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Teaching and utilization of silver diamine fluoride and Hall-style crowns in US pediatric dentistry residency programs

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Supplemental material is available online.

ABSTRACT

Background. Nonsurgical caries management, particularly silver diamine fluoride (SDF) and Hall-style crowns, present alternative options for populations that have barriers to traditional treatment. The authors aimed to assess changes in the teaching and utilization of these modalities in pediatric dental residency programs.

Methods. The authors e-mailed a 29-question electronic survey regarding the utilization and teaching of nonsurgical caries management agents to US pediatric dentistry residency program directors. Data were compared with results from a similar survey conducted in 2015 to analyze trends, report protocols, barriers for utilization, and possible reasons for changes.

Results. Respondents from 82 programs completed the surveys (89% response rate). Although only 26% of respondents reported using SDF in 2015, 100% reported its utilization in 2020 ($P < .001$). The Hall-style crown technique is taught didactically in 90% of programs, and 69.5% of respondents use it at least sporadically in their clinics. Long wait times for the operating room (4 weeks-14 months) and sedation (1 week-12 months) motivate increased utilization of SDF, interim therapeutic restorations, and Hall-style crowns. Guidelines supporting off-label utilization of SDF have also resulted in its increased utilization.

Conclusions. US pediatric residency programs have universally adopted SDF for caries arrest in the primary dentition, and this trend seems to extend to other nonsurgical caries management agents. These changes are likely driven by diverse barriers to delivery of traditional restorative care.

Practical Implications. The rapid increases in teaching and utilization of minimal intervention techniques provide clinicians with more options for caries management in patients with barriers to traditional treatment.

Key Words. Nonsurgical caries management; silver diamine fluoride; Hall crowns; Hall technique; caries arrest; minimal intervention dentistry; pediatric dentistry.

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Untreated caries in children is one of the most common health problems that are preventable with timely intervention and preventive methods.[1,2] Young children and patients with special needs with limited cooperation for restorative treatment often require sedation or general anesthesia to receive restorative treatment. This results in additional costs and risk and can create treatment delays and additional barriers.[3] Nonsurgical methods for caries management offer a viable alternative to treat vulnerable populations who are unable to receive traditional oral health care,[4] and they include the utilization of silver diamine fluoride (SDF), interim therapeutic restorations (ITR), atraumatic restorative treatment (ART), and Hall-style crowns, usually in conjunction with other methods of caries prevention, such as fluoride products and antibacterial agents.[5]

Studies support that when SDF is utilized twice a year, caries arrest in dentinal lesions of primary teeth can approach 80%,[6] with arrest rates ranging from 54% through 90%, depending on tooth location, size of the cavity, and presence of plaque.[7] These results are achieved without caries removal[8] and without the need for local anesthetic, which makes it easy to use and minimally

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invasive.[3] In 2014, the US Food and Drug Administration approved SDF as a device to treat dentinal sensitivity in adults older than 21 years. Its main drawback is the dark staining of arrested lesions. Because it is also an affordable therapy with minimal adverse effects and relative safety, it is now used off-label for treating young patients, those with behavioral problems, and patients who experience barriers to conventional restorative care.

The Hall technique is a method of using preformed metal crowns (stainless steel crowns [SSCs]) that calls for their cementation over a caries-affected primary molar without local anesthesia, caries removal, or tooth preparation.[9] It was developed for utilization when delivery of ideal treatment was not feasible, and it has gained some popularity in the United Kingdom and Germany, where use of traditionally placed SSCs is infrequent.[10] This technique relies on the principle that sealing existing caries will stop caries progression. It might also require a separate visit for placement of a separator to create interproximal space when there are closed contacts.[11] Some researchers have reported modifications of the technique that include partial caries removal, proximal tooth slicing, or both.[12,13] In our study, we used the term *Hall-style crowns* to allow modifications of the technique to be included in the responses.

