dental care (C_{SC})

We used the 2010–2012 Medicaid Analytic Extract (MAX) files. These data were obtained from the Centers for Medicare and Medicaid Services (CMS). The selected seven states for this study included three southeastern states (Alabama, North Carolina, and South Carolina) and four northeastern states (Connecticut, Massachusetts, New Hampshire, and Vermont). This study was approved by CMS (Data Use Agreement #23621) and by the Institutional Review Board of Georgia Tech (protocol #H11287).

We estimated the per-visit expenditure including the expenditure for restorative dental procedures and for sedation. All claims with a restorative dental procedure code of one patient within the same day of care into one visit were defined as a restorative-related visit. We then aggregated the expenditure of all claims of one visit into a restorative-related visit expenditure.

Due to the short time interval over which costs were considered, we did not discount them.

In our analysis, we separated sedation into two groups: (a) nitrous oxide, and (b) intravenous sedation, oral sedation, and general anesthesia; more details are provided in in Web-Appendix A. Expenditure is provided by the Medicaid payment of a claim, reflecting the expenditure of the Medicaid payer for the reimbursed service. For visits that did not have any anesthesia or nitrous oxide claims, we estimated the expenditure for such claims by sampling from the sedation payment distributions for each state separately. These values were added to restoration expenditure assuming that nitrous oxide or a form of sedation was provided during 77.3% or restorative visits and general anesthesia was provided in 22.7% of visits. These probabilities were observed in the Medicaid claims for all states. We did not differentiate sedation payments by procedure code since all codes reflect caries treatment; moreover, the type of sedation depends on multiple factors that cannot be inferred from the claims data thus the sampling procedure is most appropriate.

The statistical distributions of the total expenditure and sedation-only expenditure per-visit were estimated separately for each state using kernel density estimation applied to the 10th through 90th percentiles of per-visit expenditure data. We removed 10% on each tail of the distribution of the per-visit expenditure observations to exclude potential outliers. Details are provided in the Web-Appendix A.

Effectiveness of SDF (PF_{SDF})

We used two distributions to estimate the effectiveness of SDF. The first distribution was based on the 95% confidence interval (CI) for SDF effectiveness reported in the literature (7,10) and heretofore referred to as the “base-case” distribution. Because this is based on the 95% CI, we assumed SDF effectiveness was uniform between 41.2% and 90.7% with 95% probability and between 0% and 100% with 5% probability (7). To test the sensitivity of lower SDF effectiveness, a second distribution was considered and referred to as the “lower” distribution. The lower distribution assumed SDF effectiveness was uniform between 20% and 60% with 95% probability and between 0% and 100% effective with 5% probability. The second distribution was used due to the somewhat limited data available on SDF effectiveness.

Expenditure for SDF application (C_{SDF})

There was no CDT code specific to SDF before 2016. The authors obtained information on the reimbursement amount and frequency restrictions from six states where Medicaid currently reimburses SDF. Two of these states reimbursed SDF at the same amount as for fluoride varnish and in the remaining four states, reimbursement varied from $12.97 to $35.00. We assumed that SDF is reimbursed at 200% of the Medicaid reimbursement amount for topical fluoride in each state. Estimated SDF expenditure in the seven states included in this study ranged from $30 to $52 per application. Details are provided in Web-Appendix A.

Data analysis: simulation model

We used Monte Carlo simulation to estimate averted restorative visits and averted Medicaid expenditure per-restorative-visit for each of the two SDF effectiveness levels and assuming SDF was used at varying penetration levels, 0%, 25%, 50%, and 75% of visits (Pr_{SDF}). The combination of four penetration levels and two effectiveness levels resulted in eight simulation settings used in the analysis. For each setting, we ran 100 simulations sampling from the distribution of each parameter to allow for variations in the model parameters. We provide both the mean and the lower and upper bounds of the resulting 95% confidence intervals.

Results

Expenditure for restorative dental care

Summary statistics for the expenditure distributions used are provided in Web-Appendix B Table B1. Detailed histograms of expenditures and the distribution density estimates for the total Medicaid payments and sedation expenditures by state are shown in Web-Appendix B Figures B1–B28. The difference between these two types of distributions is the expenditure associated with the per-restorative visits. Total payments for children who received nitrous oxide and children who received general anesthesia ranged between approximately $100 to $600 and $1,000 to $5,000 per visit, respectively. In Connecticut, the total payment range for children who received general anesthesia was even wider, from approximately $1,000 to $8,000 per visit.

