Evaluating the Knowledge and Opinions of Army Dentists Regarding Silver Diamine Fluoride

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Submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Oral Biology in the Uniformed Services University of Health Sciences

Fort Bragg, NC

2019

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THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: "Evaluating the Knowledge and Opinions of Army Dentists Regarding Silver Diamine Fluoride"

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Master of Science Degree
June 14, 2019

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ACKNOWLEDGMENTS

I would like to express my sincere gratitude to the AEGD Research Mentor, LTC Pelaez, AEGD Program Director, LTC Lambert and AEGD Assistant Director, MAJ Bullock for their guidance and support throughout this project. I greatly appreciate our Medical librarian Mrs. Jennifer S Kuntz for the literatures colleting portion of this project. I greatly appreciate our Statistician, Mr. Beltran, for his expert assistance and guidance throughout the analysis portion of this project.

DISCLOSURES AND AFFILIATIONS

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ABSTRACT

Introduction

Silver Diamine Fluoride (SDF) is a FDA-approved metal amine liquid with antibacterial properties for treating dentinal hypersensitivity. However, SDF is better known for its off-label use in arresting the progression of dental caries. SDF has the potential to aid in achieving dental readiness because it is effective at arresting caries and is simple to use. For some Soldiers with multiple carious sites, treatment time is demanding and it is not unusual for Soldiers to miss their dental appointments. Delaying treatment could cause dental class II (moderate) caries to become dental class III (urgent and non-deployable). During the "Go First Class" dental appointment, Army dentists can identify the Soldiers with multiple carious sites and begin to arrest caries at the same appointment with SDF. Future appointments will still be needed, but it buys more time for Army dentists to treat patients in multiple visits without worrying about the progression of the caries if there is a delay in their next appointment.

Purpose

This cross-sectional descriptive survey was designed to evaluate the opinions and perceptions of Army dentists on SDF.

Materials and Methods

A ten-question survey was designed to evaluate participants' knowledge and attitudes toward SDF. The survey was conducted online through SurveyMonkey.com. An email with the link to the survey was sent to every active duty Army dentist with the Area of Concentration of 63A (General Dentist), 63B (Comprehensive Dentist), and 63K (Pediatric Dentist), to include residents in training, through the Army Outlook e-mail system. The survey did not record any personally identifiable information of the participants, and the data was stored in a password-protected single user online account.

Descriptive statistics were used for frequency of responses and where appropriate cross-tabulations were applied. Multiple comparisons were accomplished using the Kruskal-Wallis test. Significance was declared at $P < 0.05$ for all tests. All data were analyzed by using SPSS version 25.0 (SPSS, Chicago, IL).

Results

237 out of 747 people responded to the survey (31.73% response rate). The results showed 87.76% of respondents had heard of SDF before taking the survey, but only 47.68% of the total respondents reported knowing how to properly utilize SDF. 14.66% of respondents claimed that they had SDF in their dental clinic. 73.28% of the respondents that do not have SDF in their clinic are interested in having SDF available in their clinics. For respondents who are not willing

to consider using SDF, their reasons included, “SDF may weaken bonding strength for resin restoration,” “prefer to use other materials for caries prevention and remineralization such as fluoride varnish,” “SDF is technique sensitive, not simple to apply”, “not believing in the effectiveness of SDF” and “other.”

Conclusion

Based on the survey results, Army dentist with >10years in dental practice felt less comfortable using SDF than respondents with less experience. 93.53% of survey participants will consider SDF as a treatment option but only 47.68% of them claimed they know how to properly apply SDF (Survey question No. 5 & 8). Only 14.66% of the participants work in an Army Dental clinic that has SDF (Survey question No. 7). 5.49% of survey participants had an incorrect concept of the true effect of SDF and 52.32% claimed they do not know how to properly apply SDF (Survey question No. 4 & 5). More continuing education on SDF is recommended for Army dentists who are currently using SDF or considering using it in the future.

Key words:

Silver Diamine Fluoride (SDF), Off-label use, Caries prevention, Caries arrest, Remineralization.