Pediatric dentistry residency programs deliver care to children who have problems with access and limited cooperation for treatment and require extensive care, many of whom are enrolled in Medicaid. Minimal intervention approaches provide treatment options that are particularly useful in caring for this population, and it is likely that specialists who serve these children will find utility in this approach. The curriculum standards for these programs require dental schools to prepare residents beyond the level of general dentists. However, because pediatric dentistry faculty are generally responsible for training both pre- and postdoctoral students, it is likely that dental students will also be exposed to these concepts. As a result, curriculum trends in these specialty programs represent the leading edge of dental education and may be an indication of changes to come in undergraduate dental education and dental hygiene curricula.[14]

A 2015 survey of pediatric dentistry graduate program directors[14] assessed the utilization and teaching of SDF and other caries-control techniques. It found that although only 26% of the programs utilized or taught SDF in their clinics, 69% expected an increase in implementation. The main barrier cited for utilization was parental acceptance. Since then, the American Academy of Pediatric Dentistry has created a guideline for the use of SDF and numerous other studies have been published on this topic.[4,15]

The purpose of our study was to assess the current utilization and teaching of SDF, Hall-style crowns, and other caries-control methods in postgraduate pediatric dentistry programs and compare our results with those obtained in the 2015 survey. In addition, we determined factors associated with implementation, protocols for use, and potential barriers.

METHODS

Our study's protocol for a Web-based questionnaire was determined to be exempt from federal policy by the New York University Institutional Review Board under IRB-FY2020-4061.

Participants

The questionnaire was directed to pediatric dentistry residency program directors and associate program directors. The instructions allowed the program director to designate a faculty member to answer the questionnaire if preferred. A list and contact information for all registered US programs were obtained from the American Academy of Pediatric Dentistry Web site (www.aapd.org). It consisted of 92 sites with 80 program directors and 13 associate program directors from the NYU Langone residency programs. The list was updated for errors and missing data directly from the Web sites of individual programs via e-mail or phone up until the date of the end of the survey.

Survey instrument

To allow for direct comparison, we used the same questions asked in the 2015 survey, which was composed of Likert-style, multiple-choice, and fill-in responses. Questions about the teaching and utilization of Hall-style crowns were appended to the original survey instrument. Additional questions covered indications for utilization, actual protocols, consent forms, follow-up for SDF, and perceived barriers to its utilization. In addition, we inquired about the wait times for general anesthesia and sedation in each program and whether long wait times had affected use of

ABBREVIATION KEY

APF: Acidulated phosphate fluoride.
CHX: Chlorhexidine.
F: Fluoride.
FV: Fluoride varnish.
ITR: Interim therapeutic restoration.
NR: Not reported.
OR: Operating room.
SDF: Silver diamine fluoride.
SSC: Stainless steel crown.

Table 1. Characteristics of pediatric dentistry residency programs.

CATEGORY	SURVEY YEAR	
	2015[14]	2020
Program Surveyed		
Responses received, no. (%)	74 (100)	82 (100)
Response rate, %	85.1	89.1
Program Region, No. (%)		
Northeast	29 (39.2)	39 (47.6)
South/Southeast	20 (27.0)	19 (23.2)
Midwest	10 (13.5)	10 (12.2)
West	12 (16.2)	12 (14.6)
Missing*	3 (4.0)	2 (2.4)
Program Type, No. (%)		
University-based	11 (14.8)	13 (15.9)
Hospital	37 (50.0)	40 (48.8)
Combined	23 (31.1)	27 (32.9)
Missing*	3 (4.0)	2 (2.4)
Program Directors' Years in Practice, No. (%)		
1-5	10 (13.5)	2 (2.4)
6-10	13 (17.5)	19 (23.2)
11-15	17 (23.0)	18 (22.0)
16-20	4 (5.4)	14 (17.1)
≥ 21	27 (36.5)	28 (34.1)
Missing*	3 (4.0)	1 (1.2)
Years as Program Director, No. (%)		
0-5	48 (64.9)	43 (52.4)
6-10	14 (18.9)	20 (24.4)
11-15	6 (8.1)	7 (8.5)
16-20	NR†	3 (3.7)
≥ 21	2 (2.7)	2 (2.4)
Missing*	4 (5.4)	7 (8.5)

* Data missing because the respondent chose not to answer that question. † NR: Not reported.

nonsurgical methods. Directors were queried regarding their own practice experiences and years in the director position, and they had a choice to sign their name and provide contact information or submit the survey anonymously. The total number of questions was 29, and the survey was designed to be completed in approximately 10 minutes.

