Lifelong Effectiveness of Caries Prevention Programs by System Dynamics Model

Tin Htet Oo

A Thesis Submitted in Fulfillment of the Requirements for the
Degree of Doctor of Philosophy in Oral Health Sciences
Prince of Songkla University
2022

Lifelong Effectiveness of Caries Prevention Programs by System Dynamics Model

Tin Htet Oo

A Thesis Submitted in Fulfillment of the Requirements for the
Degree of Doctor of Philosophy in Oral Health Sciences
Prince of Songkla University
2022

Thesis Title	Lifelong Effectiveness of Caries Prevention Programs by System Dynamics Model
Author	Miss Tin Htet Oo
Major Program	Oral Health Sciences

Major Advisor

……
(Assoc. Prof. Dr. Sukanya Tianviwat)

Co-advisors

…….
(Assoc. Prof. Dr. Songchai Thitasomakul)

……
(Asst. Prof. Dr. Phongpat Sontamino)

Examining Committee:

…… Chairperson
(Dr. Yot Teerawattananon)

…….. Committee
(Assoc. Prof. Dr. Sukanya Tianviwat)

……..... Committee
(Assoc. Prof. Dr. Songchai Thitasomakul)

…….. Committee
(Asst. Prof. Dr. Phongpat Sontamino)

…… Committee
(Dr. Vorasith Sornsricichai)

.....……Committee
(Asst. Prof. Dr. Areerat Nirunsittirat)

The Graduate School, Prince of Songkla University, has approved this thesis as a fulfillment of the requirements for the Doctor of Philosophy Degree in Oral Health Sciences.

……
(Asst. Prof. Dr. Thakerng Wongsirichot)
Acting Dean of Graduate School

This is to certify that the work submitted here is the result of the candidate's own investigations. Due acknowledgment has been made of any assistance received.

……..……. Signature
(Assoc. Prof. Dr. Sukanya Tianviwat)
Major Advisor

…… Signature
(Assoc. Prof. Dr. Songchai Thitasomakul)
Co-advisor

……. Signature
(Asst. Prof. Dr. Phongpat Sontamino)
Co-advisor

……. Signature
(Miss Tin Htet Oo)
Candidate

I hereby certify that this work has not been accepted in substance for any degree and is not currently being submitted in candidature for any degree.

……. Signature
(Miss Tin Htet Oo)
Candidate

Thesis Title	Lifelong Effectiveness of Caries Prevention Programs by System Dynamics Model
Author	Miss Tin Htet OO
Major Program	Oral Health Sciences
Academic Year	2022

ABSTRACT

Dental caries is still considered a burden of disease not only in Thailand but also around the world. Various preventive and promotion programs are implemented for dental caries in individuals and communities among the population. For long-term assessment of preventive programs, simulation models are gaining attention to be approached. **Objective**: This study aims to estimate the lifelong outcomes of caries prevention programs among Thai age groups by conducting the System Dynamics Model (SDM). **Methodology**: Systematic reviews and meta-analyses were conducted to identify the efficacy of interventions: supervised toothbrushing, fluoride varnish, dental sealant, and oral health examination for dental caries according to age groups. Based on the effectiveness of interventions from meta-analyses and their coverage rates, the SDM was simulated to estimate the lifelong dental caries outcome under interventions: supervised toothbrushing, fluoride varnish, combined supervised toothbrushing and fluoride varnish, dental sealant, combined supervised toothbrushing, and sealant, and oral health examination by comparing base case (no intervention was provided). **Results:** it is found that at the age of 5 years old, the population with caries in deciduous teeth was the lowest in combined supervised toothbrushing and fluoride varnish, 258,876 (38.17 %) followed by supervised toothbrushing, 266,049 (39.23%), fluoride varnish, 276,703 (40.79 %), and base case, 290,829 (42.88 %). All these interventions can reduce the caries population until above 15 years old compared to the base case. The caries population was lowest under combined supervised toothbrushing and sealant, 257,655 (37.99%), followed by a sealant, 264,507 (38.99%) at 15 years old. From above 23 years old, the caries

population under all of the above interventions and the oral health examination were not different from the base case. **Conclusion:** according to SDM simulation**,** it is considered that combined interventions are more effective than other interventions provided separately. Each intervention could reduce the caries population by above 15 years from they started compared to the base case. If the interventions have better effective rates and coverage rates, the caries population could be reduced by more than the estimated result from the model.

