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Original Article

Prioritizing Preventive Oral Health: School-Based Brushing and Silver Diamine Fluoride Programs for Cambodian Children

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ABSTRACT

Ensuring access to oral health care for children in low- and middle-income countries remains a persistent challenge, with little guidance on which interventions should be prioritized. The Healthy Kids Cambodia (HKC) program introduces an innovative model for school-based dental care, focusing on a core preventive package that combines daily brushing with 1,500 ppm fluoride toothpaste and targeted use of Silver Diamine Fluoride (SDF) to address cavities in primary teeth. To assess dental outcomes at the tooth level among 8- to 10-year-old children from two schools that implemented daily toothbrushing alongside Silver Diamine Fluoride applications at different intervals. This study followed a cohort of children in the late mixed dentition phase to observe how dental lesions progressed over time in two schools. Tooth-level data were recorded using the dmft and pufa indices. Both schools implemented daily toothbrushing (DTB) with training and supplies provided at the outset. In School One, Silver Diamine Fluoride (SDF) was applied at the start of the study, while in School Two, SDF was delayed until nine months later. Oral examinations assessed cavitated primary teeth at baseline and after 12 months, with teeth that remained carious or developed pulpal involvement classified as treatment failures. The analysis included descriptive statistics, and chi-squared tests were employed to compare the proportion of failed teeth between the two schools. Of the 521 children initially enrolled, follow-up data were obtained for 470 (90.2%). Delaying the application of Silver Diamine Fluoride in School Two was associated with a threefold higher risk of poor outcomes. Specifically, 10% of primary teeth in School One were classified as having unfavorable outcomes, compared with 33% in School Two. This study provides evidence on anticipated effect sizes that could guide the design of future stepped-wedge clinical trials aimed at validating a highest-priority oral health care package for Cambodian children. Implementing a care package that combines daily toothbrushing (DTB) with Silver Diamine Fluoride (SDF) has the potential to reduce negative outcomes, including dental infections, in primary teeth affected by caries.

Keywords: Universal health coverage, Daily toothbrushing, Silver diammine fluoride, Highest priority package, School health

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Introduction

Dental caries places a heavy demand on resources for treatment, and traditional drill-and-fill approaches that involve local anaesthetic injections are often poorly accepted by children [1]. In 2002, the World Health Organization introduced the Basic Package of Oral Care (BPOC) as a practical framework for delivering essential oral health services in resource-constrained environments and as a step toward universal oral health coverage [2]. Universal Health Coverage (UHC) is defined by WHO as ensuring that all individuals can obtain the health services they require, when and where they need them, without facing financial difficulty [3]. A core challenge in achieving UHC is prioritising services—deciding who receives which interventions and under what conditions—so that cost-effectiveness, impact on disease burden, and feasibility in low- and middle-income countries (LMICs) can be rigorously assessed. These criteria help shape an Essential

Universal Health Coverage (EUHC) package or Highest Priority Package (HPP).

The BPOC was put forward as one such EUHC and consists of three main components: Oral Urgent Treatment (OUT), Atraumatic Restorative Treatment (ART), and Affordable Fluoride Toothpaste (AFT). Several countries have incorporated elements of the BPOC into national policy. Although each component has proven clinical effectiveness when used individually, evidence on the cost and population-level impact of delivering the full package remains limited. Cambodia is among the countries that partially adopted the BPOC, with dental nurses

providing basic services in community health centres; however, Chher *et al*. highlighted persistent difficulties with the reliable supply of instruments and consumables [4].

Cambodian children experience an exceptionally high caries burden; the average dmft in 6-year-olds reaches 9 affected teeth, yet fewer than 5% have ever received restorative treatment [5]. In 2016, the Healthy Kids Cambodia (HKC) programme was launched in selected schools. It incorporates key elements of the BPOC while adding silver diamine fluoride (SDF) as a central non-invasive treatment option. This differs from the regional Fit for School (FFS) programme, which focuses on daily supervised toothbrushing with 1,500 ppm fluoride toothpaste and handwashing. The FFS initiative achieved a 17% reduction in new carious lesions in pilot schools, but it did not significantly lower the development of pulpally involved teeth or adequately manage the already high levels of existing severe disease [6].

