Pediatric Dentists' Silver Diamine Fluoride Education, Knowledge, Attitudes, and Professional Behavior: A National Survey

Mario B. Antonioni, Margherita Fontana, Larry B. Salzmann, Marita R. Inglehart

Abstract: Silver diamine fluoride (SDF) is an inexpensive treatment for arresting cavitated carious lesions in a minimally invasive way. The aims of this study were to assess U.S. pediatric dentists' SDF educational experiences, knowledge, attitudes, and professional behavior and to explore the relationships among these constructs. For the cross-sectional survey, recruitment emails were sent to all 6,230 members of the American Academy of Pediatric Dentistry (AAPD). Responses were received from 582 members (response rate 9.34%). In the results, only 3% of the respondents reported having been well/very well educated about SDF in classroom settings in dental school and only 9.6% during their residency. Positive SDF professional development was reported frequently (education through publications 53%, online resources 41%, continuing education courses 38%). The majority knew much/very much about what SDF is used for in dentistry (77%), about treating caries in pediatric patients (80%), and which problems SDF use can have (62%). Their SDF attitudes were positive: SDF use was considered a good treatment alternative for restorations in children with behavioral problems (85%) and for patients who were medically fragile (85%) or had severe dental anxiety (81%). Among the respondents, 31% used SDF often/very often to arrest carious lesions in primary teeth, and 87% expected increased future SDF use. The more SDF professional education the respondents had, the more self-reported knowledge they had ($r=0.52$; $p<0.001$), the more positive their SDF-related attitudes ($r=0.25$; $p<0.001$), and the more likely they were to use SDF ($r=0.37$; $p<0.001$). These results suggest that expanded education about the proper use, benefits, and limitations of SDF is needed and is likely to increase pediatric dentists' SDF utilization.

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Data from the 2011-12 National Health and Nutrition Examination Survey showed that approximately 37% of U.S. children between two and eight years of age had experienced cavitated carious lesions in their primary teeth and that 14% of them had untreated caries in their primary dentition.[1] Furthermore, the National Center for Health Statistics reported that 14.3% of two- to 17-year-old children had not had a dental visit during the previous year and that socioeconomic challenges might be associated with this lack of oral health care utilization.[2] Silver diamine fluoride (SDF) is a relatively inexpensive treatment that might help to address access to care issues for socioeconomically disadvantaged patient groups.[3] Furthermore, SDF allows a minimally invasive approach to treating certain carious lesions.[4]

SDF is a topically applied liquid that has been used to treat tooth hypersensitivity and arrest cavitated carious lesions.[5] Lesion arrest can be achieved by painting the cavitated lesion with the SDF liquid without removing any infected soft dentin.[6] SDF can serve as an alternative, particularly for patients who cannot tolerate traditional dental treatment, and can reduce the need for dental care to be performed under general anesthesia, with its associated health risks.[7-10] In 2014, the Food and Drug Administration (FDA) approved the use of SDF in the U.S. as a "device" to treat tooth hypersensitivity, which is a similar regulatory pathway to the clearance of fluoride varnish.[11] Thus, use of SDF in the U.S. for caries management is "off label."

There is considerable evidence of the efficacy and safety of SDF for treating primarily cavitated

carious lesions. The American Academy of Pediatric Dentistry (AAPD) supports using 38% SDF in primary teeth to arrest cavitated lesions as part of a comprehensive caries management plan.[12] The AAPD assessed the current evidence for the usage of SDF as low-quality evidence due to the risk of bias in the studies they reviewed.[13] A systematic review rated the level of evidence supporting SDF use to be high in primary teeth.[14]

However, one barrier to SDF use is that it discolors the treated lesion black. In addition, Yee et al. found that the percentage of arrested cavitated lesions decreased over a period of two years after a single initial application, suggesting that reapplication is necessary over time.[15] Applying SDF twice yearly has been shown to be slightly more effective than once yearly.[16] When applied twice per year, the 38% SDF solution had a success rate of 84.8% for arresting caries.[17] In addition, there seems to be a dose-response to the effectiveness of SDF, with a 38% SDF solution being more effective than a 12% SDF solution.[15,18]