Introduction

Army dentistry, whether conducted in a garrison or a field environment, demands efficient, effective, and affordable treatment options to better serve the needs of Soldiers. Silver Diamine Fluoride (SDF) has the potential to be a great adjunct in dental care regarding caries control. SDF is a metal amine liquid with antibacterial properties that received approval from the Food and Drug Administration in 2014 for treating dentinal hypersensitivity. However, in the United States, SDF is better known for its off-label use in arresting the progression of dental caries and promoting remineralization. This is comparable to 5% Sodium Fluoride Varnish which was also approved for treating dentinal hypersensitivity, but has become well known for its off-label use as a drug to prevent caries [1]. Countries like Japan, Australia, Brazil, China, Argentina, and New Zealand have been using SDF to arrest caries for decades [2], with both *in vitro*, and *in vivo*, studies demonstrating caries-arresting properties on both primary and permanent teeth [3]

[4]. It is important to note that the caries-arresting property of SDF does not eliminate the need for a definitive dental restoration to restore the lost tooth structure from the caries. The main side effect when using SDF is the dark staining of carious dentin which can be an esthetic concern and often limits the use of SDF to posterior teeth [5]. Additionally, SDF is contraindicated in patients with silver allergy.

The military relevance for SDF is that it is well suited for a field/combat environment since it is easily transported (it is sold in 8 mL plastic bottles), does not require any special handling, such as refrigeration, and application only requires a microbrush and proper isolation with cotton rolls. There is no need for dental equipment and instruments or administration of local anesthesia. SDF is also affordable with a price of approximately $160 per bottle which is sufficient to treat approximately 250 carious lesions.

The purpose of this study was to evaluate the opinions and perceptions of Army dentists regarding the clinical use of SDF. The survey specifically targeted clinicians in the Area of Concentration 63A (General Dentist), 63B (Comprehensive Dentist), and 63K (Pediatric Dentist) because these are the dentists who treat the majority of caries in the Army.

Materials and methods

A ten-question survey was designed to evaluate participants' knowledge and attitudes toward SDF. The survey was conducted online through SurveyMonkey.com. An e-mail distribution list of all eligible study participants was obtained through the United States Army Human Resources Command. An email with the link to the survey was sent to every active duty Army dentist with the Area of Concentration of 63A (General Dentist), 63B (Comprehensive Dentist), and 63K

(Pediatric Dentist), to include residents in training, through the Army Outlook e-mail system. The survey did not record any personally identifiable information of the participants, and the data was stored in a password-protected single user online account.

The survey was open for three months.

The survey was sent to a total of 747 individuals (516 General dentists (63A), 214 Comprehensive dentists (63B), and 17 Pediatric dentists (63K)).

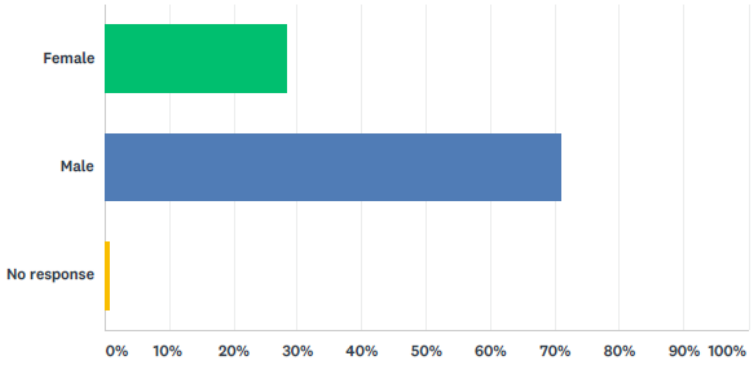
Descriptive statistics were used for frequency of responses and where appropriate cross-tabulations were applied. Multiple comparisons were accomplished using the Kruskal-Wallis test. Significance was declared at $P < 0.05$ for all tests. All data were analyzed by using SPSS version 25.0 (SPSS, Chicago, IL).

Results

The survey was closed at the three-month mark, with a total of 237 responses, for a 31.73% response rate. The survey was designed in a 2-page format online with questions #1-5 on the first page and question #6-10 on the second page. In the first page of the survey, it was clearly stated "There are only 10 Questions." However, there were 5 respondents who did not proceed to the second page, and the final result did not remove those 5 respondents since they cannot be identified. Graph illustration of responses for each question:

Q1 What is your gender?