Keywords: System Dynamics Model, Lifelong Effectiveness, Caries Prevention, Dental caries

ACKNOWLEDGEMENT

Firstly, the completion of the thesis could not have been possible without the guidance and support of my advisor, Associate Professor Dr. Sukanya Tianviwat. It was an honor for me to receive her scientific knowledge and her supervision. I would like to give my sincere gratitude to my advisor. I also would like to express my sincere gratitude to my co-advisor, Associate Professor Dr. Songchai Thitasomakul, who sacrificed his valuable time to complete the thesis. I also would like to give thankfulness my co-advisor, Assistant Professor Dr. Phongpat Sontamino, who helped me with the system dynamics model and gave me valuable advice in completing the thesis.

I would like to express my warmest gratitude to the thesis committee members, Dr. Yot Teerawattananon, Dr. Vorasith Sornsricichai, and Assistant Professor Dr. Areerat Nirunsittirat for their advice and valuable comments in widening my knowledge from various perspectives. I would like to acknowledge and give special thanks to all experts who participated in the group model-building sessions (GMB sessions) for the system dynamics model. Their suggestions and valuable knowledge helped me a lot to complete the research.

I am grateful to the Postgraduate School, Prince of Songkla University, for providing me with the financial aid necessary to complete my research.

Last but not least, I would like to express my profound appreciation to my family, friends, and classmates. No matter where I am, they always give me a hand whenever I need help.

Tin Htet oo

CONTENTS

Chapter Page

LIST OF TABLES

Chapter Page

LIST OF FIGURES

Chapter Page

LIST OF ABBREVIATIONS

SDM = System Dynamics Model

CLD = Causal Loop Diagram

STB = Supervised Toothbrushing

FV = Fluoride Varnish

Combined STB+FV = Combined Supervised Toothbrushing and Fluoride Varnish

Combined STB+Sealant = Combined Supervised Toothbrushing and Dental Sealant

OH exam = Oral Health Examination

NOHS = National Oral Health Survey

HDC = Health Data Center

NSO = National Statistical Office

MOPH = Ministry of Public Health

Dmnl = Dimensionless

CHAPTER I
INTRODUCTION

1.1 Background

Oral health is a fundamental component of overall health and is now recognized as equally important to general health [1]. Dental caries and periodontal diseases have historically been considered the most important global oral health burdens [1]. These two oral diseases may lead to severe tooth loss. Therefore, dental caries, periodontal diseases, and tooth loss have a significant burden of disease effects. [1] Globally, it was estimated that 2.3 billion people suffer from caries of permanent teeth, and 486 million children with primary teeth suffer carious lesions [1]. Periodontal disease was more prevalent in adolescents, adults, and older individuals, affecting about 20-50% of the global population [2]. Besides, gingivitis was a prevalent oral disease in most children globally. [1] Also, in Thailand, according to the 8th National Oral Health Survey, the prevalence of dental caries was detected above 50% in 3 to 5 years old, above 60 % in 15 years old, above 90% in 35–44 years, 60–74 years, and 80-85 years age groups respectively [3]. It has still been high in the whole country without many differences among geographical locations, urban and rural. It is seen that dental caries and periodontal problems have still been considered public health problems in the Thai population, although they are preventable.

Simulation modeling in healthcare services has been widely used in studying healthcare management problems. Since they have been widely used in health care, they were gaining intention to be used in dental care, such as preventive interventions due to the burden of oral diseases. It plays an important role not only as an educational tool but also in making decisions for stakeholders to implement planning processes for the long term. [4] It is a computer simulation to build decision-analytic models representing systems of interest in real life to help the stakeholders make decisions for relevant strategies [5]. Simulation models have been designed and implemented in healthcare for different purposes, such as to simulate populations with a specific chronic disease or diseases that provide healthcare services, management of patient flow inside

emergency rooms, allocation of human resources in hospitals, patient admission, and hospital bed utilization. [6] Besides, they have been used as decision-analytic models in economic evaluation for healthcare interventions to inform decision-makers about an alternative policy. [7] There are different modeling approaches in healthcare, such as the Decision Tree model, Markov cohort model, Microsimulation model, System Dynamics model, Discrete Event simulation model, and Agent-Based model. [7] Therefore, we must consider more modeling for preventive programs in oral care. In this study, we must consider conducting the system dynamics model (SDM) for the effects of oral health preventive programs for dental caries among the Thai population in lifelong aspects.

System Dynamics Model (SDM)

The system dynamics model (SDM) came from electrical engineering and was developed by Jay W. Forrester in the mid-1950s. [5, 8] This modeling focuses on analyzing the behavior of complex phenomena or systems over time. [4, 5]. It was believed that many challenges in public health with dynamic complexity might be virtually approached with systematic dynamic modeling to alleviate the problem [8].