While no research so far has explored how well dental schools educate their graduates about SDF, Nelson et al. reported in 2016 that 79.9% of U.S. pediatric dentistry residency programs had started to include SDF-related content in their curricula, with a quarter of the programs using it in clinical settings.[7] Surveying pediatric dentists about their SDF educational experiences, knowledge, attitudes, and professional use would offer an opportunity to investigate whether increased education in this context would result not only in more knowledge, but also in more positive attitudes and increased use. The aims of this study were therefore to assess U.S. pediatric dentists' SDF educational experiences, knowledge, attitudes, and professional behavior and to explore the relationships among these constructs. Specifically, we sought to determine if SDF education in dental school, graduate programs, and professional development would be positively correlated with SDF knowledge, attitudes, and use.

Methods

This study was a cross-sectional survey and was determined to be exempt from Institutional Review Board (IRB) oversight by the Health Sciences and Behavioral Sciences IRB (IRB-HSBS) at the University of Michigan on September 19, 2016 (#HUM00120744). An a priori power analysis was conducted with the program package G*Power 3.1.2 (www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3) to determine the sample size needed to test for positive relationships among SDF-related constructs. We assumed that the alpha error was 0.05, the power 0.95, the effect size small (rho=0.15), and that a one-sided hypothesis would be tested that predicted positive relationships among the SDF-related constructs. The a priori power analysis showed that a sample size of 472 respondents would be needed. Based on experiences with previous surveys of AAPD members, we expected a response rate under 10%. Recruitment emails were therefore sent to all 6,230 members of the AAPD.

The email addresses of all AAPD members were purchased from the AAPD. The recruitment email described the study as follows: "The purpose of this study is to determine pediatric dentists' educational experiences, opinions, and professional behavior related to the use of silver diamine fluoride (SDF) to treat dental caries." A web-link to an anonymous web-based survey was included in this email. A pediatric dentist (coauthor L.B.S.) sent the email in the first week of November 2016. The last responses were received in January 2017. Responding to the survey was considered implicit consent, and no explicit consent to participate in the research was therefore required. No follow-up emails were sent.

The survey had five parts. Part 1 consisted of questions on the respondents' characteristics. Part 2 asked about respondents' SDF education such as the quality and extent of their education in dental school, graduate program, and professional development activities. Part 3 addressed respondents' general and specific clinical knowledge of SDF. Part 4 measured respondents' SDF-related attitudes with 11 items on specific clinical scenarios. The final part evaluated respondents' professional behavior related to SDF use in their offices. The first draft of the survey was pilot tested with ten pediatric dentists and residents. The pilot respondents made some suggestions concerning wording and content of the items. The survey was finalized based on these comments to ensure content validity.

The data were downloaded and imported into SPSS, Version 22 (IBM Corp., Armonk, NY, USA). Descriptive statistics such as frequency distributions, percentages, and means were computed to provide an overview of the responses. To avoid correlating numerous single item indicators with each other to determine the relationships between SDF educational experiences, knowledge, attitudes, and professional

behavior, factor analyses (Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization) were used to identify the underlying factor structure of the SDF education, knowledge, attitude, and professional behavior items. Items with factor loadings over 0.40 were used to create indices. The factor analyses were conducted using SPSS. Missing data were excluded listwise.[19]

The indices were constructed by averaging the responses to the items loading on each specific factor. Three SDF education indices, four knowledge indices, four attitudinal indices, and one SDF use index were created. Cronbach's alpha inter-item consistency coefficients were computed to determine the reliability of these indices. Three indices had excellent reliability (alpha >0.9), three had good reliability (alphas 0.8-0.9), five had acceptable reliability (alphas 0.7-0.8), and three had borderline acceptable reliabilities (alphas 0.6-0.7).[20,21] Pearson correlation coefficients were used to determine the relationships among the indices. To account for the relatively high number of statistical tests, a Bonferroni correction was used, and the level of significance was set at $p<0.001$.[22]

Results

Survey responses were received from 582 AAPD members, for a response rate of 9.34%. The number of responses received exceeded the number needed as determined with the power analysis (N=472), supporting use of the data to explore the hypotheses of interest. When we considered whether the respondents represented AAPD members in general, the data showed that the percentage of respondents under 40 years of age in our study (41%) was higher than the percentage in the general AAPD membership in 2015 (30%).[23] Correlations between the respondents' age and their index responses were therefore computed, and only two significant correlations were identified: correlations between age and evaluations of the quality of SDF graduate education and between age and acceptance of patient considerations.

