Comparing Dental Treatment between Children Receiving and not Receiving Silver Diamine Fluoride

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Objectives: *The objective was to compare dental visits, procedures, and expenditures in children with newly diagnosed caries.* ***Study design:*** *A retrospective chart review was conducted in a two dentist private practice in North Carolina. Demographic data, health status, and dental treatment data was collected. Analysis relied upon nearest neighbor matching to estimate the average treatment effects of silver diamine fluoride (SDF) by comparing children who received SDF to children who did not receive SDF (n=104 matches).* ***Results:*** *After matching on age, gender, race, insurance status, dental cooperation, and dmft, the SDF group had significantly more dental visits (average treatment effect on treated (ATET)=1.08), fewer restorations (ATET=2.37), and fewer restorative and overall treatment expenditures (ATET=$402 and $292, respectively) than the non-SDF group. The SDF group more frequently received treatment under general anesthesia (26% vs 7%), so this group was excluded in secondary analysis. Among children who did not receive general anesthesia, the SDF group had significantly more dental visits (ATET=.66), fewer restorations (ATET=2.74), and fewer restorative and overall treatment expenditures (ATET=$566 and $515, respectively) than the non-SDF group.* ***Conclusion:*** *SDF can offer cost savings when used as an adjunct to, rather than a complete replacement for, restorative treatment in young children.*

Keywords: Silver Diamine Fluoride, dental caries, dental economics.

INTRODUCTION

Early childhood caries (ECC) is a chronic disease that affects a significant proportion of young children—with prevalence estimates between 25-40% in the United States.[1, 2] Because of its high prevalence, its impact on young children's quality of life and potential for increasing their risk of caries in the permanent dentition, ECC is arguably one of the most serious and costly health conditions among young children.[3]

Traditionally, dentists have provided invasive restorative treatment to eliminate caries lesions and restore form, function and esthetics. In many pre-school age children, this is often accomplished with advanced behavior management techniques, including procedural sedation and general anesthesia (GA).[4] Recently, however, this restorative paradigm has been challenged by the increased utilization of non-surgical caries management techniques such as silver diamine fluoride (SDF).[5] The use of SDF provides an alternative treatment option for patients with high caries risk, patients with medical or behavior management challenges, or patients who face difficulty accessing care.[6] For some patients, SDF is used as an attempt to delay or defer the need for more extensive restorative procedures or advanced pharmacologic management.[7]

For public health programs and third party payers, the use of SDF serves as a potentially budget-friendly solution to control dental caries and reduce caries treatment related expenditures.[8] A 2019 simulation estimated that SDF utilization in Medicaid-enrolled children aged 1-5 years could avert thousands of caries treatment related visits, saving between $100 and $350 per visit.[8] In North Carolina, for example, this totals more than $48 million in dental expenditures.[8] These findings contrast with retrospective claims analyses in Oregon that found SDF or silver nitrate plus fluoride

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varnish (SN/FV) did not change per-patient dental costs compared to children treated traditionally.[5, 9] Even though costs were lower and diagnostic and preventive utilization was higher following SN/FV application, after more than two years of follow-up, overall costs per patient were similar to traditionally treated children.[9] Despite its potential to avert expensive caries-related procedures in simulations, there appears to be discordance with how SDF performs at the individual, practice, and population level.

The purpose of this study was to describe the actual use of SDF in day-to-day private practice operations and to evaluate its relationship to subsequent treatment and expenditures. Specifically, the study aimed to compare dental visits, procedures, and expenditures between children with newly diagnosed ECC who received and did not receive SDF.

MATERIALS AND METHOD

This study was reviewed and approved by the Institutional Review Board at the University of North Carolina at Chapel Hill Adams School of Dentistry according to 45 CFR 46.110. This retrospective cohort study used administrative claims and patient records from a single office, two provider private practice in Raleigh, North Carolina.