Survey methods

The survey was administered via SurveyMonkey, with a cover invitation from the principal investigator to the program directors with a description of the study and a link to the survey. Participating in the survey implied consent. The first mailing was sent on January 20, 2020, with an e-mail reminder sent to program directors who had not responded 1 week later. A third e-mail was sent 1 week after that. The end date of the survey was February 17, 2020.

Data analysis

Survey responses were exported to and analysis was completed using IBM SPSS software, Version 26. Frequencies and percentages were calculated for each survey item. Comparison of those

Table 2. Reports of utilization and teaching caries control in US pediatric residency programs in 2015* (n = 74) and in 2020 (n = 82).

VARIABLE	UTILIZATION, NO. (%)		TEACHING, NO. (%)			
	Utilized 2015	Utilize Currently 2020	Didactic 2015	Didactic 2020	Clinical 2015	Clinical 2020
Silver Diamine Fluoride	19 (25.7)	82 (100)	59 (79.7)	80 (97.6)	19 (25.7)	80 (97.6)
Povidone Iodine	1 (1.3)	2 (2.5)	43 (58.1)	24 (29.6)	2 (2.7)	0 (0)
Silver Nitrate	7 (9.5)	2 (2.5)	46 (62.2)	35 (43.2)	6 (8.1)	2 (2.5)
Fluoride Varnish	74 (100)	82 (100)	69 (93.2)	79 (96.3)	70 (94.6)	80 (97.6)
Acidulated Phosphate Fluoride Foam	36 (48.6)	23 (28.4)	63 (85.1)	64 (79.0)	38 (51.4)	27 (33.3)
Hall-Style Crown	NR*	56 (69.1)	NR	74 (90.2)	NR	57 (69.5)

* NR: Not reported. † Source: Nelson and colleagues.[14]

frequencies between the 2015 and 2020 survey responses was accomplished with the χ^2- statistic. Analysis of variance was used to compare reported wait times between groups. In general, exact *P* levels are provided, except when less than .001. A *P* value $< .05$ implies significance.

RESULTS

The response rate was 89%. Surveys were completed by 64 residency directors, 10 associate directors, and 6 faculty designees. Two surveys were completed anonymously.

The distribution of the respondents by region and program type, as well as the directors' years in practice and years as program director, are provided in Table 1. These distributions were similar to those in the 2015 survey. The largest group of current respondents had been in practice for more than 20 years (34%), but most respondents had been a program director for less than 5 years (52%).

Our results indicate that although only 26% of respondents reported using SDF in their clinics in 2015, 100% reported using it in 2020, an increase of 74% (95% confidence interval, 61% to 83%; $P < .001$). Although there was a small increase in the number of programs that taught the utilization of SDF didactically, the major change seems to be a 72% increase in teaching its utilization in graduate program clinics (95% confidence interval, 58% to 81%; $P < .001$) (Table 2).

Universal utilization of fluoride varnish (FV) was unchanged from 2015, as was the minimal utilization of povidone iodine. The utilization of silver nitrate and acidulated phosphate fluoride foam trended lower but was statistically similar over time (from 9.5% to 2.5% and from 49% to 28%; $P = .10$ and $P = .06$, respectively).

In 2020, respondents from 90% of programs reported didactic teaching of Hall-style crowns and 69.5% of respondents reported using them in their clinics, although most (62%) reported using the procedure for few patients (Figure 1) (this question was not asked in the 2015 survey).

Use of preventive agents in 2020 varied on the basis of caries risk. Although FV was reportedly administered to nearly all patients, 5,000 parts per million fluoride gel and SDF were reportedly utilized selectively for those at high risk of developing caries. Respondents reported that povidone iodine and silver nitrate were rarely utilized clinically, and there was considerable variation among programs in utilization of agents such as casein phosphopeptide—amorphous calcium phosphate paste and chlorhexidine rinse (Figure 1).

In terms of utilization and indications, there appears to be general agreement that SDF should be utilized in high-risk patients and on cavitated lesions in the primary dentition. There was less consensus on its use on permanent teeth. Most respondents felt that SDF was appropriate in special situations (for example, precooperative children, those with behavioral issues, medically fragile children) and given logistical challenges. As in the 2015 survey, more than one-half of the respondents agreed that parental acceptance of SDF is a barrier to treatment. Reimbursement also appears to be a major concern, with 45% of respondents strongly agreeing or agreeing that it is a barrier to utilization. By contrast, most respondents did not cite safety, off-label use, standard of care, evidence base, training, product supply, or cost as barriers to SDF care (Table 3).