Slightly more of the 582 respondents were male (53%) than female (47%) (Table 1). The respondents ranged in age from 26 to 79 years; they had graduated from their DDS/DMD program between

Table 1. Characteristics of U.S. pediatric dentists participating in survey about silver diamine fluoride (N=582)

Characteristic	Mean (SD)	Range
Age	45.68 (12.71)	26-79
DDS/DMD graduation year	1997 (13.08)	1964-2015
Pediatric dentistry residency graduation year	2001 (12.92)	1968-2016
	Number	Percentage
Gender		
Male	303	53%
Female	264	47%
Graduate program was		
University-based	79	14%
Hospital-based	180	32%
Combined university-hospital	313	55%
Practice/employment situation		
Solo practice	179	32%
Partnership	80	14%
Associateship	106	19%
Group practice	105	19%
Corporate dentistry	25	5%
Hospital dentistry	23	4%
Academic appointment	37	7%
Workplace location		
Rural (<5,000)	15	3%
Small town/city (5,000-24,999)	65	11%
Moderate-sized city (25,000-250,000)	151	26%
Suburb near large city	168	29%
Large city (>250,000)	176	31%
Percentage of patients who are	Mean (SD)	Range
Children under 13 years of age	76% (17)	0-100
Patients covered by Medicaid	38% (34)	0-100

Note: Numbers for each category may not add up to total number of respondents become some skipped items. Percentages were calculated on number of respondents in each category and may not total 100% because of rounding.

1964 and 2015 and from their pediatric dentistry residency program between 1968 and 2016. Two of the respondents were still residents, and two did not indicate in which year they graduated from a pediatric dentistry residency program, leaving the possibility open that they might not have graduated from a pediatric dentistry program. The majority had attended a pediatric dentistry residency program in a combined university/hospital setting (55%), while 32% had attended a hospital-based program and 14% a university-based program. About a third practiced in solo practices (32%), 19% in an associateship, 19% in a group practice, and 14% in a partnership. The majority worked in a large city (31%), a suburb near a large city (29%), or a moderate-sized city (26%), with only 11% in a small town/city and 3% in a rural area. Most of their patients were children under 13 years of age (76%); on average, 38% of their patients were covered by Medicaid.

Table 2 provides an overview of the respondents' SDF educational experiences. In their professional development education, the majority (53%) reported that dental journals/other publications had educated them well/very well about SDF. Approximately four of ten reported being educated well/very well through use of online resources (41%) or in continuing education courses (38%) and about a quarter through their dental organizations (27%). In contrast, their predoctoral and residency program experiences were less positive. Only 3% reported being well/very well educated about SDF in classroom settings and only 2% in clinical settings while attending dental school. Only 10% reported being well/very well educated about SDF in classroom settings and 8% in clinical settings in their residency programs. Nearly all (98%) said they had never used SDF in dental school, and 91% had never used it in their residency program.

Regarding SDF knowledge, seven items assessed self-reported knowledge about distinct types of dental treatments (Table 3). The majority (77%) reported that they knew well/very well what SDF was used for in dentistry, 68% that they knew the advantages SDF treatment can have over traditional dental treatment, and 45% that they knew under which codes SDF treatments can be billed. Five items assessed knowledge concerning when SDF can be used to treat lesions. A large majority (85%) agreed/strongly agreed that SDF can be used to arrest cavitated lesions in enamel, 82% that it can be used to arrest cavitated lesions in dentin, and 59% that infected dentin must not be removed prior to applying SDF. When asked about non-cavitated lesions, 64% agreed/strongly agreed that SDF can be used to arrest non-cavitated lesions in enamel. The majority (76%) disagreed/strongly disagreed that SDF should be used prior to all restorations, and 59% that SDF should be used prior to all restorations in at-risk patients.