SDF Treatment Protocol

Following American Academy of Pediatric Dentistry (AAPD) guidelines,[6] case selection for SDF in this practice included:

- to treat ECC as a definitive measure applied 2 weeks after initial application, and every 6 months thereafter, absent sign/symptoms of caries progression or pathology,
- to treat ECC as an interim measure in pre-cooperative children until traditional treatment can be accomplished without sedation or general anesthesia,
- to arrest any carious lesion until traditional treatment can be completed, and
- to arrest caries in patients with special health care needs who cannot tolerate traditional treatment.

While this study was not intended to evaluate a specific SDF clinical application protocol, it was included here for reference. Following the initial examination, caries risk assessment, anticipatory guidance, and radiographs if behavior permitted, the risks, benefits, and treatment alternatives were discussed with the family. Informed consent including photographs of SDF treated lesions was obtained if this was the selected treatment approach. If interproximal lesions were identified, elastomeric separators were placed, and the patient was rescheduled for 1 week later. At the application visit, SDF was dispensed in a disposable dappen dish: 1 drop for children less than 40 pounds, and 2 drops for children over 40 pounds. The tooth receiving SDF was isolated using cotton rolls and the lesion cleansed using a toothbrush and air/water syringe. The lesion was dried, and the dentist applied SDF using a microbrush for 1-3 minutes as behavior allowed. A curing light was applied to ensure complete coverage of lesions. Follow-up visits were scheduled 4-8 weeks following initial application.

At the time of this study, there were no specific protocols available to determine both the necessity and timing when an SDF treated tooth should subsequently be restored. In this practice, these decisions were driven by either progressive disease or caregiver preference.

Inclusion Criteria and Cohort Selection

In this study, inclusion was limited to children under the age of 6 years-old for two reasons. First, this is the age criteria listed in the definition of ECC recently published by the International Association of Pediatric Dentistry Bangkok declaration.[10, 11] Second, when North Carolina Medicaid initiated reimbursement for SDF treatment, reimbursement was limited to children ages 1 to 5 years-old.

Two cohorts of children were selected based on newly diagnosed ECC and subsequent treatment between January 1, 2017 and December 31, 2017. The practice began using SDF in July 2015, and by deferring data collection until 2017, the office had time to refine its SDF protocol and increase provider experience. The SDF group included 104 children and the non-SDF group included 250 children. Pragmatically, treatment groups were decided by a combination of provider and caregiver preference. Both groups were followed in progress notes and billing claims for one year.

Variable Definitions

Demographic information was collected from the patient record including age at the time of initial treatment, gender, race/ethnicity, special health care needs, and insurance status. For analysis, age was treated as a continuous variable, while the others were treated as categorical. Insurance status was recorded according to third-party provider, and then collapsed into 3 categories: public dental insurance, private dental insurance, and no dental insurance. The Frankl behavioral score[4] listed in the patient record for the initial treatment visit was recorded to measure a child's level of cooperation.

Both a decayed, missing, filled surfaces (dmfs) and decayed, missing, filled teeth (dmft) index was recorded for each subject based on validated WHO criteria.[12] Treatment information was recorded for each visit using Current Dental Terminology **(CDT)** codes. For reporting, codes were summarized by the CDT categories of diagnostic, preventive, restorative, endodontic, surgical, and adjunctive services. Subjects treated with SDF were identified using the CDT code D1354. Dental sealants on primary molars are used frequently in this practice; therefore, this specific procedure was recorded separately from the overall preventive category. For the restorative, endodontic, and surgical procedures, the number of teeth treated within each category, as well as the number of visits a patient made was recorded. Restorative procedures included one-, two-, and three-surface restorations as well as full coverage crowns. Endodontic procedures were limited to pulpotomies, and surgical procedures were limited to extractions. The adjunctive services included the use of nitrous oxide (D9230) or the use of general anesthesia (D9420—Hospital Call). For analysis, the use of nitrous oxide or general anesthesia were recorded as binary for each child. For expenditure analyses, the office fee schedule (in $USD) for each CDT code was recorded from administrative claims. Medical and opportunity costs associated with dental treatment were beyond the scope of the research question and not considered for the expenditure summary.