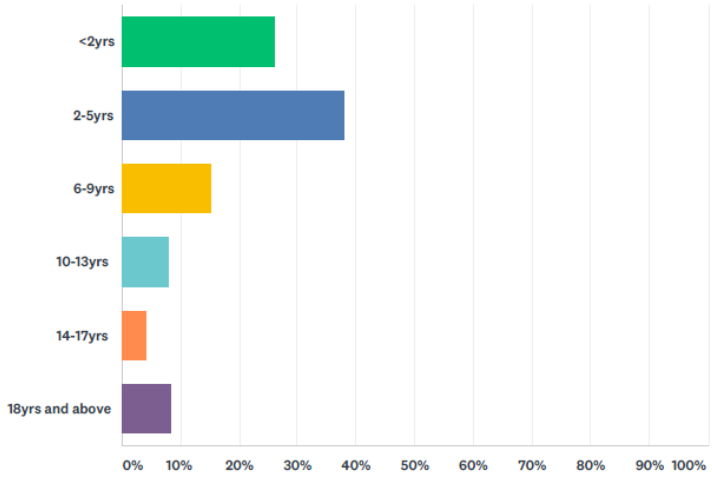
Answered: 237 Skipped: 0



ANSWER CHOICES	RESPONSES	
Female	28.27%	67
Male	70.89%	168
No response	0.84%	2
TOTAL		237

Q2 Years in Dental Practice (include civilian time):

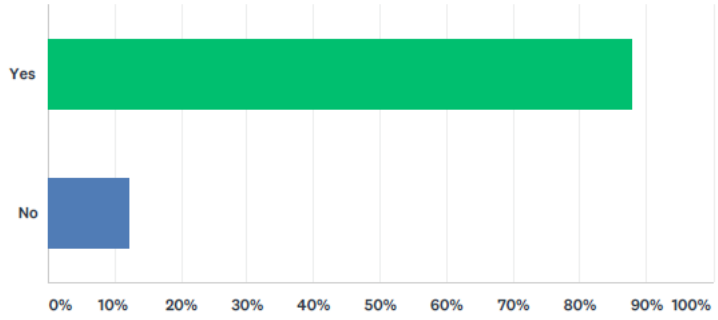
Answered: 237 Skipped: 0



ANSWER CHOICES	RESPONSES	
<2yrs	26.16%	62
2-5yrs	37.97%	90
6-9yrs	15.19%	36
10-13yrs	8.02%	19
14-17yrs	4.22%	10
18yrs and above	8.44%	20
TOTAL		237

Q3 Have you ever heard of Silver Diamine Fluoride (SDF) before this survey? If your answer is “No”, the summary at question 6 will give you a brief idea of SDF.

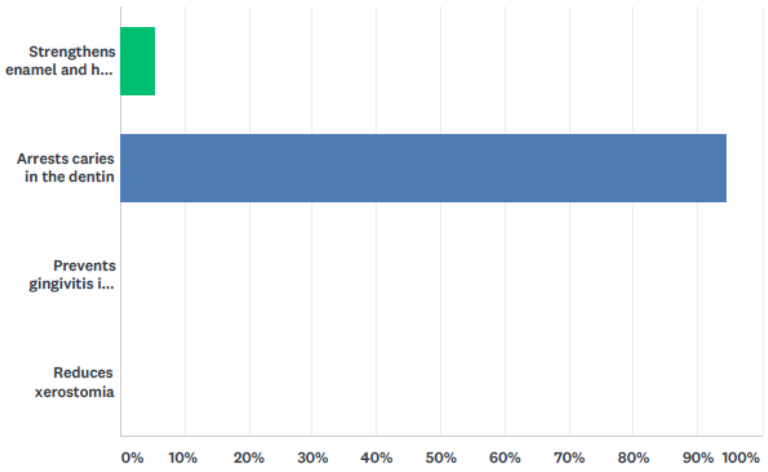
Answered: 237 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	87.76%	208
No	12.24%	29
TOTAL		237

Q4 Which ONE of the following effects is TRUE concerning Silver Diamine Fluoride?