Building on lessons from the FFS programme, HKC introduced an innovative triage system **(Table 1)** to allocate resources efficiently across prevention, non-restorative caries control, and restorative care [7]. Scaling the full three-tier HKC model nationally faces two major obstacles: (i) the complete package may be too costly to sustain, and (ii) there may not be enough trained personnel to deliver all components. The least resource-intensive tier (Level 1) costs approximately US$3 per child per year. The present study evaluates the clinical outcomes for carious lesions in primary teeth among children in late mixed dentition from two schools that implemented the HKC programme at different points during the 2017–2018 school year.

Table 1. Three-level triage framework categorizing children based on the severity of their oral health status and corresponding treatment requirements.

Care Level & Eligibility	Interventions Provided
Level 1 Every child in the program	- Basic health check when possible - Daily brushing with fluoride toothpaste + hand-washing routine - Every 6 months: simple health check, de-worming tablet, Vitamin A dose - Silver diamine fluoride painted on decaying baby teeth to halt progression - Oral hygiene lessons for children and caregivers
Level 2[a] Children 6–8 years old OR any older child with visible holes in permanent molars/premolars	- Hand-excavation and filling of cavities using Atraumatic Restorative Treatment (ART) - Sealing of grooves on permanent teeth with glass ionomer sealant
Level 3[a] Any child with signs of active infection/pain/swelling OR cavities on front permanent teeth OR very large cavities in back permanent teeth that ART cannot fix	- Full dental treatment in a proper clinic (fixed or mobile) - Includes extractions when needed and regular drill-and-fill restorations

[a]Depending on their oral health status, children might be assigned to both Level 2 and Level 3, as the classification system allows for overlap.

Materials and Methods

This research focused on caries progression among children at two Phnom Penh schools within the HKC initiative, designated here as “School One” and “School Two.” Dental care services were delivered through a partnership involving the Faculty of Dentistry at the University of Puthisastra, New York University College of Dentistry’s Global Student Outreach Program, and the Cambodian NGO One-2-One. Participation followed a standard consent process, with parents and teachers provided with detailed information and the option to opt out. Children and their guardians could decline involvement at any stage without any consequences. The study protocol was approved by the National Ethics Committee for Health Research under the Ministry of Health, Cambodia.

Clinical interventions

The HKC program was planned to begin at both schools at the start of the 2017–2018 academic year. To prepare, staff at each school received training and supplies to implement daily toothbrushing with 1,500 ppm fluoride toothpaste. At the study’s outset, students in Grades 3 and 4 underwent thorough clinical assessments, and both schools were equipped with the materials and guidance necessary for DTB. School One received Level 1 care immediately, while School Two

did not receive Level 1 interventions until nine months later. **Figure 1** outlines the timeline of activities for each school. Silver Diamine Fluoride (SDF) was applied to eligible primary teeth with carious lesions by dental students, under the supervision of an experienced UP community outreach dentist.

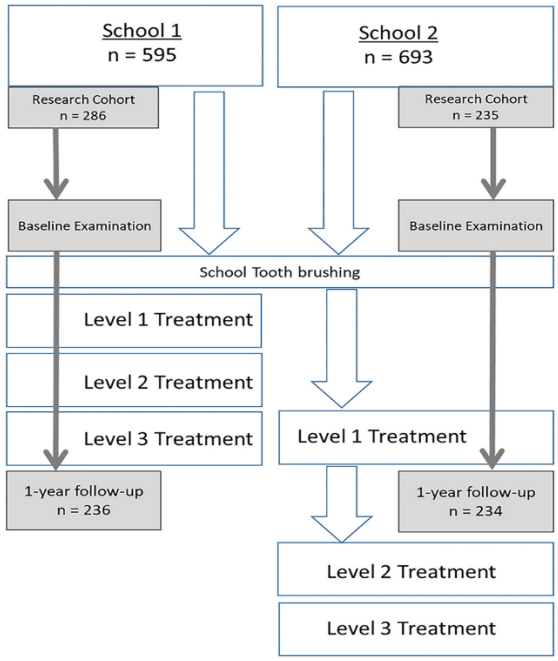

Figure 1. Project flow of events.

Clinical examination

School-based examinations were conducted with children in a supine position, using handheld torches for lighting, at both the baseline assessment in June 2017 and the follow-up in July 2018. Dental caries were recorded following the WHO Basic Methods for Dental Surveys for the dmft index [8] and the pufa index [9]. At each time point, one of three trained examiners performed the assessments. Examiners underwent four hours of preparatory training before each data collection phase and were calibrated against the principal investigator (BT), achieving high inter-examiner reliability (Intraclass Correlation Coefficient >0.85). For cavitated primary teeth that had not reached the pulp, additional lesion characteristics were noted at follow-up, including hardness and color. Hardness was rated on a three-point scale—soft, leathery, or hard—based on probing with a ball-ended instrument, while color was categorized on a four-point scale as brown, mixed, black, or yellow.