Statistical analysis

All analyses were conducted using STATA (version 15.1, STATA, Inc.; College Station, TX, USA). The outcomes of interest included the number of visits, the number of procedures, and the expenditures stratified by CDT category. Descriptive statistics included means and standard deviations for continuous variables and counts and frequencies for categorical variables. Bivariate methods compared the demographic data, number of visits, procedure utilization, and expenditures according to CDT category between the SDF and non-SDF group. Student's t-tests were used for continuous variables, and Pearson chi-square tests were used for categorical variables. The level of significance was set at alpha=0.05.

To address the retrospective and observational nature of the study, a matching procedure was employed to account for the non-random assignment to study groups. Figure 1, outlines the process used to arrive at the analytical dataset. The goal of matching the two groups was to standardize them to determine the effect of SDF on the outcomes of interest. Nearest neighbor matching, rather than propensity score matching or regression adjustment, does not assume any parametric models and thus gives robust results.[13] Nearest neighbor matching calculates potential outcomes based on a weighted average of specified covariates for each matched subject. The output, or average treatment effect, averages the difference between the actual and potential outcome for each subject to estimate the magnitude of effect of the clinical intervention, in this case SDF. The average treatment effect carries a similar interpretation as the mean difference calculated during paired student's t-tests while accounting for desired covariates.

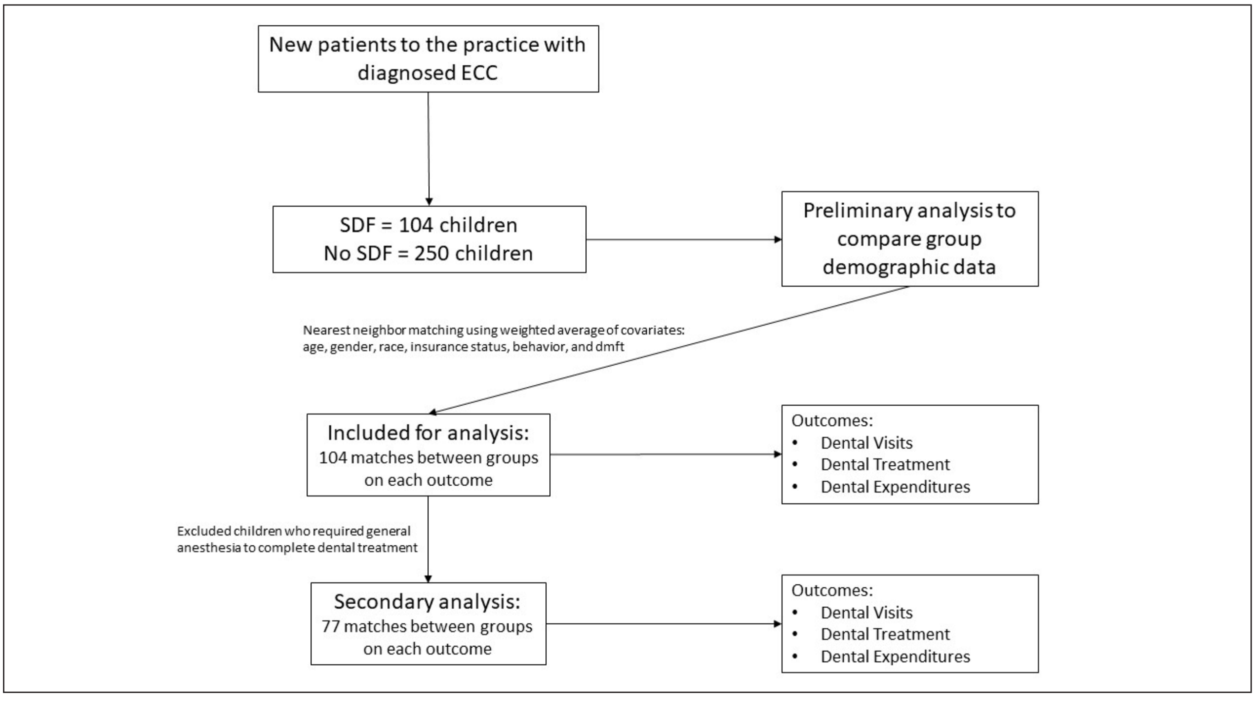
This analysis was carried out in STATA using the "teffects nnm" function specifying one match per subject, a bias adjustment for continuous covariates, and a Euclidean distance to find the nearest neighbor. The output specified average treatment effect on the treated since individuals self-selected into the SDF or non-SDF group based on their child's needs or family preferences. Balance for the included covariates was verified for each outcome such that the absolute value of the standardized difference in means was <0.25 and the variance ratio was between 0.5 and 2 for each covariate following the match.[13] Overestimation of dmfs was explored by including dmfs alone or in combination with dmft as a match covariate.[14] The resulting match was imbalanced. However, including dmft resulted in a balanced match, and therefore was included in the final matching procedure. One hundred four matches between the SDF and non-SDF groups based on the covariates of age, gender, race, insurance status, behavior score, and dmft were included in the final analysis for each outcome. Not all patients reported gender or race, resulting in missing data for these variables. For analysis, the missing data was treated as its own category.[15]