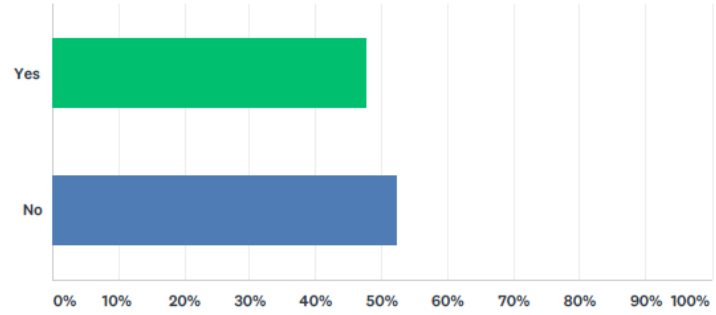
Answered: 237 Skipped: 0



ANSWER CHOICES	RESPONSES	
Strengthens enamel and has a whitening effect	5.49%	13
Arrests caries in the dentin	94.51%	224
Prevents gingivitis in AIDS patients	0.00%	0
Reduces xerostomia	0.00%	0
TOTAL		237

Q5 Do you know how to properly apply Silver Diamine Fluoride (SDF) on patients?

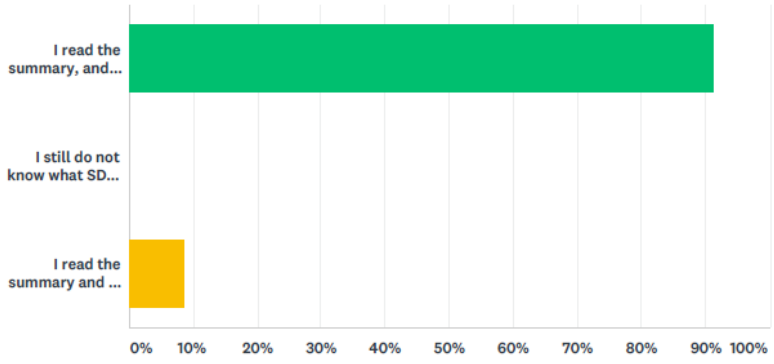
Answered: 237 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes	47.68%	113
No	52.32%	124
TOTAL		237

Q6 Summary: Silver Diamine Fluoride (SDF) is an FDA-approved antibiotic liquid for treating teeth hypersensitivity. However, SDF is more well known for its off-label use in arresting the progression of dental caries. Treatment with SDF will not eliminate the need for restorative dentistry to repair function or esthetics but has been effective in preventing further decay. Since only one drop is needed to apply on multiple teeth, SDF is proven to be very cost effective. Application of SDF also does not require the use of anesthesia. However, while it will effectively treat a carious lesion, a permanent dark stain will be left in its place.

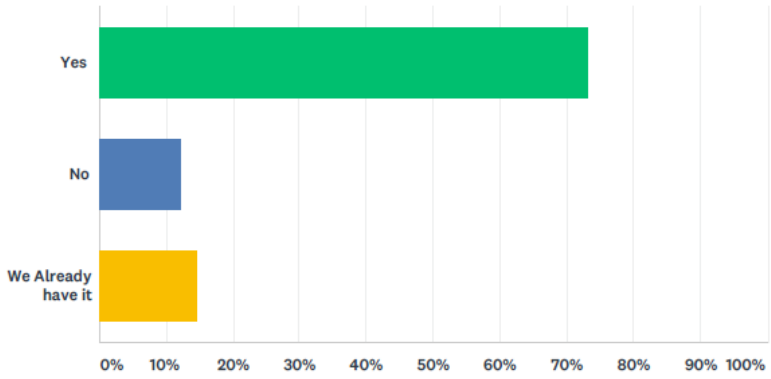
Answered: 232 Skipped: 5



ANSWER CHOICES	RESPONSES	
I read the summary, and I want to know more about SDF in clinical use.	91.38%	212
I still do not know what SDF does after reading the summary.	0.00%	0
I read the summary and I have no interest in using SDF	8.62%	20
TOTAL		232

Q7 Are you interested in making Silver Diamine Fluoride (SDF) available in your military clinic?

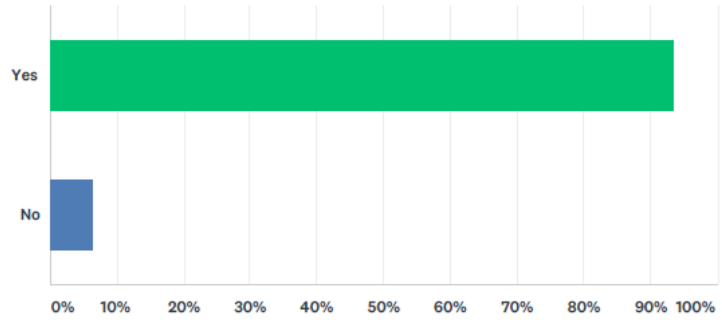
Answered: 232 Skipped: 5



ANSWER CHOICES	RESPONSES	
Yes	73.28%	170
No	12.07%	28
We Already have it	14.66%	34
TOTAL		232

Q8 If the Army Dental Corps started providing Silver Diamine Fluoride (SDF) in every clinic (CONUS & OCONUS), would you consider it as a treatment option?