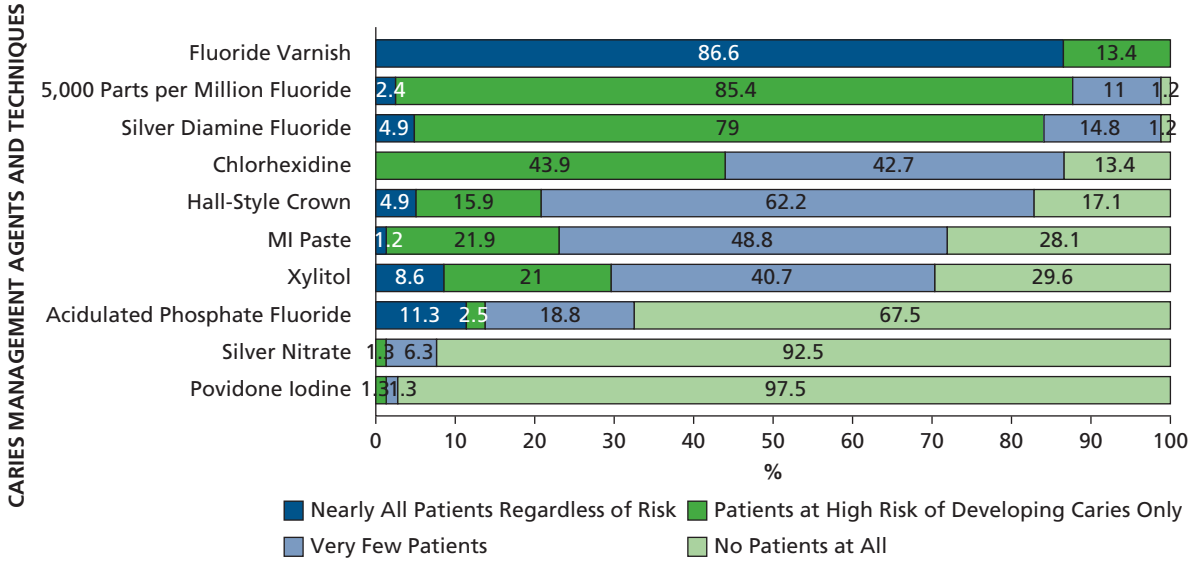

Figure 1. Use of specific caries management agents and techniques. MI: Casein phosphopeptide-amorphous calcium phosphate paste.

Almost all respondents (99%) report using the 2017 American Academy of Pediatric Dentistry guideline for SDF as a resource when teaching, and 86% said that this guideline has resulted in increased utilization of SDF in their clinics. Most (98%) were familiar with the Current Dental Terminology dental procedure code to bill for SDF.

Table 4 shows the breakdown of reported protocols for utilization.

Almost all respondents (95%) reported using SDF as an interim treatment, 91% agreed that a consent form should be obtained, and 83% use a specific consent form in their programs.

Wait times for treatment in the operating room (OR) ranged from 4 weeks through 14 months and wait time for in-clinic procedural sedation ranged from 1 week through 12 months. Figure 2 shows the distribution of reported wait times for each procedure. The median wait time for the OR was 4 months and for sedation it was 6.4 weeks. Reported wait times were statistically similar in different parts of the country (data not shown) and when reported by different types of program (university-based, hospital, or combined). Seventy-seven percent of respondents claim that these long wait times to receive definitive treatment have influenced their increased utilization of SDF. Sixty-eight percent reported using ITR, and only 29% use Hall-style crowns for this reason.

DISCUSSION

Historically, dental providers treating early childhood caries had few alternatives to conventional restorative treatment, and behavioral limitations in young children often necessitated use of sedation and anesthesia. We present evidence that the paradigm is shifting, with nearly all pediatric dentistry residencies now teaching caries management with techniques like SDF, IRT, and Hall-style crowns. Availability of professional guidelines on minimal intervention and nonrestorative treatment has also likely increased understanding, justification for off-label utilization, and clinical implementation.