The analytical sample was likely biased towards children receiving GA, particularly within the SDF group. Therefore, as a secondary analysis, the match was repeated on a sample that excluded all subjects who received general anesthesia (excluded SDF group=27, non-SDF group=18). Again, balance was confirmed as described above. Seventy-seven matches between the two groups based on age, race, gender, insurance status, behavior score, and dmft were included in this sub-analysis for each outcome.

RESULTS

Differences were noted in demographic composition of each group in preliminary analysis. The SDF group was younger (p<0.001) and less cooperative (p=.006) than the non-SDF group (Table 1). The SDF group was also significantly more likely to require GA to complete treatment compared to the non-SDF group (26% vs. 7%, p<.001). To address these differences prior to analysis, subjects were matched on age, gender, race, insurance status, behavior, and dmft using nearest neighbor estimation. Special health care needs was not included due to its low overall frequency within

Figure 1. Flowchart to arrive at analytical dataset



the sample (3%). Following the match, the SDF group was younger, but the match was balanced since the estimate accounted for a weighted average of the covariates.

The matched results between 104 children each in the SDF and non-SDF group revealed significant differences with respect to the number of visits (Table 2). The SDF group had significantly more preventive visits (.54) and total visits (1.08), but fewer restorative visits (.66). For procedures, the children in the SDF group averaged 2.37 fewer restorations than the non-SDF group, and this difference was statistically significant (p<.001). The number of endodontic and surgical procedures was not different between groups. For expenditures, there were three statistically significant differences according to expenditure category. The SDF group had significantly fewer diagnostic ($33.04), restorative ($402.45), and total dental expenditures ($292.15) than the non-SDF group in the one year follow-up period.

When excluding subjects who required general anesthesia, 77 subjects matched between groups. Similar differences persisted, though the magnitudes decreased for visits and intensified for expenditures (Table 3). The SDF group had more preventive (.45) and total visits (.66), but fewer restorative visits (.9) than the non-SDF group. For procedures, the children in the SDF group averaged 2.74 fewer restorations than the non-SDF group, and this difference was statistically significant (p<.001). The number of endodontic and surgical procedures was not different between groups. The SDF group had significantly fewer diagnostic ($41.62), restorative ($566.06), adjunctive ($53.16), and total dental expenditures ($513.30) than the non-SDF group in the one-year follow-up period.