Table 4 shows responses concerning patient-related SDF indications and considerations. These questions evaluated respondents' attitudes about SDF use. Large percentages agreed/strongly agreed that

Table 2. Participating pediatric dentists' responses about their silver diamine fluoride (SDF) educational experiences, by percentage of respondents to each item

Item	1	2	3	4	5	Mean, SD
How well were you educated about SDF in dental school[a]						
In classroom settings? (N=577)	91%	5%	1%	2%	1%	1.17, 0.646
In clinical settings? (N=576)	95%	3%	1%	1%	1%	1.09, 0.462
How frequently did you use SDF while in dental school?[b] (N=561)	98%	1%	0	0	1%	1.04, 0.341
How well were you educated about SDF in your residency[a]						
In classroom settings? (N=568)	78%	9%	4%	6%	4%	1.49, 1.069
In clinical settings? (N=569)	86%	4%	2%	2%	6%	1.37, 1.044
How frequently did you use SDF during your residency program?[b] (N=562)	91%	2%	4%	2%	1%	1.21, 0.729
How well were you educated about SDF after graduation[a]						
In continuing education courses? (N=563)	34%	10%	18%	21%	17%	2.79, 1.516
With dental journals/other publications? (N=570)	9%	12%	26%	29%	24%	3.45, 1.232
Through dental organizations? (N=563)	36%	19%	18%	16%	11%	2.47, 1.398
With online resources? (N=514)	30%	13%	17%	20%	21%	2.88, 1.526

Note: Percentages may not total 100% because of rounding.

[a]Response options were 1=not at all, 2=a little, 3=somewhat, 4=well, and 5=very well.
[b]Response options were 1=never, 2=rarely, 3=sometimes, 4=often, and 5=very often.

Table 3. Participating pediatric dentists' responses about their silver diamine fluoride (SDF) knowledge, by percentage of respondents to each item

Item	1	2	3	4	5	Don't Know	Mean, SD
How much do you know about[a]							
What SDF is used for in dentistry? (N=576)	2%	5%	15%	40%	37%	n/a	4.05, 0.960
How SDF is used for treatment of tooth hypersensitivity? (N=573)	9%	13%	27%	29%	22%	n/a	3.42, 1.228
How SDF is used to treat dental caries in pediatric patients? (N=573)	2%	5%	13%	39%	41%	n/a	4.12, 0.957
How SDF is used to treat dental caries in adult patients? (N=569)	15%	18%	24%	24%	19%	n/a	3.15, 1.329
The advantages SDF tx can have over traditional dental treatments? (N=570)	5%	8%	20%	35%	33%	n/a	3.84, 1.102
The potential problems SDF usage can have? (N=568)	5%	11%	22%	35%	27%	n/a	3.67, 1.144
Which, if any, codes SDF tx can be billed under? (N=572)	23%	13%	18%	21%	25%	n/a	3.12, 1.498
Self-perceived general SDF knowledge index (alpha=0.923)	Mean=3.63		SD=0.979		Range= 1.00 to 5.00		N=558
How much do you disagree/agree with the following statements?[b]							
SDF can be used to arrest cavitated lesions in enamel. (N=553)	1%	1%	8%	44%	41%	5%	4.28, 0.773
SDF can be used to arrest cavitated lesions in dentin. (N=548)	1%	3%	9%	40%	42%	5%	4.27, 0.812
SDF can be used to arrest cavitated root caries. (N=499)	1%	2%	12%	37%	34%	13%	4.20, 0.816
Infected soft dentin must be removed prior to applying SDF. (recoded) (N=529)	24%	36%	17%	11%	3%	9%	2.27, 1.091
SDF is a good tx for arresting caries when it is not possible to restore all lesions in one appointment. (N=537)	2%	4%	14%	37%	35%	6%	4.06, 0.963
Cavitated lesion knowledge index (alpha=0.756)	Mean=4.11		SD=0.633		Range= 1.00 to 5.00		N=467
SDF can be used to arrest non-cavitated lesions in enamel. (N=527)	3%	9%	14%	34%	30%	9%	3.87, 1.101
SDF can be used to arrest non-cavitated root caries. (N=492)	2%	7%	15%	33%	27%	15%	3.90, 1.029
Non-cavitated lesion knowledge index (alpha=0.919)	Mean=3.88		SD=1.023		Range= 1.00 to 5.00		N=488
SDF should be used prior to placing all restorations in all patients. (N=523)	43%	33%	11%	2%	1%	9%	1.72, 0.860
SDF should be used prior to all restorations in at-risk patients. (N=523)	27%	32%	22%	7%	2%	9%	2.16, 1.034
SDF use prior to all restorative treatment index (alpha 0.793)	Mean=1.94		SD=0.841		Range= 1.00 to 5.00		N=512

Note: Percentages may not total 100% because of rounding.

