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Randomized controlled trial on the effectiveness of silver diamine fluoride in arresting caries in Lagos, Nigeria

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Treatment of dental caries in children still remains challenging due to lack of cooperation with conventional treatment modalities. Recently, the use of Silver Diamine Fluoride (SDF) has proved useful in addressing this challenge. **Aim:** This clinical trial aimed to evaluate the effectiveness of Silver Diamine Fluoride (SDF) in arresting caries in children in Lagos, Nigeria. **Methods:** This was a phase III balanced randomized controlled school based interventional study on 240 children. The study group was treated with SDF while GIC was used in the control group. Follow up visits in 2 weeks, 1 month, and 3 months were carried out to assess the treatment outcome. Inferential statistics with the use of Pearson Chi-square test and Independent Student t-test were used at 5% level of significance. **Results:** There was significant relationship between SDF and caries arrest in 2 weeks, 1 month and 3 months' assessment period (p = 0.001). The control group showed continuous decline (71.7%, 54.3% and 50.9%) in restorative success from 2 weeks to 3 months respectively. The mean ± SD and Confidence Interval (CI) of arrested caries in the SDF group were 113± 1.24 and 113.1 – 113.5 respectively. In the control group the mean ± SD and CI of restorative success were 69.3±11.8 and 67.2 – 71.4. The effect size was 5.24. **Conclusion:** The result of the study showed that SDF was effective in arresting caries in children without any harm and there was statistically significant difference in the use of 38% SDF in arresting caries in children.

Keywords: Dental caries. Glass ionomer cement. Fluorides, topical.

Introduction

According to the Global Burden of Disease Study, an estimated 3.8 billion people are affected by dental caries[1]. In Nigeria, the prevalence of caries among children is still high despite current preventive and control strategies[2,3]. Recently, Adeniyi et al.[4] reported 14.8% prevalence of dental caries among children aged 5 – 10 years in Lagos, Nigeria. Though this figure is still within the WHO Millennium Development Goals target for dental caries, its impacts on children's health cannot be over emphasized as it is estimated to be the most prevalent chronic childhood disease worldwide[5]. These impacts include pain and discomfort, difficulty in masticating, sleep and speech disturbance, poor self-esteem and social isolation among others. It can also negatively affect body weight, growth, school attendance, and school performance if left untreated[5]. The commonest treatment protocol for dental caries is traditional surgical intervention but prevention of caries is more cost effective and less invasive[6]. With the recent change from the surgical model, which places emphasis on restorative treatment, to a medical model which focuses on disease prevention and conservation of tooth structure, caries management in the present decade is fast becoming more patient friendly, effective and efficient[7].

Despite recent advances, the management of dental caries still remains challenging particularly with children, the aged, vulnerable populations and special health care needs patients, where gaining cooperation is still a significant problem in traditional restorative treatment of dental caries[8]. Furthermore, among those from low economic class, access to care and cost are hindrances to conventional dental caries treatment[8,9]. Thus, innovative treatment approach that reduces the burden of care on patients and the need for more comfortable, effective and efficient treatment protocols that would promote patient cooperation have continued to engage dental researchers and clinicians in recent times. The primary focus in these researches has been the use of chemotherapeutic agents in the prevention and arrest of caries particularly in children[10]. Consequently, a variety of chemotherapeutic agents such as metal ions, antibiotics and various types of fluoride containing agents have been developed, tested and used for preventing and arresting caries[11]. A notable innovative therapy among these is the use of Silver Diamine Fluoride (SDF)[10].

Silver Diamine Fluoride has clinical usefulness in children when patient cooperation for restorative dentistry is difficult due to situational anxiety, young age or intellectual and developmental disabilities[12,13]. SDF is also very useful where the restoration of primary tooth that is about to exfoliate is not an option. Since this process requires non-invasive procedures, the risk of cross-infection is significantly reduced. Clinical studies have shown that SDF prevents and arrests caries in children[13]. A review on SDF concluded that it is a safe, effective and efficient caries control agent that can be employed to meet the WHO Millennium Development Goals for 21st-Century[12-15]. Randomized clinical trials on the effectiveness of SDF have been carried out in United States, Europe and Asia[15-17]. In an ex-vivo study, Mei et al.[18] reported a highly remineralized rich zone in calcium and phosphate on arrested caries lesion of primary teeth with SDF application. In a related study, Milgrom et al.[19] also reported that application of 38% SDF arrested caries and was effective for the short-term treatment of caries

in pre-school age children. There is however no available published or unpublished research in Nigeria nor Africa on the effectiveness of SDF in arresting caries after meticulous search of relevant literature. There is also no research evidence to support the use of SDF in Africa despite the growing interest in this agent. Thus, the aim of this study was to evaluate the effectiveness of 38% Silver Diamine Fluoride in arresting caries in children in Lagos, Nigeria.