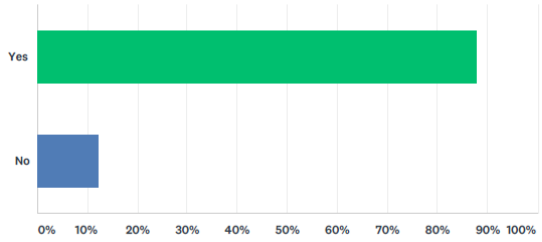
Answered: 232 Skipped: 5



ANSWER CHOICES	RESPONSES	
Yes	93.53%	217
No	6.47%	15
TOTAL		232

Q9 The SDF market mainly caters to pediatric patients with primary teeth. Since primary teeth will eventually be replaced with permanent dentition, parents/pediatric patients may be more willing to use SDF for its cost-effectiveness despite compromising esthetics. Also for the fact that SDF treatment does not involve a needle, so it could be a good option for uncooperative kids. Would you use SDF on an adult patient (permanent teeth) if it was a posterior tooth and the patient was fully aware that the carious lesion would be stained permanently?

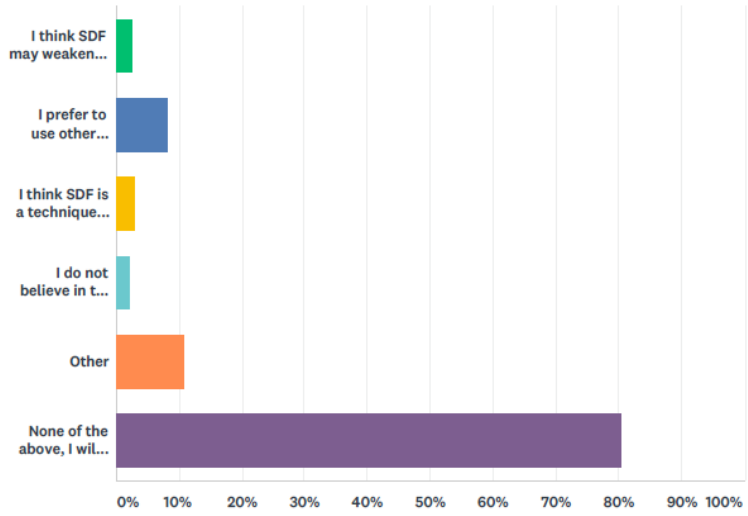
Answered: 232 Skipped: 5



ANSWER CHOICES	RESPONSES	
Yes	87.93%	204
No	12.07%	28
TOTAL		232

Q10 If you chose NOT to use SDF, what is/are your reason(s)? (Can choose multiple answers)

Answered: 232 Skipped: 5



ANSWER CHOICES	RESPONSES	
I think SDF may weaken bonding strength for resin restorations	2.59%	6
I prefer to use other materials for caries prevention and remineralization. (EX: Fluoride Varnish, Prevident, MI paste)	8.19%	19
I think SDF is a technique sensitive procedure which is not simple to apply.	3.02%	7
I do not believe in the effectiveness of SDF	2.16%	5
Other	10.78%	25
None of the above, I will use it.	80.60%	187
Total Respondents: 232		

Discussion:

In survey question #4 there were 13 dentists (5.49%) who did not know SDF's effect in arresting caries in dentin and they did not answer the question correctly. This question was purposely designed to see if people recognize SDF's most beneficial use in arresting caries and the negative side effect of staining the carious dentin. In the same question, 224 dentists (94.51%) recognize SDF's ability to arrest caries in dentin, which is also the most common off-label use. However, question #5 showed that only 113 dentists (47.68%) stated they know how to properly apply SDF. Question #7 showed that 170 dentists (73.28%) are willing to make SDF available in clinic and question #8 showed that 217 dentists (93.53%) are willing to consider using SDF as a treatment option.