It has been applied in health issues since the 1970s, including diseases epidemiology affecting population health for chronic conditions, patient flows in emergency and extended care, health care capacity and delivery in such areas as population-based health maintenance organization planning, dental care, mental health, and economical approach in health care interventions [8]. Dental care has been designed and implemented for different purposes, such as economic evaluating and estimating the required resources in preventive interventions, and exploring the dynamic changes of dental caries and their related factors. [9-13]

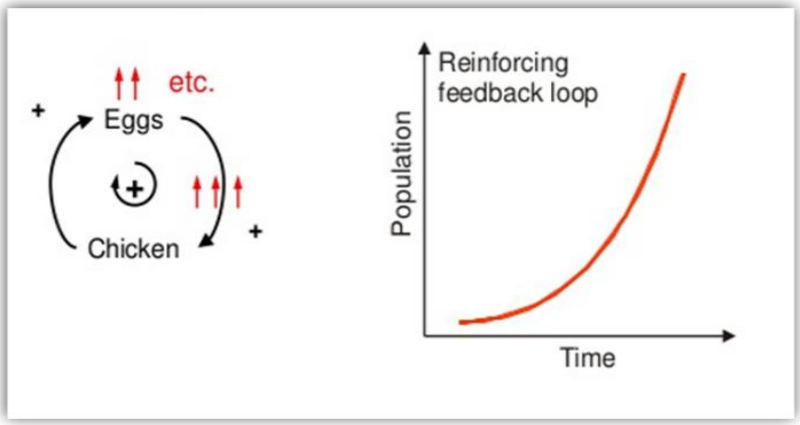
SDM has two distinct aspects: one qualitative and one quantitative. [14] The causal loop diagram represents the qualitative aspect, and the stock and flow diagram represents the quantitative aspect. Nevertheless, both show relationships among variables that have the potential to change over time. [14, 15].

The Qualitative Aspect of SDM

The qualitative aspect involves the construction of causal loop or feedback loop diagrams, which depict graphically how the system elements are related. [14]. The causal link from element A to B is positive (+) if either A adds to B or a change in A produces a change in B in the same direction, and the causal link from element A to B is negative (-) if either A subtracts from B or a change in A produces a change in B in the opposite direction. [15] This analysis aims to find loops where elements are connected by a directed arrows cycle. Balancing loops contain an odd number of "-" signs, whereas reinforcing loops contain an even number of "-" signs. [14] Balancing loops keep the system steady, whereas the system spirals out of control in reinforcing circles. [14] Figures 1 and 2 showed a straightforward example of a causal loop diagram, reinforcing feedback loop, and balancing feedback loop.

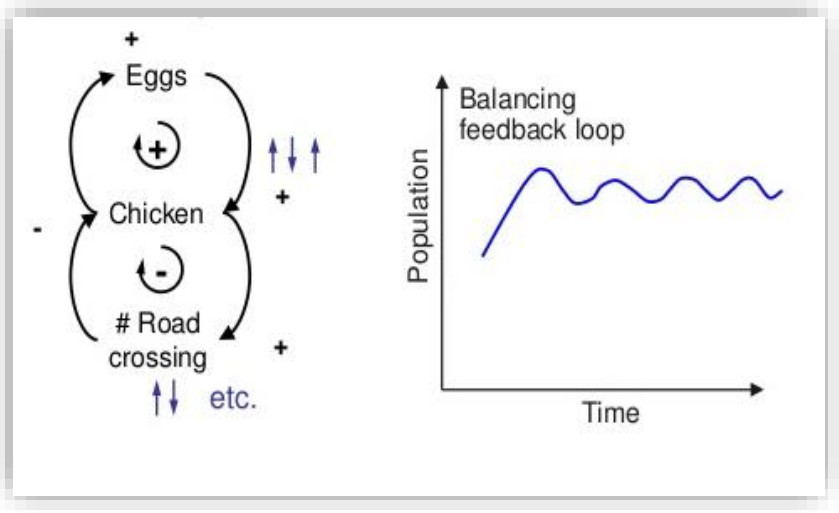
Reinforcing feedback loop

(Simple example 1) [16]



Balancing feedback loop

(Simple example 2) [16]