Materials and methods

Description of study area: The study was conducted in Lagos, Nigeria from October 2019 to March 2020. Lagos lies between latitude 6.465422 and longitude 3.406448[20]. It is bordered essentially in the south by Atlantic Ocean and hence it is a coastal city. As epicenter of commerce and industry, it is a heterogeneous State with mixed proportion of different ethno-religious groups and socioeconomic class. More significantly, because it is a commercial city the production and consumption of refined sugars is very high[21]. This is a favorable predisposing factor for the development of caries.

Study population: Children aged 3 – 10 years living in Lagos, Nigeria made up the study population. According to the National Population Commission the population of children aged 0 – 9 years in Lagos State in 2006 population census was 2,109,862[22]. The study age group ranks highest in the prevalence of dental caries in Lagos State estimated at 14.8%[4]. It is also the group with high incidence of Early Childhood Caries[4]. More importantly, it is the age group that poses difficulty in tolerating traditional restorative technique due to situational anxiety, low emotional stability and low intellectual understanding[23].

Study design: The study design was a Phase III Balanced Randomized Controlled Trial; Parallel Groups, Multicentre School Based Interventional Study conducted in Lagos Nigeria.

Ethical considerations: Approval for the study was obtained from the Lagos State University Teaching Hospital (LASUTH) Health Research and Ethics Committee with reference number LREC/06/10/1221 dated 31 July 2019. Approval for the study was also obtained from the Lagos State Government with reference no: LS/C-530/T.3/755-756 dated 28 Oct 19 with respect to the use of schools and primary school children for the study. Approval was also obtained from various school authorities where the study was conducted through the Education Secretaries of various districts used for the study. Informed and signed consents were obtained from parents, guardians and caregivers of children who participated in the study. Informed assent was obtained from the children during the study. Participants with increased caries activities during the course of the study were planned to be withdrawn from the study and given conventional treatment.

Registration of trial: The clinical trial was registered at Pan African Clinical Trials Registry (PACTR) with Trial no: PACTR201908699150281 dated 16/04/2019. Trial was registered in accordance with WHO and ICMJE standards.

Sampling Technique: A multistage sampling technique was utilized. Eight (8) public primary schools in Lagos State were selected in the first stage using computer gen-

erated random numbers, with the list of schools serving as the sampling frame. The second stage involved selection of classes in eligible classes in the schools by simple random sampling using the nominal rolls as a sampling frame. Children who fulfilled the eligibility criteria for the study were eventually enlisted. Eventual allocation of the recruited sample population into 2 equal groups was also done by simple randomization.

Sample size estimation: This was done with the formula:

$$n = \frac{(Z_{\alpha} + Z_{\beta})^2 \times 2p(1-p)}{d^2}$$ where:

n = sample size required in each group; Z_{α} = value for α at desired confidence level of 95%; α = 0.05 (two-tailed test) = 1.96; Z_{β} = value of β error, which is 1- β (statistical power). At statistical power of 95% and β error of 5%, $z_{\beta =}$ 1.94; p = proportion of dental caries in children aged 5 – 10 years in a reference study (prevalence is 14.8%; 0.148)[4;] and d = the minimum difference in the clinical performance between the two study groups. The minimum difference for this study was set at 20% in order to increase power of the study and give more validity to the study. Hence d = 20%.

Thus, n = 96.7

With 10% attrition or follow up losses (9.67), minimum sample for each group was 107 or 214 for the two groups. However, 240 subjects were recruited in all.

Eligibility Criteria

Inclusive Criteria: Children aged 3 -10 years, with dental caries ICDAS 5 or 6, with signed consent form from parents/guardians and signed or thumb printed the assent form that allowed for oral examination and application of intervention medicament and control treatment were included.

Exclusion Criteria: Children with symptomatic carious tooth (toothache or sensitivity), mobile carious tooth, with dental caries ICDAS 0-4; those who were exposed to fluoride from other sources apart from a dentifrice; those that were allergic to silver or heavy metals; with Amelogenesis or Dentinogenesis Imperfecta; with oral ulceration, stomatitis, swelling or abscess; with cooperation challenge; obviously mentally retarded; systemic illness like Asthma, Epilepsy, Leukaemia, Kidney disease and those whose parent or guardian could not understand the consent documentation were excluded from the study.