The sociomedical climate must also be considered. Today's parents are less tolerant of physical behavior management strategies and are more likely than past generations to accept procedural sedation and general anesthesia for treatment.[16,17] Accordingly, in the US and Canada, we have seen an increase in use of pharmacologic behavior guidance for pediatric oral health care.[2,18] Although relatively well accepted by many parents, these procedures carry risk, especially in children younger than 3 years and those with comorbidities.[19,20] These concerns have affected the way parents and oral health care providers view treatment of caries in young children, influencing pediatric dentistry training programs to rapidly adopt new minimal intervention treatments.

Although the utilization of SDF is widely adopted, Hall-style crowns are still used sparingly in US programs (Table 1). This may be partly because familiarity with use of conventional SSCs make it a fast and easy procedure to perform with minimal patient discomfort.[12] The conventional procedure

Table 3. Perceived indication and barriers to the utilization of silver diamine fluoride in US pediatric dentistry residency programs in 2020 (n = 82).

VARIABLE	STRONGLY AGREE, NO. (%)	AGREE, NO. (%)	DISAGREE, NO. (%)	STRONGLY DISAGREE, NO. (%)	MISSING,* NO. (%)
Perceived Indications for Silver Diamine Fluoride					
Patients at high risk of developing caries	69 (84.1)	12 (14.6)	1 (1.2)	NA†	NA
Cavitated lesions					
Primary teeth	59 (72.0)	18 (22.0)	3 (3.7)	2 (2.4)	NA
Permanent teeth	40 (48.8)	27 (32.9)	13 (15.9)	2 (2.4)	NA
Incipient lesions (enamel defects)					
Primary teeth	29 (35.4)	31 (37.8)	15 (18.3)	7 (8.5)	NA
Permanent teeth	23 (28.0)	29 (35.4)	22 (26.8)	8 (9.8)	NA
Patients who cannot receive conventional treatment					
Precooperative	73 (89.0)	8 (9.8)	NA	1 (1.2)	NA
Behavioral issues	74 (90.2)	7 (8.5)	1 (1.2)	NA	NA
Medically fragile	75 (91.5)	6 (7.3)	1 (1.2)	NA	NA
Logistical challenges	69 (84.1)	11 (13.4)	2 (2.4)	NA	NA
Perceived Barriers to Implementation of Silver Diamine Fluoride					
Concern regarding					
Parental acceptance	25 (30.5)	24 (29.3)	27 (32.9)	5 (6.1)	1 (1.2)
Safety	9 (11.0)	11 (13.4)	37 (45.1)	24 (29.3)	1 (1.2)
Off-label utilization	3 (3.7)	14 (17.1)	36 (43.9)	28 (34.1)	1 (1.2)
Standard of care	6 (7.3)	22 (26.8)	33 (40.2)	20 (24.4)	1 (1.2)
Evidence base	14 (17.1)	13 (15.9)	31 (37.8)	22 (26.8)	2 (2.4)
Reimbursement	13 (15.9)	25 (30.5)	33 (40.2)	11 (13.4)	NA
Residents have inadequate training	8 (9.8)	6 (7.3)	42 (51.2)	26 (31.7)	NA
Obtaining product	4 (4.9)	3 (3.7)	39 (47.6)	36 (43.9)	NA
Cost	4 (4.9)	11 (13.4)	42 (51.2)	25 (30.5)	NA

* Data missing because the respondent chose not to answer that question. † NA: Not applicable.

can be completed in 1 visit and it avoids problems like transient open bite and traumatic occlusion. Teaching of the conventional SSC technique has changed considerably over time, as modern preformed crowns require minimal tooth preparation, and most programs have embraced the concept of partial caries removal with indirect pulp therapy, which has reduced the need for pulpotomies before SSC placement.[21] This is not only the case in the United States. Investigators studied the practices of 709 pediatric dentists from 65 different countries and found that although 54% reported using Hall-style crowns, practitioners largely consider this technique a treatment option, not the reference standard.[12] The authors also reported that for a cooperative 6-year-old patient, 75% of respondents would choose a conventional SSC over a Hall-style crown.[12] This is consistent with our findings, in which most programs teach the technique didactically and utilization it clinically in a limited number of patients.