Data management and analysis

All study data were first compiled in Excel and then imported into SPSS Version 23 (IBM SPSS Inc., Chicago, IL, USA) for statistical analysis. Descriptive analyses were conducted to summarize participants' sociodemographic profiles and the clinical status of their teeth. Key outcome variables were generated by reclassifying the original data. Lesions were considered "arrested" if they were either hard to the touch or black in color, while lesions that remained soft or leathery and were not black were classified as "caries active." Teeth were categorized as "pulpally involved" if they satisfied any of the four PUFA criteria, and the "active infection" category included teeth with a fistula or abscess. A "new pulpally involved tooth" was defined as a tooth that progressed from having a non-pulpally involved carious lesion at baseline to meeting any PUFA criteria at follow-up.

For analysis, teeth were classified as having an "acceptable outcome" if the lesion had arrested without pulpal involvement or if the tooth had exfoliated within the 12-month period. Teeth where caries remained active or progressed to any PUFA category were considered to have an "unacceptable outcome." The Chi-squared test was applied to compare the distribution of acceptable and unacceptable outcomes between schools.

Results and Discussion

Among the 521 participants, the majority (319; 61.2%) had at least one pulpally involved tooth at baseline. The children, who were in the late mixed dentition stage, had a mean dmft score of 3.0 (SD 2.9). A significant difference in age was observed (P = 0.001), with children in School Two being slightly younger (mean 8.8 years; SD 0.9) than those in School One (mean 9.0 years; SD 1.1), with an overall mean age of 9.0 years (SD 1.0). Additionally, the proportion of children presenting with one or more pulpally involved teeth at baseline differed significantly between the two schools: 54.2% in School One compared with 69.8% in School Two **(Table 2)**.

Table 2. Baseline sociodemographic profiles and clinical referral status of participants.

Characteristic	Total children n (%)[a]	Children with at least one dental fistula or abscess n (%)	Children with one or more teeth involving the pulp n (%)	dmft score Mean (SD)
School				
School 1	286 (54.9)	4 (1.4)	155 (54.2)[b]	2.6 (2.6)[c]
School 2	235 (45.1)	3 (1.3)	164 (69.8)[b]	3.7 (3.1)[c]
Sex				

Male	264 (50.7)	4 (1.5)	161 (61.0)	3.2 (3.0)
Female	257 (49.3)	3 (1.2)	158 (61.5)	2.9 (2.8)
Overall	521 (100.0)	7 (1.3)	319 (61.2)	3.0 (2.9)

a Values in parentheses represent column percentages.
b Difference between the two schools is statistically significant ($P < 0.05$, chi-square test).
c Difference between the two schools is statistically significant ($P < 0.05$, Kruskal–Wallis test).

A total of 470 children completed the study, representing a 90.2% follow-up rate. Follow-up rates differed significantly between schools, with School Two achieving 99.6% compared to 82.5% for School One **(Table 3)**.

Table 3. Participant retention from baseline to one-year follow-up.

Characteristic	Completed follow-up n (%)	Lost to follow-up n (%)	Total enrolled n (%)[a]
Age group			
7 years	3 (100.0)	0 (0.0)	3 (0.6)
8 years	110 (89.4)	13 (10.6)	123 (23.6)
9 years	159 (93.0)	12 (7.0)	171 (32.8)
10 years	129 (86.0)	21 (14.0)	150 (28.8)
11 years	50 (94.3)	3 (5.7)	53 (10.2)
12 years	15 (93.8)	1 (6.2)	16 (3.1)
13 years	2 (66.7)	1 (33.3)	3 (0.6)
14 years	2 (100.0)	0 (0.0)	2 (0.4)
Sex			
Male	236 (89.4)	28 (10.6)	264 (50.7)
Female	234 (91.1)	23 (8.9)	257 (49.3)
School[b]			
School 1	236 (82.5)	50 (17.5)	286 (54.9)
School 2	234 (99.6)	1 (0.4)	235 (45.1)
Overall total	470 (90.2)	51 (9.8)	521 (100.0)

[a]Brackets contain column percentage.
[b]P-value ≤ 0.05; chi squared test for differences in proportions among groups within the same column.