Research Questionnaire: An interviewer administered close ended structured questionnaire developed from previously validated questionnaires was used. It comprised sections A to E. Section A to D captured a participant's biodata, history, examination, and intervention and control data while section E documented the study outcomes.

Dental Caries Examination Tools and Treatment Set: The caries examination tools and treatment set comprised a comfortable field examination mobile dental chair unit which was set up in a well-lit and airy room in the schools used for the study. The examination instrument comprised standard WHO periodontal probe, wooden spatula, mouth mirror, 5ml hypodermic syringes with water, cotton gauze and rolls, meth-

ylated spirit and dental tray. The treatment set for SDF comprised dispensing dish, microbrushes, guage, cotton wool/rolls and dental tray. The treatment set for GIC restoration comprised atraumatic hand instruments (excavators, condensers, explorer, tweezers, dental hatchet, mouth mirrors, carvers, examination probes and periodontal probes), mixing pads, mixing spatula, plastic applicators, gauge, wedges, cotton wool/rolls/pellets, petroleum jelly and dental tray. The researchers were trained and calibrated to use these tools and instrument for diagnosis of ICDAS 5 or 6[24], treatment of caries and assessing the study outcome which is Arrested Caries using ICDAS II criteria by a Consultant Paediatric Dentist.

Intervention Medicament and Control Medicament: The intervention or experimental medicament for the study was 38% Silver Diamine Fluoride: TEDEQUIM S.R.L B.[25] The control Medicament was Glass Ionomer Cement (GIC): PrevestDenPro.[26]

Details and Sequence of Data Collection

Phase I - Recruitment and Intervention Phase.

Day 1: On the first day in each school, school children aged 3- 10 which cut across Nursery 1-2 and Primary 1-6 were examined for dental caries ICDAS 5 and 6. The examination was done in a well-lit open hall or school clinic provided by the school. The children were made to sit comfortably in a mobile dental chair unit. Examination of ICDAS 5 and 6 caries was done by direct visual examination using wooden spatula by two calibrated examiners. Records of the children with ICDAS 5 and 6 were taken and documented. The documented children with ICDAS 5 and 6 were given consent document and forms to give to their parents to authorize intervention.

Day 2 - *Interventions*: The children that were given the consent document and forms were recalled on day 2. The children with signed consent forms were randomized into experimental group and control group by randomization. The children in the two groups were counseled and then signed or thumb print the assent form. The children in Group 1 received SDF while the children in Group 2 received GIC.

***Administration of SDF*:** The children in Group 1 thereafter were treated with topical SDF. Using a comfortable mobile chair unit, Section A - C of the Questionnaire were administered to the children by the investigators. Thereafter, the affected carious tooth with ICDAS 5 or 6 was gently cleaned, dried and isolated with cotton rolls. Two drops of SDF solution was then applied with a disposable microbrush on the carious tooth. The treated participants were instructed not to rinse for the next 10 minutes. Subjects were also advised to continue their normal oral hygiene care. The intervention received with the treatment date as well as the tooth treated (ICDAS 5 or 6) and the caries class was all documented on Section D (Intervention Section) of the questionnaire. The date of the treatment and the school name were also recorded in the study book to calculate subsequent time of follow up visits.

***Administration of GIC*:** The children in Group 2 received GIC intervention. Like in Group 1, the children in Group 2 were administered Section A - C of the Questionnaire by the investigator and the research assistant (House Officer). Thereafter the researcher administered conventional GIC. The carious lesion of the affected tooth

with ICDAS 5 or 6 was excavated with disposable plastic excavator. The tooth was cleaned, dried and isolated with cotton rolls. Conventional GIC was then mixed in a high viscosity consistency and condensed on the tooth cavity and allowed to set. Petroleum jelly as a separating medium was then used to seal the GIC surface from saliva. The participants were instructed not to rinse for the next 10 minutes. Participants were also advised to continue their normal oral hygiene care. The intervention received with the treatment date as well as the tooth treated (ICDAS 5 or 6) and the caries class was all documented on Section D (Intervention Section) of the questionnaire. The dates of the treatment intervention and the school name were also recorded in the study book to calculate subsequent time of follow up visits.