Data analysis: simulation model

The estimated number of averted restorative visits and averted per-restorative visit expenditure (mean, upper and lower confidence bounds) along with the corresponding ICER are reported in Table 1. The number of SDF applications and the number of averted restorative visits increased with the percentage of children who received SDF and with the SDF effectiveness. Overall, there is little sensitivity to variations in the model parameters since the confidence intervals are tight. In setting 1 (penetration = 25% and lower effectiveness distribution), the populations in Vermont and North Carolina averted 633 and 18,706 of restorative visits from the application of SDF to 1,559 and 46,137 children, respectively. This corresponded to an ICER of $73.88 and $77.00 per averted restorative visit, respectively. The lower numbers of SDF applications observed in some of the states (Vermont) were due to the smaller populations of children. In setting 4 (penetration = 50% and main effectiveness distribution) those numbers changed to 2,049 and 60,542 averted restorative visits from the application of SDF to 3,121, and 92,320 children, and an ICER of $45.63 and $47.61 per averted restorative visit respectively.

Table 2 presents averted per-restorative visit expenditures by state for setting 4. Figure 1 in Web-Appendix C shows the outcome measures across all states stratified by metropolitan counties and nonmetropolitan counties for the same setting. Averted per-restorative visit costs ranged from $100 to $350 per visit (which were above the ICER values for all cases). Alabama and South Carolina had the lowest averted costs with values under $150 per restorative visit while the averted per-restorative visit costs in most other states ranged from $200 to $340 per restorative visit. North Carolina, New Hampshire, and Vermont had the highest averted expenditures per-visit with mean averted expenditures per-child of $302, $322, and $338 respectively. There were higher averted per-restorative visit costs in nonmetropolitan counties.

Averted per-restorative visit expenditures are shown in Web-Appendix C Table 2 with comparison across all settings. Web-Appendix C Figure 2 shows the difference in expenditures averted per person by state and setting. Higher expenditures averted per-child are found as SDF effectiveness rises and as more children received treatment from SDF. VT consistently had the highest averted expenditures per-child in all settings with AL at the bottom, followed by SC. For setting 1, mean averted per-restorative visit costs varied between $662 k for Vermont and $15M for North Carolina. In setting 4, the mean per-restorative visit costs for all states were over $2.5M and up to $53M in North Carolina. The mean per-restorative visit costs were between $119 and $338 in setting 4 and between $178 and $504 in setting 6, where total mean per-restorative visit costs ranged between $3.7M and $78M.

Mean total averted expenditures during the study period of 3 years ranged from $2.1M in Vermont to $48.5M in North Carolina. Alabama, Massachusetts, and South Carolina had mean total averted per-restorative visit expenditure of over $12M.

Discussion

For young children aged 1–5 years, using SDF has the potential to not only arrest caries but also avert restorative costs. For the youngest children, SDF also has the potential

Table 1 SDF Application Visits, and 95% Confidence Intervals for Averted Restorative Visits and Averted Cost for the Seven States at the Three SDF Penetration Levels for the Two Effectiveness Distributions