Among the respondents who choose not to use SDF 2.16% of them selected, "I do not believe in the effectiveness of SDF." SDF achieves its caries-arresting ability from the bactericidal effect of the silver ions (Ag^{+}). Silver ions disrupt the bacterial cell wall membrane, sulfur-containing enzymes, and phosphorus-containing DNA particles within the bacteria [6]. The silver ions also create an electronic adhesion effect from the charge difference between silver ions and bacterial cell wall which prevents the aggregation of bacteria [6]. In the United States, silver nitrate was used in the 1950s during cavity preparation to ensure the caries were arrested [7]. Moreover, the silver ion content in SDF also creates a "zombie effect" which means the killed bacteria that remain are capable of killing the rest of the living bacteria [8]. Silver ions are able to create this "zombie effect" from their metallic feature, which does not degrade through the bactericidal process. The dead bacteria act as a reservoir for silver ions which leads to a long-term antimicrobial effect [8]. SDF has been proven to be a great antibacterial agent toward cariogenic

biofilm with members like *S. mutans*, *S. sanguis*, *Actinomyces naeslundii*, and *Lactobacilli* from multiple *in vitro* and *in vivo* studies [9, 10, 11, 12, 13, and 14].

Among the respondents who choose not to use SDF 2.56% of them selected, “I think SDF may weaken bonding strength for resin restorations.” SDF does not weaken bond strength of resin material to dentin. SDF has been used in clinical practice for over 80 years in Japan, and *in vitro* studies have shown that SDF actually improves the bond strength between glass ionomer to bovine dentin [16] [17]. Another *in vitro* study concluded that there was no significant difference in bond strength in both self-etch (SE) and etch-and-rinse (ER) groups post SDF treatment [18], which means that SDF will not affect bonding strength in both SE and ER adhesive systems. These results were supported by another study that combined SDF and a saturated solution of potassium iodide (SSKI). SSKI was added to decrease the black staining effect from SDF [19]. Finally, another *in vitro* study done by professors from University of Texas School of Dentistry at Houston and University of Michigan School of Dentistry suggested that “bonding is stronger between adhesives and dentin pretreated with SDF” rather than without SDF pretreatment [20].

Among the respondents who choose not to use SDF 8.19% of them selected, “I prefer to use other materials for caries prevention and remineralization (e.g., Fluoride Varnish (NaF), Prevident, MI paste). There is nothing wrong with using other materials. However, it is important to know the reasons behind every clinical decision as a provider instead of just doing what others have done for years. It is better to actually understand the underlying rational. For example, if the clinical goal is remineralization, then first the clinician should realize the remineralization mechanisms are different between enamel and dentin because of their composition. In dentin caries, beside the demineralization of hydroxyapatite, the degradation of organic matrix is also

involved [21]. Therefore, to achieve successful remineralization of the dentin layer, just by providing abundant fluoride ions is not enough. The bacterial enzymes such as collagenases should be inhibited from degrading collagen in dentin [21] because collagen is a matrix for hydroxyapatite crystals needed for remineralization [22]. A study in 2012 compared the inhibitory effect on matrix metalloproteinases (MMPs) of SDF and sodium fluoride (NaF) with the same fluoride ion concentration of 44,800 ppm. The result shows that 38% SDF has a significantly higher inhibitory effect on MMP than NaF [21]. SDF is also strongly alkaline which creates a favorable environment for remineralization [23]. A 2016 systematic review with five included studies concluded that SDF is more effective than NaF varnish in preventing caries and arresting dentin caries [3, 10, 24, and 25]. Clinicians should not ignore the black staining effect which creates an esthetic issue. Therefore, posterior teeth and primary teeth are preferred in SDF treatment. The clinician can also apply SSKI to decrease the black staining effect as long as the patient is not pregnant [1].

Among the respondents who choose not to use SDF 3.02% of them selected, “I think SDF is a technique sensitive procedure which is not simple to apply.” The key is to isolate the lesion properly with gauze and cotton rolls, so the lesion can remain dry before applying SDF. Good isolation prevents accidental black-staining in other locations including the patient’s clothes. SDF should be applied to the lesion for 1-3 minutes then rinse it off with water [1]. Dental hygienists and assistants are allowed to apply SDF in the state of California and Oregon under regulation for topical fluoride [1]. Nevertheless, providers should always be trained and review product’s instructions regardless of how simple the procedure is.