DISCUSSION

In this retrospective cohort study, children in the SDF group were younger, were less cooperative in the dental office, and were more likely to need general anesthesia to complete dental treatment than the non-SDF group. After matching according to age, race, gender, insurance status, behavior, and disease burden, as well as excluding children who needed general anesthesia, children treated with SDF had significantly more preventive and total dental visits, fewer restorations, and fewer restorative and total dental expenditures, which is consistent with previous literature.[9]

The demographic differences between the SDF and non-SDF groups in this study are consistent with the case selection criteria in clinical guidelines for SDF treatment. Very young children or those who present with uncooperative behavior to a dental office are candidates for SDF treatment,[6, 7] although it can be difficult to discern whether it is age, behavior, or both driving the decision to use SDF. The present results lean towards behavior as a leading factor. Although the variable of behavior was balanced as a variable, the SDF group had more outliers in the definitely uncooperative category. This same category of child is also the most frequent user of general anesthesia.[16,17] Especially in very young children, treating carious lesions with SDF conveys multiple advantages over traditional restorative care including ease of use, low material cost, and the non-invasive nature of the procedure.[6] In that respect, the present results confer the overlapping recommendations of current clinical guidelines for case selection criteria for SDF and general anesthesia.

Medical and opportunity costs were not evaluated in this study due to limitations accessing the medical costs for included subjects.

Table 1. Demographic characteristics of children treated with silver diamine fluoride (SDF) versus children not treated with SDF (non-SDF). Due to differences in demographic characteristics, the groups were matched on these variables as covariates for each outcome, which was verified according to two criteria: the absolute value of the standardized difference in mean <.25 and the variance ratio was between .5 and 2 for each covariate.[1]

	SDF Group	Non-SDF Group	p-value
Total Participants (N)	104	250	
Age (mean, SD)	2.6 (0.97)	3.1 (0.78)	<0.001[a]
Gender (n, %[b])			0.02[c]
Female	50 (48%)	132 (53%)	
Male	39 (38%)	103 (41%)	
Missing	15 (14%)	14 (6%)	
Race/Ethnicity (n, %[b])			0.3[c]
White	17 (16%)	61 (24%)	
Asian	2 (2%)	3 (1%)	
Black or African American	22 (21%)	44 (18%)	
Hispanic or Latino	19 (18%)	51(20%)	
Unknown	44 (42%)	91 (36%)	
Insurance Status (n, %[b])			0.1[c]
Private Insurance	24 (23%)	88 (35%)	
Public Insurance	76 (73%)	153 (61%)	
No Insurance	4 (4%)	7 (3%)	
Unknown		2 (1%)	
Behavior Score (n, %[b])			0.006[c]
1	6 (6%)	9 (4%)	
2	19 (18%)	27 (11%)	
3	44 (42%)	76 (30%)	
4	33 (32%)	134 (54%)	
Unknown	2 (2%)	4 (2%)	
dmft (mean, SD)	6.6 (4.5)	4.2 (3.6)	<.001[a]
dmfs (mean, SD)	24.4 (23.8)	16.8 (17.1)	<.001[a]

[a] Independent t-test

[b] Column percentage

[c] Pearson Chi-Square

dmfs: decayed, missing, filled surfaces

dmft: decayed, missing, filled teeth

Differences in total due to rounding

[1]Stuart EA. Matching methods for causal inference: A review and a look forward. Stat Sci 2010;25(1):1-21.

Table 2: Matched comparisons for number of visits, number of dental procedures, and expenditures ($USD) between the silver diamine fluoride (SDF) and non-SDF group. Subjects were matched on age, gender, race, insurance status, behavior, and dmft for each outcome using nearest neighbor estimation. Negative average treatment effects on the treated (ATET) indicate fewer visits, procedures, or expenditures in the SDF group.