[a]Response options ranged from 1=nothing to 5=a great deal.
[b]Response options were 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree.

Table 4. Participating pediatric dentists' responses regarding silver diamine fluoride (SDF) considerations/attitudes, by percentage of respondents to each item

Item	1	2	3	4	5	Don't Know	Mean, SD
SDF is a good treatment alternative							
For restorations in children with behavioral issues. (N=555)	1%	2%	7%	32%	53%	3%	4.40, 0.823
When patients are medically fragile. (N=548)	1%	1%	8%	41%	43%	4%	4.33, 0.749
When patients have severe dental anxiety. (N=553)	1%	2%	10%	41%	40%	3%	4.23, 0.822
When patients are undergoing or have recently undergone radiation therapy or chemotherapy. (N=503)	1%	1%	11%	38%	36%	11%	4.23, 0.818
When patients take bisphosphonate medications. (N=432)	1%	2%	21%	26%	24%	24%	3.92, 0.950
If patients would have to be put under general anesthesia for dental treatment otherwise. (N=547)	2%	4%	15%	38%	36%	4%	4.10, 0.922
If patients would be unable to receive normal dental treatment and could also not be put under general anesthesia for treatment. (N=542)	1%	0%	7%	35%	50%	4%	4.44, 0.696
If patients with microstomia have difficult to access lesions that require treatment. (N=525)	1%	1%	11%	38%	39%	6%	4.26, 0.796
Patient-related indications for SDF usage index (alpha=0.923)	Mean=4.24		SD=0.668		Range= 1.00 to 5.00		N=400
SDF is a good treatment alternative							
When a patient wants a composite restoration at a later time but cannot currently afford it. (N=540)	4%	14%	27%	32%	17%	5%	3.49, 1.072
When a patient wants an amalgam restoration at a later time but cannot currently afford it. (N=540)	2%	6%	24%	37%	24%	5%	3.82, 0.961
When patients cannot pay for restorations. (N=546)	2%	6%	22%	34%	30%	4%	3.91, 0.986
Cost-related indications for SDF usage index (alpha=0.824)	Mean=3.74		SD=0.870		Range= 1.00 to 5.00		N=530

(continued)

Table 4. Participating pediatric dentists' responses regarding silver diamine fluoride (SDF) considerations/attitudes, by percentage of respondents to each item *(continued)*

Item	1	2	3	4	5	Don't Know	Mean, SD
SDF is a good treatment for lesions that							
Are not in the esthetic zone on primary teeth. (N=556)	2%	2%	12%	38%	42%	3%	4.22, 0.880
Are not in the esthetic zone on permanent teeth. (N=538)	2%	5%	20%	37%	28%	5%	3.91, 0.973
Considerations to treatment not in esthetic zone (alpha=0.745)	Mean=4.07		SD=0.826		Range= 1.00 to 5.00		N=537
SDF is a good treatment for lesions that							
Are in the esthetic zone on primary teeth. (N=558)	12%	21%	30%	24%	9%	3%	2.98, 1.159
Are in the esthetic zone on permanent teeth. (N=550)	26%	30%	24%	10%	5%	4%	2.33, 1.124
Considerations to treatment in esthetic zone (alpha=0.744)	Mean=2.66		SD=1.02		Range= 1.00 to 5.00		N=549

Note: Response options were 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree. Percentages may not total 100% because of rounding.

SDF was a good treatment alternative for restorations in children with behavioral issues (85%), patients who were medically fragile (85%), patients with severe anxiety (81%), patients who were undergoing or had recently undergone radiation therapy (74%), and patients who had to be put under general anesthesia for dental treatment (74%). SDF was perceived as a good treatment alternative for primary teeth not in the esthetic zone by 80% of respondents; 65% agreed/strongly agreed that SDF is a good alternative for treatment of permanent teeth not in the esthetic zone. However, only 33% agreed/strongly agreed with treating primary teeth in the esthetic zone with SDF, and only 14.3% with treating lesions on permanent teeth in the esthetic zone with SDF.