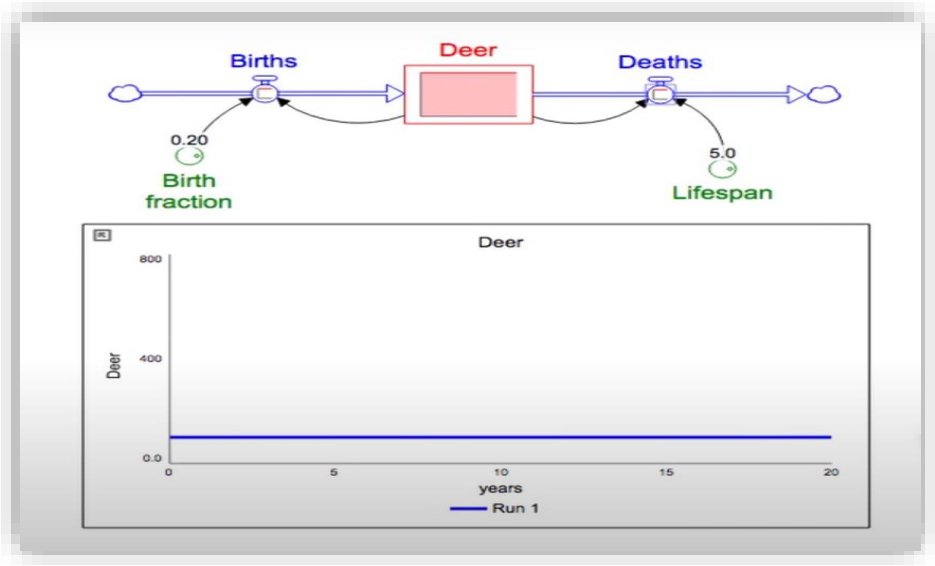


The Quantitative Aspect of SDM

The quantitative aspect is adopting a system using basic building blocks such as stocks, flows, and feedback loops. [4, 5] The stocks are fundamentals of any system denoted as dynamic objects such as accumulations or levels or states of variables that move through the system [4]. The flows are represented as into and out valves of the stocks that determine the movement of states [4]. In other words, movement between stocks is defined by the flow rate. A feedback loop is formed when changes occur in stock that affects the flows of the system (into and out of stock) [4]. The reinforcing feedback loop occurs when a stock of the system can reproduce a fraction that affects the flow into it. [4] The balancing feedback loop means that it keeps the stock at a certain level by balancing the flow out of stock. [4] Outcomes may be attributed to the time-in-stocks or movements between the continuously updated stocks. [7] On the other hand, the model can become very complex when situations with lots of variables are modeled. Figures 3, 4, and 5 showed an elementary example of stocks, and flow diagrams with runs 1, 2, and 3, respectively.

Stocks and flows diagram

(Simple example) [17] Run 1.



Births = Births fraction x Deer

= 0.2 x 100 = 20

Deaths = Deer / lifespan

= 100 / 5 = 20

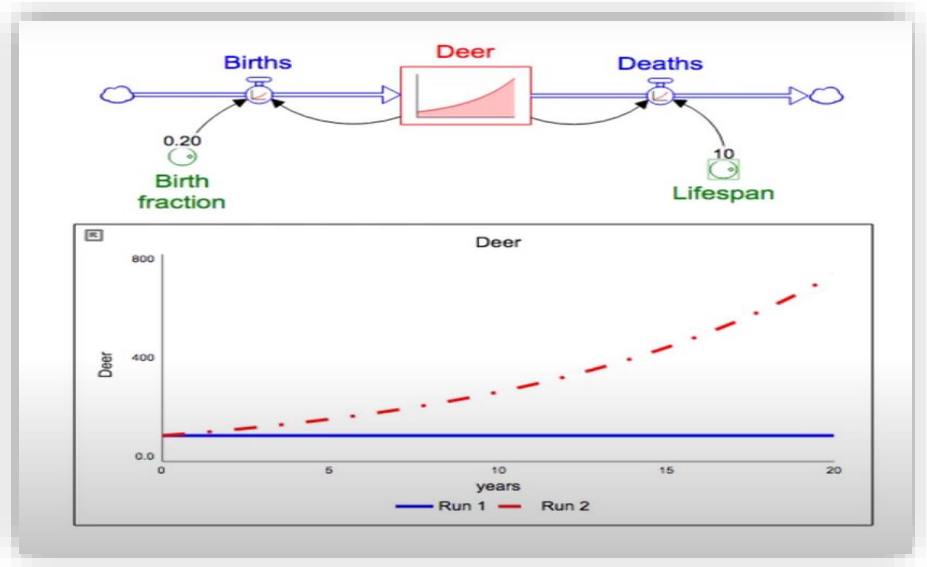
20 growth per year and 20 die per year, deer population is not changed after 20 years.

Stock 

Flow 

Stocks and flows diagram

(Simple example) [17] Run 2.