***Phase II - Outcome Phase*:** Since it was a prospective study the second phase assessed the treatment outcomes. The outcomes were assessed in 2 weeks, 1 month and 3 months respectively. The outcomes that were assessed were as follows:

***Primary Outcome*:** The expected primary outcome for the experimental group was arrested caries while that for the control group was restorative success.

***Arrested Caries for SDF Group (Experimental Group)*:** Arrested caries was assessed using the ICDAS II criteria and findings were recorded in the questionnaire. The researcher examined the treated teeth for arrested and active caries. The assessment was done using visual tactile examination with aid of WHO probe and mouth mirror using the ICDAS II criteria[24] to classify active and arrested caries.

***Restorative Success for GIC Group (Control Group)*:** The restorative success of Glass Ionomer Cement was determined when signs of restorative failure were absent. Signs of GIC restorative failure included restoration losses (full or partial loss), fractures and wear. Assessment of restorative failure was done using both visual and tactile examination with the aid of examination probe and mouth mirror. The restoration was gently probed to assess for any sign of failure such as fracture, wear, partial loss or total loss. Findings were recorded accordingly in the participant's questionnaire. The type of restorative failure was also noted in each case. The follow-up outcome assessments were carried out in 2 weeks, 1 month and 3 months respectively after the intervention.

***Secondary Outcomes*:** The secondary outcomes that were assessed in both the experimental group and control group included toothache, sensitivity, stain, nausea, vomiting, silver allergy, oral soft tissue ulceration, rashes and any other noted complications. The assessments for secondary outcomes were done concurrently with the assessment of primary outcome. There was no case that necessitated hospital referral.

Data analysis: The obtained data was analyzed using Statistical Package for Social Sciences (SPSS IBM New York, USA) Windows Version 23. Data were coded and entered into Microsoft Excel spreadsheet and later imported into SPSS for cleaning and analysis. Descriptive statistics with the use of frequencies, percentage/proportion, mean and standard deviation were used to summarize data. Inferential statistics with the use of Pearson Chi-square test, Fisher exact test and Independent Student t-test were used to test for association between bivariate at 5% level of significance (95% Confidence interval). A value of $P < 0.05$ was considered statistically significant.

Results

A total of 240 school children aged 4 – 10 years participated in the study. Out of these, 124(51.7%) were male while 116(48.3%) were female, giving a male-to-female ratio of 1.1:1. The SDF group had 64(53.3%) males and 56(46.7%) females giving male to female ratio of 1.1:1 The Control group had 60 (50.0%) male and 60(50.0%) female giving male to female ratio of 1:1.