Regarding how frequently respondents used SDF in their own offices, 33% reported they had never used SDF in their offices to arrest carious lesions in primary teeth, but 30% had used SDF often/very often for this purpose (Table 5). In contrast, 47% had never used SDF to arrest carious lesions in permanent teeth, and only 11% had used it often/very often for this purpose. When asked about their future use of SDF, 36% reported it would increase a lot, and 51% that it would increase a little.

The final objective was to explore how the respondents' different SDF educational experiences were related to their self-reported knowledge, attitudes, and professional behavior. One question was whether age would play a role because of the relatively recent introduction of SDF in the U.S. Correlations between respondents' age and the indices showed two were significant. First, the older the respondents were, the less well they were educated about SDF during their graduate education ($r=-0.356$; $p<0.001$); second, the older the respondents were,

Table 5. Participating pediatric dentists' responses about their use of silver diamine fluoride (SDF), by percentage of respondents to each item

Item	1	2	3	4	5	Mean, SD
How often did/do you use SDF[a]						
In your office to treat tooth sensitivity? (N=557)	62%	17%	15%	3%	3%	1.67, 1.010
Off-label in your office to prevent dental caries? (N=557)	54%	8%	22%	9%	7%	2.07, 1.322
Off-label in your office to arrest dental caries in primary teeth? (N=554)	33%	6%	31%	18%	13%	2.72, 1.402
Off-label in your office to arrest dental caries in permanent teeth? (N=556)	47%	17%	24%	6%	5%	2.05, 1.191
Off-label in your office to definitively treat dental caries (continual SDF treatment with no preparations and restorations seen as required on the carious tooth)? (N=556)	46%	21%	23%	6%	4%	2.00, 1.133
Do you expect your future usage of SDF to ____?[b] (N=570)	1%	1%	10%	51%	36%	4.23, 0.744
Office use of SDF index (alpha=0.868)	N=523 Mean=2.46		SD=0.896		Range= 1.00 to 5.00	

Note: Percentages may not total 100% because of rounding.

[a]Response options were 1=never, 2=rarely, 3=sometimes, 4=often, and 5=very often.
[b]Response options were 1=decrease a lot, 2=decrease a little, 3=not change, 4=increase a little, and 5=increase a lot.

the less they considered SDF as a positive treatment option for their patients (r=-0.21; p<0.001). No other significant correlations were found.

Concerning intercorrelations between the constructs of interest, the SDF educational indices concerning dental school (A) and residency education (B) were correlated (r=0.35; p<0.001) (Table 6). Correlations among the self-reported knowledge indices showed that general SDF knowledge (D) correlated with cavitated lesion knowledge (E) (r=0.47; p<0.001) and non-cavitated lesion knowledge (F) (r=0.20; p<0.001). In addition, cavitated lesion knowledge (E) was correlated with non-cavitated lesion knowledge (F) (r=0.27; p<0.001). We expected that the educational and self-reported knowledge indices would be correlated. However, there were no significant correlations between the SDF dental school education index (A) and any of the four knowledge indices (D, E, F, and G). The professional development education index (C) correlated significantly with the self-reported SDF general knowledge index (D) (r=0.52; p<0.001) and the cavitated lesion knowledge index (E) (r=0.27; p<0.001).

An analysis of the relationships between respondents' SDF education and knowledge and their SDF attitudes and behavior showed that neither the SDF dental school index (A) nor the SDF residency education index (B) were correlated with respondents' attitudes and behavior. However, the professional development education index (C) was correlated with two of the four SDF attitudinal indices (H, I) and the behavioral index (L). In addition, the self-reported general SDF knowledge index (D) and the cavitated lesion (E) and non-cavitated lesion (F) indices correlated with the majority of the attitudinal indices and the behavioral index (L).

Additional correlational analyses between these indices and three practice characteristics (type of practice, location of practice, and percentage of patients covered by Medicaid) were conducted. The results showed that the type of practice was significantly correlated only with respondents' cavitated lesion knowledge, with academicians knowing more than pediatric dentists in solo practices, partnerships, and associateships about this content (r=0.196; p<0.001). There were no significant correlations between the SDF indices and practice location. However, there were significant correlations between percentage of patients covered by Medicaid and evaluations of the quality of SDF graduate education (r=0.154; p<0.001) and esthetic concerns (r=0.150; p<0.001).