				Number of averted restorative visits			Averted cost ($1,000)			
State	Penetration level	Effectiveness distribution	Number of SDF application visits	Lower	Mean	Upper	Lower	Mean	Upper	ICER*
AL	25%	Low	27,508	11,117	11,137	11,156	3,910	3,921	3,932	74.09
		Base-case	27,515	18,011	18,034	18,058	6,320	6,334	6,347	45.77
	50%	Low	55,068	22,292	22,318	22,344	7,826	7,841	7,856	74.02
		Base-case	55,069	36,091	36,121	36,151	12,681	12,698	12,716	45.73
	75%	Low	82,576	33,431	33,462	33,492	11,738	11,756	11,774	74.03
		Base-case	82,587	54,124	54,156	54,188	19,006	19,024	19,043	45.75
CT	25%	Low	9,883	3,999	4,011	4,023	2,952	2,972	2,991	98.56
		Base-case	9,898	6,474	6,489	6,503	4,815	4,839	4,863	61.01
	50%	Low	19,803	7,998	8,014	8,030	5,924	5,949	5,973	98.84
		Base-case	19,782	12,948	12,967	12,987	9,614	9,644	9,673	61.02
	75%	Low	29,689	12,020	12,038	12,057	8,922	8,950	8,977	98.65
		Base-case	29,687	19,459	19,479	19,498	14,491	14,520	14,548	60.96
MA	25%	Low	16,126	6,515	6,530	6,545	3,807	3,822	3,837	64.21
		Base-case	16,118	10,552	10,569	10,587	6,164	6,183	6,201	39.64
	50%	Low	32,243	13,032	13,053	13,074	7,619	7,640	7,661	64.22
		Base-case	32,257	21,131	21,155	21,179	12,373	12,398	12,422	39.64
	75%	Low	48,371	19,566	19,589	19,612	11,452	11,475	11,498	64.20
		Base-case	48,381	31,707	31,733	31,758	18,562	18,588	18,614	39.64
NC	25%	Low	46,137	18,680	18,706	18,732	14,986	15,021	15,055	77.00
		Base-case	46,111	30,200	30,231	30,262	24,200	24,243	24,286	47.62
	50%	Low	92,232	37,321	37,355	37,389	29,888	29,936	29,984	77.08
		Base-case	92,320	60,502	60,542	60,581	48,449	48,504	48,560	47.61
	75%	Low	138,434	56,005	56,044	56,082	44,891	44,944	44,997	77.12
		Base-case	138,406	90,743	90,785	90,827	72,701	72,761	72,821	47.60
NH	25%	Low	2,790	1,125	1,131	1,137	916	926	935	88.81
		Base-case	2,793	1,825	1,833	1,841	1,501	1,512	1,522	54.85
	50%	Low	5,587	2,259	2,268	2,276	1,847	1,858	1,870	71.96
		Base-case	5,594	3,661	3,671	3,681	2,996	3,010	3,024	54.86
	75%	Low	8,374	3,381	3,391	3,401	2,777	2,790	2,804	88.90
		Base-case	8,386	5,496	5,506	5,516	4,497	4,512	4,527	54.83
SC	25%	Low	24,529	9,915	9,933	9,952	4,304	4,317	4,331	78.47
		Base-case	24,521	16,047	16,070	16,092	6,962	6,978	6,994	48.49
	50%	Low	49,013	19,839	19,863	19,888	8,605	8,622	8,639	78.42
		Base-case	49,053	32,137	32,166	32,194	13,948	13,969	13,989	48.46
	75%	Low	73,566	29,765	29,792	29,820	12,904	12,924	12,945	78.48
		Base-case	73,566	48,210	48,241	48,272	20,912	20,934	20,957	48.46
VT	25%	Low	1,559	628	633	638	652	662	672	73.88
		Base-case	1,558	1,016	1,022	1,028	1,061	1,073	1,086	45.73
	50%	Low	3,118	1,259	1,265	1,272	1,311	1,324	1,337	73.94
		Base-case	3,121	2,042	2,049	2,057	2,130	2,146	2,161	45.69
	75%	Low	4,685	1,895	1,902	1,909	1,965	1,980	1,995	73.89
		Base-case	4,684	3,063	3,071	3,078	3,194	3,211	3,227	45.75

* ICER—Incremental cost effectiveness ratio measured as dollars spent on SDF application visits per averted restorative visit.

to reduce the exposure to the use of general anesthesia or various forms of sedation. For these children, SDF can either prevent more invasive restorative treatments entirely if the caries remain arrested until permanent teeth replace the affected primary teeth, or it can delay the treatment until the child is sufficiently old enough that they do not need to be treated under general anesthesia or conscious sedation. Note that the potential health risks of putting children under general anesthesia for caries treatment can be quite serious, including death (15,17). For slightly older children, SDF has the potential to prevent restorative procedures on the primary teeth until they are replaced by healthy permanent teeth.

Providing SDF as a caries management strategy for young children has the potential to reduce Medicaid program dental care expenditures by averting more expensive

Table 2 Comparison of Number of Caries Restoration Visits and Expenditures ($) from Baseline (Status Quo) and 50% SDF Penetration to Setting 4

State	Baseline		50% SDF penetration*		Resulting expenditures reduction†
	Caries visits	Total expenditures ($)	Caries visits	Total expenditures ($)	Expenditures ($)
AL	110,120	38,694,799	73,999	27,649,827	12,698,442
CT	39,578	29,464,430	26,611	20,611,996	9,643,631
MA	64,491	37,771,638	43,336	27,050,586	12,397,653
NC	184,534	147,876,973	123,992	102,255,192	48,504,298
NH	11,168	9,163,117	7,497	6,354,779	3,009,890
SC	98,102	42,583,782	65,936	30,174,043	13,968,640
VT	6,235	6,506,346	4,186	4,454,594	2,145,555

* Under main expenditure distribution.