Births = Births fraction x Deer

= 0.2 x 100 = 20

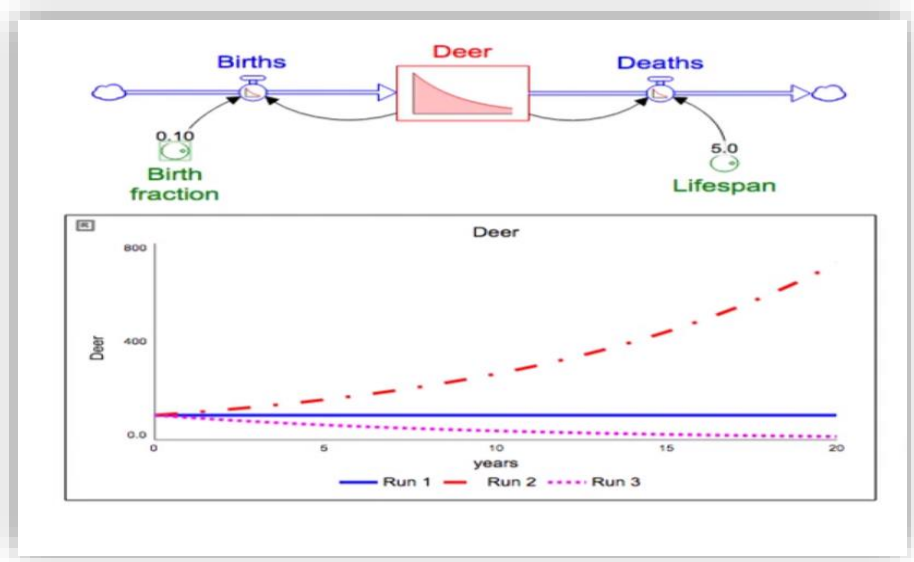
Deaths = Deer / lifespan

= 100 / 10 = 10

20 growth per year and 10 die per year, deer population is growing after 20 years.

Stocks and flows diagram

(Simple example) [17] Run 3.



Births = Births fraction x Deer

= 0.1 x 100 = 10

Deaths = Deer / lifespan

= 100 / 5 = 20

10 growth per year and 20 die per year, deer population is declining after 20 years.

1.2 Rationale

Since dental caries, periodontal diseases, and tooth loss have been considered the significant burden of diseases in Thailand and around the world, various approaches for preventive and promotion programs at individual and community levels among each target age group have been implemented. [18] Moreover, when preventive programs are performed, long-term outcomes assessments are also necessary to conduct better decision-making between policymakers for alternative interventions or strategies. Therefore, simulation models or analytical decision models were gaining attention to be used in preventive programs for long-term assessment due to the burden of oral diseases since they have been widely used in health care services.

In one study, Qu et al. [18] conducted a systematic review of decision-analytic modeling for dental caries preventive interventions. They described the primary type of modeling used in dental caries interventions, including the Markov model followed by the Markov/microsimulation mixed model, systematic dynamic models, microsimulation models, and decision tree model. By following the above review, Qu et al., [18] I would like to use SDM in my study for lifelong effectiveness oral health preventive programs. It is because, not like Markov and the microsimulation model that describes the transition of health states over a more extended period and repeated events, SDM allows seeing the interaction among entities through the system by modeling the rate of change of the system to be dependent on the system itself (i.e., Feedback loops). [19] In addition, complex behavior that may emerge from the interaction of multiple feedback loops can be seen. [7] It can be used as a cohort-based model and used in a complex system, unlike the decision tree model, which is usually used when the time frame is short, the process is not complicated, and reoccurring events are unimportant. In addition, the discrete event simulation model also describes the flow of entities through the system, but for individual trajectories, the model would be medium to large. Therefore, in this study, SDM was used for lifelong simulation even though it can become very complex when actual situations with lots of variables are modeled. Moreover, one study in Thailand [13] used SDM to explore the changes in dental caries status and oral health behaviors among Thai adults and the elderly under the different policy options, but it did not consider the lifelong effects of oral health programs.

Therefore, the above mentions were knowledge gaps in why SDM should be approached more as a cohort-based model for alternative preventive interventions as a lifelong aspect.

In this study, the provided interventions were primary preventive interventions from the Ministry of Public Health (MOPH) according to age groups. All of the interventions focused on the dental caries outcome since the primary prevention is to prevent the occurrence of diseases in healthy conditions before the disease process begins. Moreover, the health promotion activities are not included in the study since they are not specific in the activities according to MOPH guidelines and are conducted at the National policy level. In addition, before conducting SDM, systematic reviews and meta-analyses were conducted to identify the effectiveness of interventions for each age group to use this information in SDM. Although practical information could get from previous systematic reviews and meta-analyses, some are from a long time ago, and some may not be reliable for specific interventions for each age group in this study.