At baseline, 1,391 teeth with carious lesions were identified, of which 1,233 (88.6%) were available for follow-up **(Table 4)**. The majority of these teeth were molars (76.6%), and nearly half (46.7%) were pulpally involved. A significant difference in follow-up rates was observed between schools ($P \leq 0.001$, chi-squared test), with teeth from children in School One more likely to be lost to follow-up.

Table 4. One-year follow-up and attrition of teeth by clinical characteristics.

Characteristic	Teeth followed-up / present at follow-up n (%)	Teeth lost to follow-up / missing at follow-up n (%)	Total teeth examined at baseline n (%)[a]
Pulpal involvement at baseline			
One or more pulpally involved teeth	574 (88.4)	75 (11.6)	649 (46.7)
No pulpal involvement	659 (88.8)	83 (11.2)	742 (53.3)
Tooth type			
Permanent molars	942 (88.5)	123 (11.5)	1,065 (76.6)
Permanent incisors	291 (89.3)	35 (10.7)	326 (23.4)
School[b]			
School 1	497 (76.0)	157 (24.0)	654 (47.0)
School 2	736 (99.9)	1 (0.1)	737 (53.0)
Overall total	1,233 (88.6)	158 (11.4)	1,391 (100.0)

[a]Brackets contain column percentage.
[b]P-value ≤ 0.05; chi squared test for differences in proportions among groups within the same column.

Figure 2 illustrates the outcomes of individual teeth after one year. For teeth that were not pulpally involved at baseline, 76.3% showed a favorable outcome, independent of the school. Teeth from School One exhibited a significantly greater likelihood of caries arrest and overall acceptable outcomes, accounting for both lesion arrest and natural exfoliation. In contrast, at School Two, roughly one-third of teeth with carious lesions at baseline had an unfavorable outcome at follow-up, compared with just 10% in School One. Importantly, none of the cavitated teeth treated with SDF at baseline in School One progressed to pulpal involvement, whereas 7.7% of teeth in School Two, which received delayed SDF treatment, developed pulpal involvement.