	Raw				Matched (104 matches)		
	SDF Group		Non-SDF Group		ATET	95% CI	p-value
Visit Types	$\bar{x}$	s.d.	$\bar{x}$	s.d.			
Preventive visits	1.11	.64	.72	.82	.54	[.31, .76]	<.001*
Sealant visits	.10	.30	.23	.45	-.09	[-.19, .02]	.1
SDF visits	1.25	.44	[redacted]				
Restorative visits	.84	.71	1.38	.66	-.66	[-.87, -.45]	<.001*
Total visits	3.31	.13	2.34	.08	1.08	[.66, 1.50]	<.001*
Procedure types	$\bar{x}$	s.d.	$\bar{x}$	s.d.			
Sealants	.31	1.05	.85	1.93	-.21	[-.52, .10]	.2
SDF treated teeth	4.32	2.66	[redacted]				
Restorations	3.17	4.84	3.54	3.51	-2.37	[-3.07, -1.67]	<.001*
Pulpotomies	.44	1.21	.25	.89	-.003	[-.39, .38]	.99
Extractions	1.00	1.65	.68	1.28	.02	[-.45, .48]	.9
Expenditure Category	$\bar{x}$	s.d.	$\bar{x}$	s.d.			
Diagnostics	90.18	63.29	133.14	70.51	-33.04	[-49.45, -16.62]	<.001*
Preventive	84.44	100.61	94.73	99.28	8.16	[-18.44, 34.76]	.5
Sealants	10.99	41.55	30.36	76.81	-10.01	[-23.30, 3.29]	.1
SDF	139.15	186.35	[redacted]				
Restorative	564.66	890.48	626.61	732.03	-402.45	[-576.90, -228.00]	<.001*
Endodontics	38.91	133.22	23.46	83.94	-.33	[-41.36, 40.70]	.99
Surgical	80.56	146.78	57.86	172.84	16.28	[-18.73, 51.28]	.4
Adjunctive	70.46	114.02	77.04	58.77	-18.86	[-40.53, 2.80]	.1
Total	1082.74	1193.55	1042.05	863.23	-292.15	[-499.54, -84.77]	.01*

*p<.05

Differences in total due to rounding

Despite this limitation, the findings from the present study can be compared and evaluated in context of existing findings. Primarily, children receiving SDF averaged 1 additional office visit. A recent study estimated opportunity costs for a dental GA visit to be around $600 and for a dental sedation office visit to be around $460 per visit.[18] The opportunity cost for the additional office visit ($460) is greater than the reduced expenditures of the SDF group ($292). However, among non-GA subjects, the opportunity costs for the additional visit ($460) is less than the reduced expenditures of the SDF group ($515), which could be interpreted as a cost benefit. In addition to the potential medical cost savings by avoiding GA (>$2,000-10,000)[18], SDF has also been suggested to reduce the incidence of dental emergencies for children on GA waiting lists by 80%,[19] another avenue for cost savings. SDF appears to offer some reduction in overall costs to families. However, caution is emphasized as the SDF group also used GA more frequently (26% versus 7%). The true financial benefits of SDF may be for the children with mild and moderate levels of disease who do not require GA to complete dental treatment where more aggressive treatments are recommended.[20]

The present findings can also contrast to a recently published simulation, which suggested that SDF utilization could save many millions of dollars for state Medicaid programs.[8] A fundamental limitation of the simulation were two assumptions that all caries-related care was provided under sedation or general anesthesia and that SDF was used as definitive treatment. Literature suggests that fewer than 5% of children ages 1-5 require general anesthesia to safely complete dental treatment,[16,17,21] and the present findings suggest the frequency in this practice is between 7 and 26%. The discordance between the model assumptions and the present findings could suggest that stronger clinical guidelines are needed to determine the necessity and timing of restoring teeth following SDF treatment. A recent analysis of Medicaid claims showed no change in GA utilization 3-years following SDF implementation.[22] If the potential cost savings to public programs and third-party payers are to be realized, more descript guidelines are needed for the interim versus definitive use of SDF, especially in relationship to general anesthesia utilization.

This study should be considered in light of its findings. First, and primarily, selection bias limited the interpretation of the findings. Subjects were only able to be selected based on the treatment they had received without a valid and reliable way to assess the activity or severity of disease. Moreover, due to the retrospective design, "examiners" were unable to be calibrated to create accurate dmft

Table 3: Matched comparisons for number of visits, number of dental procedures, and expenditures ($USD) between the silver diamine fluoride (SDF) and non-SDF group, excluding subjects who required general anesthesia. Subjects were matched on age, gender, race, insurance status, behavior, and dmft for each outcome using nearest neighbor estimation. Negative average treatment effects on the treated (ATET) indicate fewer visits, procedures, or expenditures in the SDF group.