Discussion

The fact that the number of respondents exceeded the number of needed respondents based on the power analysis allowed testing the relationships

Table 6. Correlations among participating pediatric dentists' silver diamine fluoride (SDF) education, knowledge, attitudes, and frequency of use

	SDF Education			SDF Knowledge			
Index	A	B	C	D	E	F	G
SDF education							
A: SDF dental school education (alpha=0.715)	1	0.35*	0.13	0.05	-0.09	0.09	0.05
B: SDF residency education (alpha=0.899)	0.35*	1	0.08	0.14	0.05	0.09	-0.03
C: SDF professional development (alpha=0.616)	0.13	0.07	1	0.52*	0.27*	0.08	0.03
SDF knowledge							
D: SDF knowledge (alpha=0.923)	0.05	0.14	0.52*	1	0.47*	0.20*	-0.09
E: cavitated lesion knowledge (alpha=0.756)	-0.09	0.05	0.27*	0.47*	1	0.27*	-0.06
F: non-cavitated lesion knowledge (alpha=0.919)	0.09	0.09	0.08	0.20*	0.27*	1	0.00
G: SDF knowledge prior to restoration (alpha=0.793)	0.05	-0.03	0.03	-0.09	-0.06	0.00	1
Patient-related SDF considerations							
H: patient considerations (alpha=0.923)	0.01	0.05	0.25*	0.38*	0.62*	0.30*	-0.04
I: cost-related considerations (alpha=0.824)	0.04	-0.02	0.17*	0.29*	0.40*	0.21*	0.09
J: non-esthetic zone considerations (alpha=0.745)	-0.03	0.05	0.14	0.24	0.43*	0.20*	0.09
K: esthetic zone considerations (alpha=0.744)	-0.02	0.01	0.11	0.19*	0.23*	0.19*	0.08
Use of SDF							
L: office use of SDF (alpha=0.868)	0.01	0.04	0.37*	0.58*	0.37*	0.19*	0.12*

Note: Information about items used to create indices A, B, and C is in Table 2. Text of items used to create indices D, E, F, and G are in Table 3. Text of items used to create indices H, I, J, and K are in Table 4. Information about items used to create index L are in Table 5.

*p<0.001

among the constructs of interest, especially relationships between respondents' SDF educational experiences and their knowledge, attitudes, and behavior. While a 9.34% response rate is low, research concerning the response rates of practicing dentists to mail vs. web-based surveys by Hardigan et al. found that the response rate to web-based surveys (11%) was significantly lower than the response rate to mailed surveys.[24] Given that the AAPD does not provide researchers with postal addresses of their members and also does not permit follow-up emails to web-based surveys, the response rate to our survey can be interpreted as being in the range of what can be expected.

Concerning SDF education, 91% of the respondents reported they were not at all educated about SDF in classroom settings and 95% not in clinical settings in dental school. This finding is not surprising because SDF had not been cleared by the FDA for the treatment of dentin sensitivity until 2014, and only one respondent had graduated from dental school in 2015.[11] The increase in educational experiences in pediatric dental residency programs when compared to DDS/DMD programs was also not surprising because one of the main target populations for SDF use is children.[7] SDF education in pediatric dental residency programs will likely continue to increase over time now that the AAPD has endorsed its use.[12,13]

Despite the relatively low level of SDF education in respondents' predoctoral and graduate programs, their knowledge about SDF use was quite high. This finding is likely due to their professional development education. However, while 77% of the respondents answered that they knew what SDF was used for in dentistry, some responses were not consistent with empirical evidence. Most of the respondents (82%) stated that they agreed/strongly agreed that SDF can be used to arrest cavitated lesions in dentin. This use is well supported by existing evidence.[5,14,25] Similar responses were also found in a study with pediatric dentistry program directors.[6] However, while 64% of our respondents agreed that SDF can be used to treat non-cavitated lesions in enamel, there is very limited clinical evidence supporting that treatment. In addition, Chu et al. showed in 2002 that it is not necessary to remove infected soft dentin before applying SDF to arrest the lesions.[6] However, 14% of our respondents agreed/strongly agreed that infected dentin must be removed prior to applying SDF, and an additional 17% were neutral on that point.