Moreover, the effect estimate of combined interventions in the meta-analysis could be seen, and this information could be used in SDM. Therefore, systematic reviews and meta-analyses of preventive programs for dental caries were performed to use the effectiveness information in SDM. Therefore, after conducting the systematic review and meta-analysis, it has to consider conducting the system dynamics model (SDM) for the lifelong effects of preventive programs for dental caries outcomes among Thai age groups.

1.3 Objectives

1.3.1 General Objective

To estimate the lifelong dental caries outcome of primary prevention programs among Thai age groups by conducting the System Dynamics Model.

1.3.2 Specific Objectives

1. To identify the effectiveness of primary prevention programs (supervised toothbrushing, fluoride varnish, dental sealant, and oral health examination) for dental caries among 0-3, 3-5, 5-15, and 15-59 years old age groups by conducting the systematic review and meta-analysis.
2. To estimate the lifelong outcomes (dental caries and related events) under caries preventive programs (supervised toothbrushing, fluoride varnish, combined supervised toothbrushing and fluoride varnish, dental sealant, combined supervised toothbrushing and dental sealant, and oral health examination) by conducting the System Dynamics Model (SDM) in all age-group intervals (0-3, 3-5, 5-15, 15-59, and above 59 years old).

CHAPTER II
LITERATURE REVIEWS

2.1 Oral Health Status in Thailand

People with untreated caries may suffer from pain, interfering with eating and sleeping, to functional limitations such as tooth loss. [20] Extraction cases were mainly due to caries, and tooth loss was the most consequential. [21] In children with mixed dentition stage occurs, and during this transition stage, if primary teeth are lost or extracted early due to caries before permanent teeth are erupted or completed, it would lead to the mesial and distal drift of adjacent teeth, a delayed eruption of permanent teeth, and malocclusion with aesthetics and functional problems in later. [21]

Some studies showed the increasing levels of dental caries in children and adolescents in developing countries in contrast to developed countries [22]. Periodontal diseases were prevalent both in developed and developing countries [2]. In Thailand, according to the 8th National Oral Health Survey, the prevalence of dental caries was detected at 52.9%, 75.6%, 52%, 62.7%, 91.8%, 98.5%, and 99.5% among the three years, five years, 12 years, 15 years, 35–44 years, 60–74 years, and 80-85 years age groups respectively [3]. Mean DMFT/dmft was recorded at 2.8 in 3 years, 4.5 in 5 years, 1.4 in 12 years, 2.0 in 15 years, 6.6 in 35-44 years, 15.9 in 60-74 years, and 24.0 in 80-85 years age groups. [3] It has been high, and few differences were seen depending on the geographical locations, central, north, northeast, and southern Thailand. [3] On the other hand, the root caries rate was higher (about 85.1%) in the 60-74 age group than 35-44 and 80-85 age groups, where 57.1% and 64%, respectively. [3] The percentage of children aged five years with a first permanent molar was around 10%, depending on the upper and lower mouth. Even though the prevalence of posterior functional teeth was estimated at 93.3% in 35-44 years, only 39.4% in the 60-74 age group and 11.3% in the 80-85 age group were found. [3] The percentage of edentulous was detected at 8.7% in 60-74 years and 31.0% in 80-85 years old. [3]

Therefore, it is seen that dental caries with consequences of tooth loss have still been considered public health problems in the Thai population, although they were preventable.

2.2 System Dynamics Model (SDM)

The system dynamic modeling has been applied to health issues since the 1970s, including disease epidemiologists affecting population health for chronic conditions, health care capacity and delivery, mental care, and dental care. [5, 8] Healthcare researchers have attracted the application of the system dynamics model since 2013. [23] One review showed that the application of system dynamics focused on various healthcare topics, and the most popular research topics were patient flow, obesity, workforce demand, and HIV/AIDS. [23]

Related to dental health care, one systematic review [18] evaluated the decision-analytic models for dental caries intervention. In the review, studies with the application of decision-analytic models for the long-term assessment of outcomes and costs of intervention for the prevention and treatment of caries are included. The included interventions in this review were the application of fluoride, fluoride rinses, water fluoridation, pit and fissure sealant, caries management system and standard dental care, restorative and endodontic treatment, and so on. Types of modeling approaches in the included studies were mainly the Markov model followed by Markov/microsimulation mixed model, systematic dynamic models, microsimulation models, and decision trees. This review showed that all models could be used in caries preventive programs and that the qualities of all models are acceptable.

Some research applied the system dynamics model to accomplish the long-term effect, economic evaluation, and required resource use for caries interventions and dynamic changes in dental caries status, as shown in Table 1.