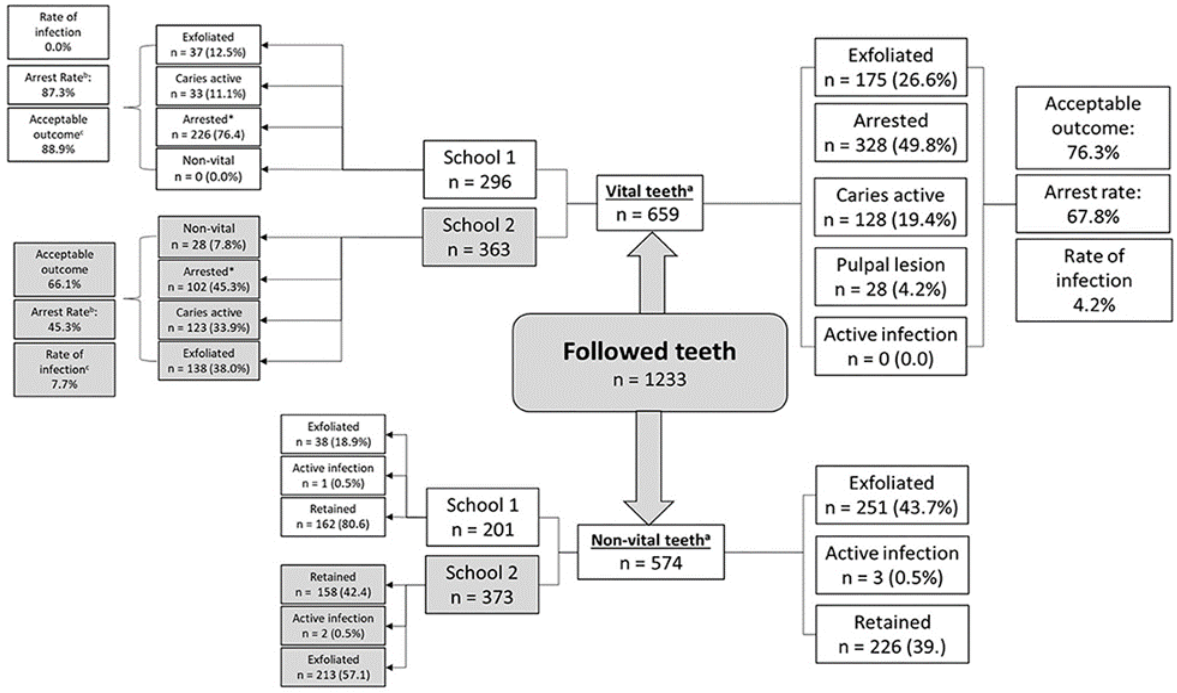

Figure 2. Tooth-level outcomes according to baseline lesion characteristics and school. aP ≤ 0.001 for differences in the proportion of cavitated versus pulpally involved lesions (chi-squared test). bP ≤ 0.001 for differences in caries arrest rates between schools (chi-squared test). cP ≤ 0.001 for differences in the prevalence of infection by school (chi-squared test).

The 28 newly pulpally involved teeth were observed in 20 children (8.5%) from School Two, who experienced a nine-month delay in receiving SDF treatment. In contrast, none of the teeth treated with SDF at baseline in School One progressed to pulpal involvement over the 12-month follow-up period.

This investigation assessed the outcomes of individual teeth in children from two primary schools in Cambodia who received daily toothbrushing (DTB) alongside Silver Diamine Fluoride (SDF). While DTB is already recognized internationally as an effective component of Essential Health Packages, such as the Fit for Schools (FFS) program, this study contributes novel evidence highlighting the protective effect of timely SDF application in preventing pulpally involved caries and reducing associated pain. Results showed that when SDF was applied at the start of the study, none of the treated primary teeth developed pulpal involvement over 12 months, and nearly 90% of teeth had favorable outcomes. In contrast, delaying SDF treatment led to pulpally involved teeth in 10% of children, and only about 70% of teeth achieved acceptable outcomes. These findings emphasize the value of early SDF intervention as part of a combined preventive and therapeutic approach in populations with high caries prevalence. Notably, this study is among the first to examine DTB and SDF together as a coordinated strategy to reduce pulpally involved lesions in late-mixed dentition.

Several limitations must be noted. Participants were recruited via convenience sampling, and there were differences between schools in demographic composition and follow-up rates, which could not be adjusted for in the analysis. As a result, while the study provides insight into clinical outcomes in this cohort, potential bias limits the generalizability of the findings. Additionally, although active infections (teeth with fistulae or abscesses, per the PUFA index) were low—1.5% at baseline and 0.5% at follow-up—there was no data capturing incident infections between

assessments, suggesting the study may underestimate the true burden of dental inflammation and infection.

The caries arrest observed with SDF in School One aligns with previous reports both internationally and within Cambodia [10-14]. Prior studies have documented arrest rates of 50–70% with annual SDF application [15]. In the current study, the delayed SDF group achieved a 45.3% arrest rate at three months, while the baseline SDF group reached 87.3%. These outcomes are consistent with longitudinal evidence indicating that lesions are more likely to arrest over time as remineralization stabilizes the affected tissue [12].

Findings from this study can inform estimates of clinically meaningful differences and expected effect sizes, which are critical for designing future stepped-wedge trials to determine which combinations of interventions should be included in a Highest Priority Package (HPP) for Cambodian children. This evidence will support recommendations on which children should receive specific treatments and under what circumstances.

Given the limited resources for conventional dental services in Cambodia, it is unlikely that such care could be scaled sustainably in a public program, and DTB alone is insufficient to prevent pulpally involved teeth. Therefore, the HKC Level 1 package, combining DTB with SDF, represents a feasible and cost-effective step toward Universal Oral Health Care for school-aged children. This package can be delivered efficiently to all children within a school setting, utilizing both dental and trained non-dental personnel, and significantly reduces the financial and logistical barriers families face in accessing conventional dental care.

Conclusion

This study provides initial evidence that combining daily toothbrushing (DTB) with Silver Diamine Fluoride (SDF) is effective in managing the majority of carious lesions in primary teeth among Cambodian children and, crucially, in lowering the occurrence of pulpally-involved teeth. The findings can also be used to estimate meaningful differences in clinical outcomes and expected effect sizes, which will be valuable for planning future rigorous stepped-wedge clinical trials.

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Conflict of Interest: None

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Ethics Statement: The studies involving human participants were reviewed and approved by National Ethics Comittee for Health Research, Ministry of Health, Cambodia. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

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