	Raw				Matched (77 matches)		
	SDF Group		Non-SDF Group		ATET	95% CI	p-value
Visit Types	x̅	s.d	x̅	s.d			
Preventive visits	1.06	.61	.75	.82	.45	[.20, .71]	<.001*
Sealant visits	.05	.23	.23	.45	-.16	[-.28, -.03]	.01*
SDF visits	1.30	.46	[redacted]				
Restorative visits	.63	.65	1.34	.66	-.9	[-1.15, -.68]	<.001*
Total visits	3.06	1.17	2.33	1.22	.66	[.21, 1.11]	.005*
Procedure types	x̅	s.d	x̅	s.d			
Sealants	.27	1.12	.89	1.99	-.32	[-.70, .06]	.1
SDF treated teeth	4.21	2.75	[redacted]				
Restorations	1.08	2.11	3.00	2.91	-2.74	[-3.46, -2.04]	<.001*
Pulpotomies	.05	.22	.14	.53	-.08	[-.22, .06]	.3
Extractions	.79	1.37	.59	1.11	-.09	[-.52, 34]	.7
Expenditure Category	x̅	s.d.	x̅	s.d.			
Diagnostics	83.05	57.88	134.22	72.36	-41.62	[-60.24, -23.00]	<.001*
Preventive	71.07	94.71	89.86	96.12	2.69	[-28.14, 33.52]	.9
Sealants	10.49	43.67	32.02	79.27	-13.74	[-28.82, 1.35]	.07
SDF	142.56	188.76	[redacted]				
Restorative	197.89	382.40	562.23	706.79	-566.06	[-732.43, -399.70]	<.001*
Endodontics	12.14	53.60	15.65	65.71	1.33	[-22.45, 25.11]	.9
Surgical	70.63	139.25	55.79	176.39	4.39	[-33.87, 42.65]	.8
Adjunctive	28.57	30.36	71.16	56.61	-53.16	[-68.22, -38.11]	<.001*
Total	619.72	563.51	958.04	824.65	-515.30	[-701.99, -328.61]	<.001*

*p<.05

Differences in total due to rounding

and dmfs indices for each subject. This limits the interpretation of the results comparing the groups because subsequent treatment, failures, and expenditures could have been influenced by initial disease activity, severity, and depth just as much as other variables. Second, demographic differences existed between the two treatment groups, though these differences were supported by case selection criteria in clinical guidelines. Despite these significant limitations, the two groups were matched on dmft and demographic variables before analysis. Third, this study only reported data from a single private practice in urban North Carolina. A larger scale study involving multiple locations across different geographies would allow better generalizability. It is unknown whether the results would be generalizable to rural practices. Last, the follow-up period was only one year. Longer follow-up and a prospective design would provide better assessments about the financial impacts of SDF treatment. Even with these limitations, the present findings align with previous studies suggesting more visits and fewer restorative expenditures in children treated with SDF.[8,9]

CONCLUSION

Based on this study's results and in light of its limitations, the following conclusions can be made:

1. SDF appears to be an adjunct to, rather than a complete substitute for, traditional restorative treatment in this private practice.
2. SDF appears to increase the number of visits while decreasing associated dental expenditures when comparing similar subjects who receive and do not receive SDF.
3. Case selection guidelines for SDF overlap with case selection guidelines for general anesthesia, and more clarity is needed for when SDF should be used as definitive versus interim treatment if large scale cost savings are to be realized.

HUMAN SUBJECTS STATEMENT

The University of North Carolina at Chapel Hill Institutional Review Board approved the study under expedited review (existing data) under 45 CFR 46.110 (#18-0721).

The authors would like to thank Bree Smith for her assistance with data collection, and Andy Ni, PhD, for his biostatistical support.

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