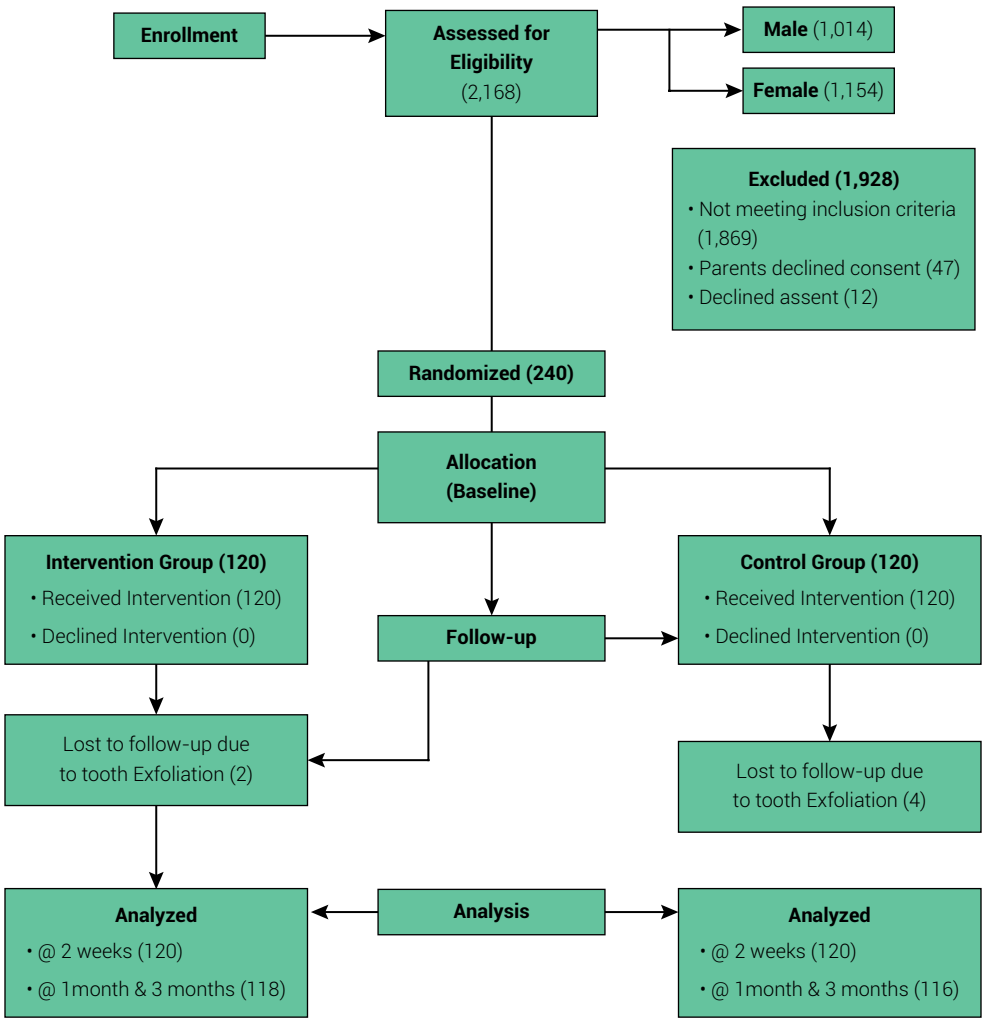

Figure 1. Participants Flowchart

The mean dmft in SDF group was 1.87±0.9 while the mean of control group was 1.75 ± 0.9. The total mean dmft was 1.81 ± 0.9. Overall, dmft score1 had the highest percentage of 47.9% closely followed by DMFT score 2 with 32.8%. dmft score 5 had the lowest percentage of 0.04%. There was no significant difference between the dmft scores in the two groups (p>0.05). **- Table 1**

Table 1. Distribution of dmft scores of participants

Variables	SDF Group (n=120) n (%)	Control (n=120) n (%)	Total (n=240) n (%)	t-test*	p
dmft Scores					
1	52 (43.3)	63(52.5)	115(47.9)	1.032	0.302
2	42(35.0)	35(29.2)	77(32.8)		
3	17(14.2)	14(11.6)	31(12.9)		
4	8(6.6)	6 (5.0)	14(5.8)		
5	0(0.0)	1 (0.8)	1 (0.04)		
6	1 (0.8)	1 (0.8)	2 (0.1)		
Mean±SD	1.87±0.9	1.75 ± 0.9	1.81 ± 0.9		

*Independent t-test

Table 2 shows the arrested/restorative success at different intervals of assessment. At 2 weeks' outcome assessment, 94.2% of the treated carious teeth in the SDF group showed hard arrested dentine, while 71.7% of the restored carious teeth in the control group showed restorative success. At the 1-month outcome assessment, the SDF group had 97.5% of the teeth showing arrested caries, while the control group had 54.3% showing restorative success. At 3 months' outcome assessment, 94.9% of the carious lesions in teeth treated with SDF were still arrested, while the control group showed 50.9% of teeth with restorative success. Chi-square test of independence showed there was significant relationship between SDF and caries arrest at 2 weeks, 1 month and 3 months' assessment period respectively ($p = 0.001$). There was a marginal increase of 3.3% in caries arrest in the SDF group between 2 weeks and 1-month outcome assessment. However, there was a slight decline in caries arrest of 2.6% between 1 month and 3 months of outcome assessment. The control group showed continuous decline (71.7%, 54.3% and 50.9%) in restorative success from 2 weeks to 3 months respectively.

Table 2. Distribution of Arrested Caries /Restorative Success at different intervals of assessment

Variables	SDF group (n=120) n(%)	Control (n=120) n(%)	Total	x^2	p-value
2 weeks' assessment					
Success	113(94.2)	86(71.7)	199(82.9)	21.444	**<0.001***
Failure	7(5.8)	34(238.3)	41(17.1)		
1 month's assessment					
Success	115(97.5)	63(54.3)	178(79.1)	60.031**	**<0.001***
Failure	3(2.5)	53(45.7)	56(23.9)		
3 months' assessment					
Success	112(94.9)	59(50.9)	171(73.1)	57.700	**<0.001***
Failure	6(5.1)	57(49.1)	63(26.9)		

Two (2) and 4 subjects lost to follow up at experimental group and control group respectively for one month and 3 months' assessments
**Fischer exact test