† Equal to the baseline expenditures minus expenditures after 50% SDF penetration.

caries treatment options. Overall, for all levels of SDF penetration and SDF effectiveness, the benefit of providing SDF outweighed the expenditures associated with its application. Assuming an SDF effectiveness as cited in the literature (7) and that 50% of children with caries received SDF, the seven states in our analysis would have an ICER of $39.65 to $61.02 per averted restorative visit that would yield a total expenditures reduction of $119 to $338 in averted per-restorative visit costs per treated child. Under our assumptions, Medicaid would have to increase SDF reimbursements by $89 to $308 (depending on the state and penetration level) and still reduce expenditures, representing an increase of 300% to 1,000% of the assumed rate.

In young children, the utilization of general anesthesia for restorative dental care was costly; 22% of claims were classified to have significantly high costs associated with general anesthesia. The potential to avert even a few of these cases could result in reduced Medicaid expenditure, varying greatly among states. Differences in expenditure outcomes between states were in part due to the result of different Medicaid reimbursement levels and the proportion of different procedures given in each state.

Our study only focuses on the Medicaid-enrolled children who have accessed and utilized dental care. However, because of potentially limited access to dental care for this population, there may children who are in need for restorative care but not realized utilization and expenditure. Because of this, the potential averted expenditure due to implementation of SDF will be higher than estimated in this paper. In addition, our exclusion of dental extractions may have led to either underestimation or overestimation of averted costs. While it sometimes may be less expensive to extract a primary tooth than to restore it in the short term, sequelae such as impaired speech development or crowding in the permanent dentition may lead to relatively expensive interventions or further impacts on oral health or quality of life.

There were several limitations in our analysis. First, we assumed a broad range in the effectiveness of SDF. While there have been systematic reviews on the effectiveness of SDF in arresting caries, previous studies have been critical of the methods used in these systematic reviews (7,10), pointing out the lack sufficient control groups or lack of details on the specific application timing and dosage of SDF necessary to obtain the quoted level of effectiveness (11). A second limitation is the lack of more specific information regarding optimal treatment guidelines for using SDF. A third limitation is that we assumed that all caries treatment for children aged 1–5 years are accompanied by sedation; when not included in the claims, we sampled randomly from the actual distribution of sedation types across the observed caries treatment with sedation. Another limitation is assumption of reimbursement at 200% of topical fluoride. We assumed a high reimbursement level for SDF to demonstrate its effectiveness to avert costs even at higher levels. We also believe SDF application requires more effort than topical fluoride. Finally, SDF use does lead to irreversible black staining on the application site. We did not quantify the impact on the child's quality of life or parental acceptance from this staining in our analysis.

In the simulation, we assumed that children who received SDF were randomly selected. It may be possible to obtain better results by targeting areas known to have more severe oral health outcomes. For example, while the majority of the expenditures averted comes from metropolitan counties, we found nonmetropolitan counties had higher expenditures averted per-visit with caries than their metropolitan counterparts. Targeting children in more rural areas who may have less access to preventive care and potentially higher treatment expenditures could provide even higher averted expenditures than shown here.

Last, the cost benefit analysis in this study does not account for differences in labor costs between SDF and restorative procedures, which may additionally bias the findings downwards since the amount of time spent treating patients using SDF is much smaller than restorative procedures. Moreover, the decrease in visit time and the opportunity cost for parents to bring their children for dental visits will also reduce the overall cost while improving the benefits of SDF relative to caries treatment.

Conclusions

Overall, SDF can prove a less expensive caries management option for young pediatric populations experiencing dental caries. If used in Medicaid-enrolled populations, accounting for the uncertainty across program parameters, SDF can reduce expenditures for state Medicaid programs by $36 to $500 for each averted restorative visit (depending on state and SDF penetration level) with an ICER of $39.64 to $98.84 per averted restorative visit. In addition to lower expenditures, using SDF could also prevent stressful restorative dental procedures for young children and reduce the health risks associated with the use of general anesthesia or sedation.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Web Appendix A: Additional Methods
Web Appendix B: Additional Results on the Distribution of Expenditure
Web Appendix C: Additional Results on Averted Expenditure