Most directors credited the long waiting times for ORs and sedation with increasing their utilization of SDF. This comes as no surprise, as wait times as long as 12 and 14 months for sedation and general anesthesia, respectively, allow plenty of time for emergency situations to emerge in children who have substantial disease burden. Written comments from respondents cited that they utilize SDF on very young children (< 24 months) "to delay treatment that requires use of sedation or [general anesthesia]." Others reported utilizing SDF routinely on patients scheduled for sedation or general anesthesia "to decrease the risk of irreversible/necrotic pulpal status while they wait."

Others reflected that minimal intervention techniques give them the time to implement other behavioral interventions to manage caries: "We notice that in the absence of compliance and diet

Table 4. Reported protocols for silver diamine fluoride utilization.

PROTOCOL	NO. (%)
Frequency of Application of SDF* (n = 82)	
2 times per year	49 (59.76)
4 times per year	11 (13.41)
Only a single application	22 (26.83)
Utilization of Glass Ionomer After SDF Application† (n = 79)	
Same visit	25 (32.1)
Later visit	65 (82.3)
Restore conventionally	78 (98.7)
Utilization of Fluoride Varnish (n = 80)	
On the same visit	57 (71.3)
3 months later	13 (16.3)
6 months later	10 (12.5)
Follow-Up Protocol After SDF Application (n = 80)	
2-4 weeks	42 (52.5)
3 months	31 (38.8)
6 months	6 (7.5)
Reapplication of SDF During the First Follow-Up Visit (n = 80)	
Yes	38 (47.5)
Only if not arrested	42 (52.5)
No	0 (0)

* SDF: Silver diamine fluoride. † Respondents were allowed more than 1 response.

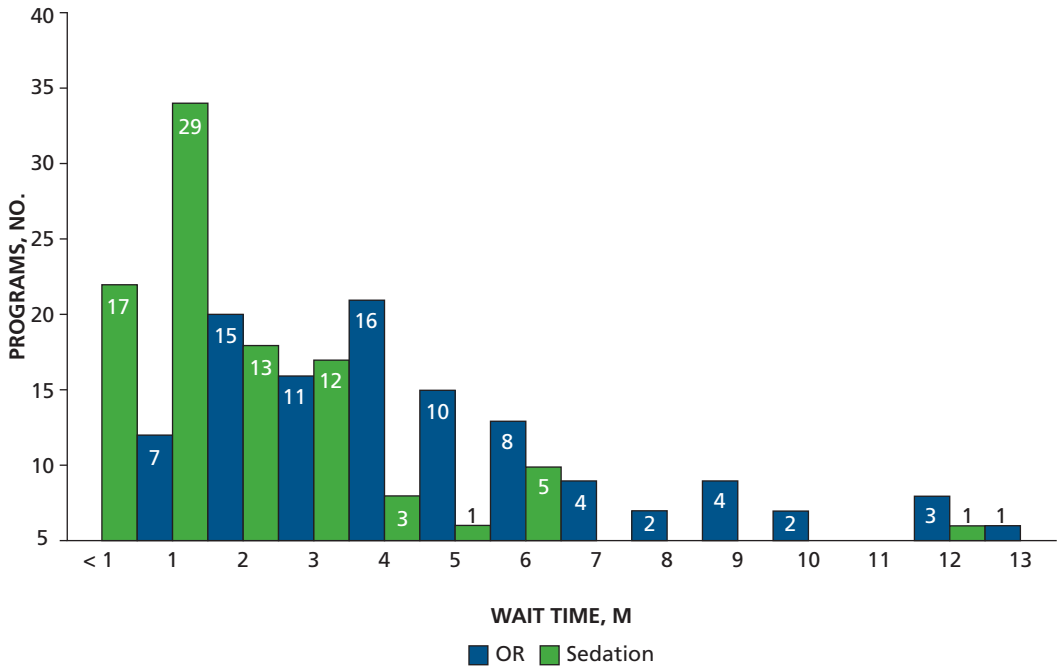

Figure 2. Wait times for procedural sedation and general anesthesia. OR: Operating room.

modification, our success rate (with SDF) has not been stellar." The desensitizing actions of SDF can allow a patient to implement the necessary hygiene practices that slow lesion progression and prevent emergency flare-ups while waiting for definitive treatment. Others commented that SDF

and Hall-style crowns also provide an alternative to manage a limited number of lesions in precooperative patients instead of opting for general anesthesia.