Table 3 shows the intervention failure at different intervals of assessment. In the SDF group, observed failure signs ranged from presence of dull enamel/dentine to soft dentine on examination. In the control group observed signs of failure ranged from partial loss of restoration to total loss and wear/fracture of restoration. At 2 weeks' outcome assessment, there were 7 non arrested carious teeth in the SDF group: 3(42.9%) were as a result of soft dentine while 4(57.1%) were as a result of dull enamel/dentine. At 1-month assessment, SDF group showed 3 non arrested cavities evidenced by dull enamel/ dentine. At three (3) months assessment. 5 treated teeth had dull dentine while one (1) had soft dentine. The control group recorded a greater number of restorative failures. There was a progressive failure rate of restoration. The restorative failure rate increased with time of assessment. A total of 57 restorative failures were observed out of 120 restored teeth giving a restorative failure rate of 47.5%. At 2 weeks' assessment there were a total of 34 restorative failures; 13(38.2%) due to partial loss of restoration, 15(44.1%) due to total loss and 6(17.6%) due to wear of restoration. One-month assessment showed a total of 50 restorative failures; 9(16.1%) was due to partial loss, 40(75.5%) as a result of total loss and one (1.9%) due to wear of restoration. At 3 months' assessment, there were 57 restorative failures: 7(12.3%) due to partial loss, 49(86.0%) as a result of total loss and one (1.8%) due to wear of restoration.

Table 3. Distribution of intervention failure at different intervals of assessment

	SDF group n(%)	Control n(%)	Total	X^2	p-value
2 weeks				41.000	**<0.001***
Dull enamel/Dentine	4(57.1)	0(0.0)	4(9.8)		
Partial loss of filling	0(0.0)	13(38.2)	17(31.7)		
Soft dentine	3(42.9)	0(0.0)	3(7.3)		
Total loss of filling	0(0.0)	15(44.1)	15(36.6)		
Wear of filling	0(0.0)	6(17.6)	6(14.6)		
1 month				26.415	**<0.001***
Dull enamel/Dentine	3(100.0)	3(5.7)	6(10.7)		
Partial loss of filling	0(0.0)	9(17.0)	9(16.1)		
Total loss of filling	0(0.0)	40(75.5)	40(71.4)		
Wear of filling	0(0.0)	1(1.9)	1(1.8)		
3 months				63.000	**<0.001***
Dull enamel/Dentine	5(83.3)	0(0.0)	5(7.9)		
Partial loss of filling	0(0.0)	7(12.3)	7(11.1)		
Soft dentine	1(16.7)	0(0.0)	1(1.6)		
Total loss of filling	0(0.0)	49(86.0)	49(77.8)		
Wear of restoration	0(0.0	1(1.8)	1(1.6)		

*Fisher exact test

The mean ± SD and Confidence Interval (CI) of arrested caries in the SDF group were 113± 1.24 and 113.1 – 113.5 respectively. In the control group the mean ± SD and CI of restorative success were 69.3±11.8 and 67.2 – 71.4. The effect size '*d*' of the study was 5.24. **- Table 4**

Table 4. Mean outcome of the two groups at different intervals of assessment and the effect size

Variables	SDF n =120	Control n =120	Mean ± SD SDF	Mean ± SD Control	d
Arrested/RS					
2 weeks	113	86	113.3±1.24	69.3±11.8	5.24
1 Month	115	63			
3 Months	112	59			
Variance			1.5*	141.5*	
95% CI			113.1- 113.5	67.2 -71.4**	

d = effect size, * variance, **CI RS Restorative Success

At two weeks' secondary outcome assessment, 6.7% of participants reported slight tooth sensitivity in the SDF group while 5.0% of participants reported tooth sensitivity in the control group. At 1-month, tooth sensitivity reduced in the SDF group to 0.8% while there was an increase in the control group to 5.2%. At 3 months the percentages of tooth sensitivity remained same for both the SDF group and control group at 0.8% and 5.2% respectively. There was significant relationship between tooth sensitivity and treatment modality at 1 month and 3 months' assessment periods ($p < 0.05$). **-Table 5**

Table 5. Tooth Sensitivity at different intervals of assessment

	Study group (n=120)	Control (n=120)	Total	X^2	p-value
2 weeks' assessment					
Yes	8(6.7)	6(5.0)	14(5.8)	0.303	0.582
No	112(93.3)	114(95.0)	226(94.2)		
1-month assessment					
Yes	1(0.8)	6(5.2)	7(3.0)	3.770**	**0.041***
No	117(99.2)	110(94.8)	227(97.0)		
3 months' assessment					
Yes	1(0.8)	6(5.2)	7(3.0)	3.770**	**0.041***
No	117(99.2)	110(94.8)	227(97.0)		