Very few respondents (3%) were in favor of placing SDF prior to all restorations, and a few (9%) favored placing SDF prior to restorations in at-risk patients. There is insufficient evidence to indicate the need to use SDF prior to restorations because clinical studies concerning the role of SDF in prevention of secondary caries are limited and have had conflicting conclusions,[26,27] despite in vitro data suggesting a positive role.[28] This situation points to the significant need for further research and education concerning these issues. Both our study with pediatric dentists and Nelson et al.'s study with pediatric dentistry program administrators found high agreement with statements that SDF is indicated for treating patients with behavioral issues and for medically fragile patients.[7] A recent study found that parents accepted SDF treatment depending on whether it was a posterior lesion (68%) or an anterior lesion (30%).[29]

The frequency of SDF use among our study respondents differed considerably. Most (67%) used SDF to arrest carious lesions in primary teeth. However, the tone of written responses ranged widely from stating that SDF has been "the most important discovery of my 35-year career" to "I would not use SDF on my dog." Nevertheless, the large majority of respondents (87%) stated that they expected to increase their SDF use in the future.

The questions for which significant percentages of respondents selected "don't know" as an answer can inform future research and educational efforts. The "don't know" response was most frequently used when asked whether SDF can be used to arrest cavitated root caries lesions (12.5%) and non-cavitated root caries lesions (14.9%), if it is necessary to remove SDF-treated dentin prior to cementing a crown (16.8%), if it should be used when patients take bisphosphonate medications (23.5%), and which, if any, codes SDF can be billed under (24.6%).

The correlations showed the importance of professional development education on SDF use. Respondents who reported SDF professional development activities had higher self-perceived knowledge than others ($r=0.52$; $p<0.001$). In addition, those respondents who perceived themselves to be more knowledgeable about SDF used it more on cavitated lesions than did those who were less knowledgeable ($r=0.47$; $p<0.001$). This finding demonstrates that those respondents with high self-perceived knowledge were more likely to follow the evidence base and use SDF on cavitated lesions. Concerning the size of the significant correlations, it is important to note that the correlations ranged from $r=0.20$ to $r=0.62$, indicating that some of the relationships explained a substantial amount of the variance of the variables involved.

This study had several limitations. First, survey research usually faces the problem that respondents who are more interested or more familiar with the survey topic may be more likely than non-respondents to take the time to respond. This possibility should be considered when interpreting the findings. Second, the percentage of respondents under 40 years of age (41%) was higher than in the general AAPD membership in 2015 (30%).[23] While a correlation between the age of the respondents and the constructs of interests showed there were only significant correlations between age and respondents' evaluations of the quality of their SDF graduate education and their acceptance of patient-related considerations, it cannot be ruled out that the respondents differed in other ways from the AAPD members at large. Finally, as is the case with all surveys, only a limited set of questions could be asked. Future research should therefore include questions concerning SDF educational interventions in more detail. It would have been informative, for example, to find out what exactly was included in respondents' classroom SDF teaching and which clinical experiences were provided. More information about their continuing education such as courses and web-based resources should also be collected in future studies.

Conclusion

The following conclusions can be drawn based on this study's results. Most respondents had received their SDF education through professional development such as continuing education courses, dental journals/other publications, and online resources. A lack of self-reported knowledge was most frequently reported concerning whether a restoration must be placed after SDF treatment even if SDF is being reapplied twice per year, whether SDF can be used on root caries lesions, and under which codes SDF treatment can be billed. Discrepancies were found between how SDF should be applied according to existing evidence and how some respondents thought SDF should be used. Educational efforts are therefore needed to increase knowledge about the proper use, benefits, and limitations of SDF. Respondents expressed interest in continuing education courses on SDF. About half of the respondents used SDF often/very often in their offices to arrest carious lesions in primary teeth and 11% to arrest carious lesions in permanent teeth. A large majority expected an increase in SDF use in the future. Most importantly, the better educated the respondents were about SDF through their professional development activities, the more knowledge they had, the more positive were their attitudes, and the more often they used SDF in their own practices. Increasing SDF educational efforts might therefore result in increased utilization of this new approach to treating cavitated caries lesions, especially in children.

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