Most of the directors agreed that SDF does not work all the time or in all situations, so patients should be closely monitored with a follow-up visit. Many suggested reapplications to be coordinated with applications of FV for primary prevention of caries. This is consistent with current guidelines.[4,15] However, as seen in Table 4, most programs apply FV on the same visit as the SDF, a protocol that was not utilized in any of the clinical trials that are cited as the basis for expected arrest rates.[3] The effect on arrest rates (or caries prevention) when SDF is immediately covered with FV has not been investigated or reported.

Although most respondents listed SDF as an interim treatment, their comments, which expand on the data in Table 4, reflect that the later placement of a glass ionomer or other restorative material depends on multiple factors, such as life expectancy of the tooth, patient behavior, overall caries risk, treatment setting, goal of SDF placement, and parental preferences. This seems to indicate that most restore after SDF on a case-by-case basis. For example, 1 director suggested that it could be utilized as "definitive treatment on patients whose medical status renders them too fragile to deliver other alternatives."

The increased utilization of FV, SDF, 5,000 parts per million fluoride, and chlorhexidine rinses (Figure 1) shows that in addition to in-office treatments, most programs support a risk-based caries management plan that includes home use of remineralizing and antibacterial agents to promote sustained health.[22,23]

As in the 2015 survey, parental acceptance is still considered to be a considerable barrier to utilization of SDF (Table 3). This is consistent with 2017 US data, indicating that parents find the treatment more acceptable when the discoloration is not clearly visible.[24] In that study, although many parents were willing to compromise esthetics to avoid general anesthesia, one-third of parents found the staining unacceptable under any circumstance. The effect was mediated by parent education, income, and ethnicity. Program directors throughout the country have found that many parents prefer tooth-colored restorations and esthetic crowns over the utilization of SDF.

Reimbursement is another frequently reported barrier (Table 3). Not all insurance programs or state Medicaid managed care companies pay for SDF; some pay an amount per tooth and others pay per treatment. It was clear from survey comments that finances influence follow-up protocols and subsequent restoration placement. Regardless of the program type (hospital, university-based, or combined), reimbursement for procedures performed is critical to sustainability of treatment to underserved communities.

At the time of this writing, we are in the midst of a global pandemic. COVID-19 is spread primarily through exposure to respiratory droplets. The practice of dentistry requires patients and oral health care providers to be in close proximity with frequent generation of aerosols, which increases the potential for transmission.[25] Although it is still uncertain how the public health crisis will change dental practice, it is apparent that it is not possible to simply put a pause on oral health care. Every day at our institutions we see patients seeking treatment for true dental emergencies. Wait times for procedural sedation and general anesthesia will get even longer, as the current situation in hospitals throughout the country has forced all programs to defer "nonurgent" treatment for 3 months and perhaps much longer. Minimal intervention approaches, such as SDF, ITR, and Hall-style crowns, can be implemented to address these needs, while limiting generation of aerosol and combining with procedural sedation to provide extractions and other urgent procedures for young patients. This experience highlights the importance of maintaining a broad skill set to safely and compassionately address the patient needs in the context of an ever-changing practice climate.

CONCLUSIONS

Pediatric dentistry residency programs in the US seem to be moving toward increased utilization of nonsurgical approaches like SDF, ITR, and Hall-style crowns as essential components of a comprehensive caries management plan based on risk assessment that is tailored to address patient needs. The simplicity and utility of these treatment options makes them an attractive component of both pre- and postdoctoral training. Accordingly, this trend in specialty programs may also be an indication of curriculum trajectory in undergraduate dental education.

Increased utilization and teaching of minimal intervention techniques in specialty education programs will eventually result in more practicing dentists embracing those approaches. This

paradigm change provides clinicians with additional options for caries management, offering flexibility to tailor treatment to suit patient needs and the constraints of practice in the modern era. ■

SUPPLEMENTAL DATA

Supplemental data related to this article can be found at https://doi.org/10.1016/j.adaj.2020.06.022.

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