SDF was never designed to replace final restorations. Interproximal areas between teeth can pose a challenge to the application of SDF. Therefore, clinical practitioners can use SDF soaked floss for interproximal areas. The Soldier will still need to come back for a final restoration; however, SDF could buy some time for both the provider and the patient by arresting multiple caries at once. The same scenario can also apply in the field or during training when a Soldier has limited time. Although there is still an esthetic concern regarding the black staining side effect from SDF application, but for patient's oral health and the mission needs, a temporary esthetic compromise should be appropriate since the final restoration could cover up most, if not all, the black stain.

The high caries activity scenario can also occur in Soldiers' dependents. SDF is a noninvasive treatment that can reduce the need for local anesthesia, oral sedation, IV or general anesthesia, which can especially be helpful in pediatrics. Although parents may have concerns about the black staining effect from SDF in their children's mouth, a survey done in 2017 show that many parents will accept SDF treatment "to avoid having their children undergo general anesthesia" [27].

During the time of this survey, there are only twelve 63K (Pediatric dentists) in the Army Dental Corps. For children with high caries activities, SDF can be an effective material to arrest multiple caries in the first visit. SDF is also a cost-effective agent that does not require expensive equipment or a dental chair with electricity and water system [26]. Application of SDF once a year can achieve a similar caries-preventive result as the application of chlorhexidine or NaF varnish four times a year [26]. There are many positive potentials in using SDF in the military, further discussion should be carried on. Also, considering military as a mission oriented working environment, providers should have SDF as one of his/her treatment options. On 07JUN2018,

the research team received valuable feedback from an Army dentist who said that, "the only difficulty with SDF at our clinic is that it is not in the ordering system and requires a credit card order. We have a hard time with credit card orders taking forever. It would be much easier if they added it to DMLS."

The limit of this survey is the inability of tracking the identity of each survey participants based on their Area of Concentration 63A, 63B and 63K. Otherwise there could be more discussion in which AOC has the better understanding and acceptance level in using SDF. Based on the nature of the questions, this is basically a descriptive report. However, according to the statistical analyzation, significant difference was noted in the respondents' ability to apply SDF when individuals with >10years experience felt less comfortable using SDF than respondents with less experience.

Conclusion

As a well-studied and financially affordable treatment material, SDF does not have enough exposure among Army dentists. The didactic understanding of SDF can be improved among military active duty dentists, specifically for 63A general dentists, 63B comprehensive dentists and 63K pediatric dentists, which are the dentists with the opportunity to use SDF in their daily practice. This survey shows 93.53% of the respondents would like to have SDF as one of their treatment plan options but currently only 14.66% of the respondents have access to SDF in their clinic. The researcher suggest Army dental clinics consider making SDF a part of their inventory and increase the discussion of SDF during future CE courses. Some Army providers would like to use SDF but the current purchasing system is hindering the process. The researcher suggest adding SDF to the DMLS.

Beside the darkening effect, SDF is contraindicated for patients who have a silver allergy. Specific locations, such as interproximal surfaces, may physically hinder the application of SDF. Therefore, each patient should be evaluated individually before the application of SDF**.**

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Appendix

Table 1. Respondent Characteristics by Years in Dental Practice

	Years in Dental Practice						*P**
	0 - 5		6 - 10		10+		
	n	%	n	%	n	%	
Gender							
Male	101	66.0	26	76.5	41	82.0	0.07
Female	52	34.0	8	23.5	9	18.0	
Prior knowledge of SDF							
Yes	139	90.8	32	88.9	39	78.0	0.05
Able to apply SDF							
Yes	78	51.0	22	61.1	15	30.0	<0.01
Interested in using SDF							
Yes	143	94.7	32	88.9	43	91.5	0.40
Would use SDF on adult tooth							
Yes	134	88.7	31	86.1	41	87.2	0.89

* Significance based on Kruskal-Wallis test

Table 2. Reasons for not using SDF

	n	%
SDF may weaken bonding strength for resin restorations	7	2.9
Prefer to use other materials for caries prevention and remineralization	20	8.4
SDF is not simple to apply	8	3.3
SDF is ineffective	5	2.1
Other	25	10.5