Two (2) and 4 subjects lost to follow up at experimental group and control group for one and 3 months' assessments
**Fischer exact test

Twenty-Four (24) hours after the interventions, there was no adverse effect in both the SDF group and control group. At 2 weeks follow up 99.2% of the participants in the SDF group had black stain without pain on the treated tooth while only one (0.8%) participant reported slight pain in the control group. At 1 month, 98.3% of the treated teeth in the SDF group showed black stain while none in the control group had any adverse effect. At 3 months follow up the black stain on treated teeth declined to 97.4% while there was no adverse effect in the control group. No allergic reaction or any other adverse effects was observed in both SDF group and control group at different intervals of assessment. Black teeth stains in the SDF group were statistically significant at 2 weeks, 1 month and 3 months' assessment period (P <0.001). **-Table 6**

Table 6. Distribution of Adverse effect of intervention at different intervals of assessment

	SDF group (n=120) (%)	Control (n=120) (%)	Total	Fischer exacts	p-value
24-hour assessment					
Nil adverse effect	120(100.0)	120(100.0)	240(100.0)	0.000	1.000
2 weeks' assessment					
Black stain	119(99.2)	0(0.0)	119(49.6)		
Slight pain	0(0.0)	1(0.8)	1(0.4)	236.033	**<0.001***
Nil Black stain/Pain	1(0.8)	119(99.2)	120(50.0)		
1-month assessment					
Black stain	116(98.3)	0(0.0)	116(48.3)	226.802	**<0.001***
Nil Black stain/Pain	2(0.02)	116(100)	118(49.2)		
3-month assessment					
Black stain	115(97.4)	0(0.0)	116(48.3)	226.802	**<0.001***
Nil Black stain/Pain	3(0.06)	116(100)	118(49.2)		

Two (2) and 4 subjects lost to follow up at experimental group and control group respectively for one and 3 months' assessments

DISCUSSION

The intervention teeth used in the study were posterior primary teeth. Most studies on the effectiveness of SDF in arresting caries in children also used posterior primary molars[23,27,28]. In this study, the second primary molars constituted the highest percentage (57.1%) of teeth used while the central incisors were least (0.4%). The high involvement of primary molars especially the second molar in caries formation could be due to the fact they are big, have broad surface areas with pits, grooves and fissures and are regularly used for chewing. Secondly, within the age bracket of the study, the primary molars experience more time exposure to caries than even the first permanent molars. With respect to ICDAS class, this study observed high ICDAS 5 - ICDAS 6 ratio of 1.5:1. This ratio is in congruence with Rosenblatt et al.[14]

and Zhi et al.[17] in their separate studies using the ICDAS system on the effectiveness of SDF in arresting caries in children. ICDAS 5 caries was more in this study because cavitation is minimal compared to ICDAS 6 and most often asymptomatic. Hence, it is unnoticed or ignored.

The clinical effectiveness of 38% SDF in arresting dental caries among children has been extensively researched and well documented[11,14,16,29-35]. Both RCTs and systematic reviews have been carried out[16,29,32-40] to evaluate its short and long-term effectiveness. In this study, the caries-arresting rate of 38% SDF was found to be 94.2% in 2 weeks, 97.5% in 1 month and 94.9% in 3 months. These findings agree comparably with recent clinical trials. Santos Jr et al.[37] reported 81% caries arrest in 1 week and 72.7% in 5 months. In a short-term clinical trial, Milgrom et al.[19] demonstrated 77.6% caries arrest in 2 weeks with 38% SDF while Clemens et al.[32] reported 100% caries arrest after 3 months. Furthermore, Zhi et al.[17] reported 91% caries arrest in 6 months and 79% arrest in 12 months while Llorda et al.[33] reported 77% caries arrest in 6 months with 38% SDF. A systematic review conducted on 8 studies concluded an overall proportion of 81% caries arrest after SDF treatment[38] while another systematic review in 2016 documented a 65% caries arrest with SDF[29]. Findings from this present study are in agreement with the reports from these systematic reviews of the effectiveness of SDF. Both this present study and all the compared recent studies adhered strictly to CONSORT guidelines for conducting RCT; had similar methodology, though the different brands of 38% SDF used could be responsible for the varying rates of success observed. On the other hand, no recent study has reported low effectiveness. Therefore, this study further validates the effectiveness of SDF in arresting caries in children.