Table 1. Studies using the system dynamics model

Study and year	Age	Objectives	States in model	The time horizon of the model	Data for baseline	Intervention and comparator	Data for Intervention	Findings
Splieth et al., 2008 [9]	6-18 years	To develop an economic prognostic model for the lifetime costs associated with caries treatment in a population and to estimate the effect of caries prevention with fluorides	Healthy, carious/one-surface filling, recurrent caries/two surface filling, recurrent caries/three-surface filling, recurrent caries/four-surface filling, endodontics at four-surface filling,	lifetime	Survey of Health in Pomerania	- Caries prevention fluoride regimes (fluoridated salt, fluoride gel weekly home application, fluoridated toothpaste, professional biannual fluoride application, fluoridated salt + toothpaste, fluoridated salt + toothpaste + gel, fluoridated salt + toothpaste gel+ professional biannual	German National Health data	- Without fluoride prevention, the mean cost of lifelong treatment for caries was €6,976. - In different scenarios of fluoride use, the combination of a fluoride salt, fluoride toothpaste, and fluoride gel was the most cost-effective. They reduced the costs for caries treatment and prophylaxis to €482, or a present value of €148 (5% discounting) when applied from age 6–18 yrs., and to €211–213

Table. 1 (Continued)

			recurrent caries/ crown			fluoride application) and without a fluoride application regime - Four different scenarios of fluoride use and effects (Use at 6–18 yrs. With constant effect, use at 6–18 yrs. With decreasing effect after age 18 yrs., use at 6–18 yrs. with linearly increasing to 12 yrs. and decreasing after age 18 yrs., lifelong use with constant effect)		for lifelong use (present value, 5% discounting).
Hirsch et al., 2012 [10]	Preschool children in Colorado	To assess and compare early childhood caries (ECC) interventions for	No caries activity, untreated caries, treated caries, symptomatic	Ten years	Colorado Child Health Survey	Six categories of ECC intervention (applying fluorides, limiting	National Health and Nutrition Examination Survey (NHANES)	- Combined interventions have the most significant potential for cavity reduction and reductions in cavity

Table. 1 (Continued)

		benefits and costs among young children in Colorado by formulating an SDM	caries (Stages of ECC)			cariogenic bacterial transmission from mothers to children, using xylitol directly with children, clinical treatment, motivational interviewing and combinations of these) compared to baseline.	and Medical Panel Expenditure Survey (MEPS) data	prevalence ranging from none to 79.1% from the baseline. - The model explores 10-year intervention costs ranging from $6 million to $245 million and the cost-saving of restorative care from $14 million to $149 million from the baseline. - Some interventions save more on dental repair than their program cost, producing substantial repair cost reductions. - The system dynamics model can provide information to maximize the return on public health and clinical care investments for policymakers.

Table. 1 (Continued)

Edelstein et al., 2015 [11]	Children younger than six years eligible for New York Medicaid population	To assess the potential for early childhood caries interventions to reduce cavity and help the project savings by applying a system dynamics model	NA	Ten years	National Survey of Children's Health	Nine preventive interventions (water fluoridation, fluoride varnish, fluoride toothpaste, medical screening and fluoride varnish application, bacterial transmission reduction, motivational interviewing, dental prevention visits, secondary prevention and combination) compared to baseline.	Literature and expert opinion	- 10-year disease reductions and net savings from water fluoridation, motivational interviewing, and fluoride toothpaste interventions. - A variety of population-level and individual-level interventions are available to control ECC and reduce state Medicaid expenditures.

Table. 1 (Continued)

Umeda et al., 2019 [12]	Preschool children in Maringa, Brazil.	To present a System Dynamics model (SDM) to estimate the cost and clinical hours required to control dental caries in preschool children	Teeth with carious lesions, teeth with white spots, and total material costs	-	An epidemiological survey in Early Childhood Education Center in the city of Maringa	Two main strategies to control caries are the application of fluoride varnish on teeth with white spots and Atraumatic Restorative Treatment (ART) in cavitated carious lesions without pulp involvement.	NA	- The SDM generated an estimated cost of US$698.00 and 112 clinical hours to treat the population. Early diagnosis and treatment of dental caries with fluoride varnish and ART treatment on preschool children has a viable strategy without incurring high costs. - The use of the SDM has the potential to assist decision-making by measuring the material and human resources required to prevent and control dental caries at an early age.
Urwannachotima et al., 2019 [13]	Thai adults and elderly (15	The study aimed to estimate the changes in dental caries	The four dental caries statuses were very low DMFT, low	2000–2040	Thai national oral health survey	Base-case - served as a reference point for comparing the	Thai national oral health survey data from	The SDM can be used to explore the relationship between the experience of suffering dental caries,