In addition, this study compared the effectiveness of SDF and restorative success rate of ART (GIC) at different intervals in the treatment of caries. Compared to the restorative success in the control group, SDF with statistically significant higher rates of treatment success at 2 weeks, 1 month and 3 months' treatment intervals over the control ($p< 0.001$). This also is in line with the reports of studies that compared the effectiveness of SDF and GIC at different intervals. Zhi et al.[17], Monse et al.[39], Dos Santos et al.[40] and Braga et al.[41] who all reported statistically significantly higher success rates ($p < 0.05$). Additionally, in order to appreciate the clinical importance of SDF in arresting caries, the effect size was also evaluated. The effect size of this study was 5.24 ($p<0.001$). Most studies on SDF failed to report effect size. However, Castillo et al.[42] in a study comparing the effectiveness of SDF and placebo in arresting caries reported a higher effect size of 12.4 compared to this study. The difference in effect size could be due to the fact that higher effect size is expected to be produced with placebo as against an active treatment. Nonetheless, this high effect size underlines the invaluable clinical importance of SDF in arresting caries. This underscores the fact that SDF is a reliable protocol in treatment of caries not only in community-based programs but also in the clinic.

With respect to secondary outcome assessment, this study observed slight tooth sensitivity in both the SDF group and the control group. However, tooth sensitivity was found to be statistically significant in the control group at 1 month and 3 months'

periods of assessment ($p < 0.05$). The significant tooth sensitivity in the control group could likely be due to the fact that the study was field-based as against clinic based and caries excavation before placement of GIC may not have been very thorough. Secondly radiographic evaluation of carious teeth was not done in the field. Nevertheless, Milgrom et al.[19] in a placebo controlled trial reported 16.0% slight tooth sensitivity in the SDF group even though it was not significant.

This study observed more intervention failures in the control group compared to the study group. The study recorded 47.5% failure rate in the control group and total loss of restoration accounted for the highest proportion (40.8%). The treatment of multiple participants on the same day on the field rather than in the clinic where improved moisture control, superior lighting source and radiographic evaluation is more feasible may likely have contributed to this high failure rate. More importantly however, it has been documented that the drawbacks of GIC include inadequate flexural strength, little toughness and low abrasive resistance leading to wear and loss of restoration thus necessitating frequent recall visits and follow up[34]. Nevertheless similar studies have also recorded this proportion of failure in Atraumatic Restorative Treatment (ART) control group treatments[17,38].

Many studies have documented and reported black staining of carious lesions as significant adverse effect associated with SDF treatment[14,16,29,32,33]. In this study, black staining of carious lesions was also observed to be associated with SDF treatment, which was significant at different assessment intervals. Some studies recommend the use of potassium iodide along with SDF to keep staining to a minimum. No other adverse effect was observed to be significant in the SDF group. According to FDA, tooth discoloration is not considered as harm that causes damage to health. However, this effect cannot be totally ignored as this drawback may cause dissatisfaction for children and parents, especially when treating anterior teeth. In addition, it can result in skin and mucosal stains which disappears after 2 days, thus, caution should be taken when applying this medicament.

This study however has some limitations. Paucity of published work on this subject in this part of the world made it difficult to have a sufficiently extensive local comparison for the findings from the study. Furthermore, the assessment outcome of the study, which was proposed to be in 2 weeks, 1 month, 3 months and 6 months respectively, was limited to 2 weeks, 1 month and 3 months due to the shutdown of schools for many months in 2020 occasioned by the COVID 19 pandemic. However, being the first study in Nigeria and possibly the whole of Africa to evaluate the effectiveness of 38% Silver Diamine Fluoride in arresting caries, it provides vital reference data for further studies and also a possible template for policy proposals for implementing field based secondary preventive initiatives among Nigeria's large population of indigent children who have limited access to dental care.

In conclusion, the result of the study showed that SDF was effective in arresting caries in children without any harm and there was statistically significant difference in the use of 38% SDF in arresting caries in children. The mean ± SD and Confidence Interval (CI) of arrested caries in the SDF group were 113± 1.24 and 113.1 – 113.5 respectively. In the control group the mean ± SD and CI of restor-

ative success were 69.3±11.8 and 67.2 – 71.4. The effect size '*d*' of the study was 5.24. SDF was demonstrated to be effective and safe for short-term treatment of dental caries in children.

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Conflict of interest

There are no conflicts of interest with respect to the study.

Dataset availability

Datasets related to this article will be available upon request to the corresponding author.

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