Table. 1 (Continued)

	years and above)	status and oral health behaviors among Thai adults and elderly under the different policy options using system dynamics modeling.	DMFT, moderate DMFT, and high DMFT, and each DMFT group was divided into "completely treated" and "untreated."		data from 2000 to 2001, 2006 to 2007, and 2012 and Thailand Official Statistics Registration	following three policies. Three polices – 1. Health promotion scenario - oral health self-care and reduced sugar consumption from 2018–2040. 2. Dental personnel intake and affordability scenario - dental personnel intake to afford dental care services. 3. Combined scenario - the combination of health promotion and dental personnel intake and affordability.	2000 to 2001, 2006 to 2007, and 2012, Thailand Office of the Cane and Sugar Board, Ministry of Industry, Report of dental personnel 2000–2015 from Bureau of Dental Health, Department of Health, Ministry of Public health, Thailand.	dental service utilization, and oral health behaviors. Dental caries experiences among Thai adults and the elderly were projected to increase from now to 2040 as the elderly population. The combined health promotion policies increased affordability, and the capacity of dental health services was found with a 3.7% reduction in the population with high DMFT and a 5.2 % increase in very low DMFT.

The study [9] in Table 1 applied a system dynamics model to estimate the lifetime costs and effectiveness of fluoride regimes for caries prevention in 6 to 8 years and compared them to those without fluoride application. They were based on national data and surveys. Two studies [10,11] in Table 1 developed the system dynamics model (SDM) to estimate the ten years' effect and costs of early childhood caries preventive strategies in preschool children. The interventions were the application of fluoride, limiting bacterial transmission from mothers to children, motivational interviewing, clinical treatment or secondary prevention, and a combination of them and compared with the baseline, which has not been given any intervention. The data utilities were based on national surveys, literature, and expert opinion. Another study [12] simulated the system dynamics model to predict the required resources, such as costs and clinical hours for fluoride varnish and atraumatic restorative treatment (ART) interventions to control caries in preschool children. The rest study [13] used a system dynamic model to evaluate the changes in dental caries status and the relationship between dental service utilization and oral health behaviors among Thai adults and the elderly. The model was simulated under three different policies, including a health promotion scenario, dental personnel intake, an affordability scenario, and a combined scenario compared to the base case scenario. The data usage was based on the Thai national oral health survey and Thailand’s official statistics registration. Nevertheless, system dynamics were used in dental care, as shown in Table 1.

It is seen that the system dynamics modeling approach in dental preventive strategies has the potential to assist in caries preventive interventions for evaluation of long-term effectiveness and cost savings or cost-effectiveness. In addition, it can be used in estimating the required resources for caries preventive intervention. Moreover, it can explore the dynamic changes of dental caries and their related factors. Nevertheless, few studies implemented system dynamics modeling in dental care services. Therefore, it should be more appraised in dental care.

2.3 Oral health prevention and promotion

Since dental caries, periodontal diseases, and tooth loss have been considered the significant burden of diseases not only in Thailand but also around the world and could lead to functional, aesthetic, and psychological problems related to oral health, the role of preventive and promotion is vital for good oral health status. [1, 20, 21]

The purpose of primary prevention is to prevent the occurrence of diseases in healthy conditions before the disease process begins. Secondary prevention leads to early diagnosis and prompt disease treatment, and tertiary prevention's role As prevention is better than curative, there are many approaches to implementing preventive interventions. For example, primary prevention includes oral health education, toothbrushing with fluoridated toothpaste, dietary control, water fluoridation, and fluoridated milk. [24] Fluoride varnish is secondary prevention, and filling decayed teeth can be tertiary prevention. [24]

Health promotion is "the process of enabling people to increase control over and improve their health" and the identified issues as important health determinants (WHO, 1986). Since the Ottawa Charter for health promotion has been advocated, oral health promotion is a deliberate effort to build healthy public policy, create supportive environments, strengthen community action, reorient health services, and develop personal skills. [25] Examples of interventions that build healthy public policy may include optimal water fluoridation, developing healthy food and nutrition policies in schools, and limiting the marketing of carbonated & sugar-containing drinks to children. [26] Examples of interventions creating healthy, supportive environments may be the provision of fluoridated toothpaste at a subsidized cost, oral health awareness, and promotion through social marketing campaigns. [26] Examples of interventions that strengthen community action may be engaging the community to support water fluoridation, engaging the community to participate in school oral health programs, and community and school collaboration to establish a safe playground or environment for children. [26] Examples of interventions that help to develop personal skills may include guided tooth brushing using fluoridated toothpaste as a self-care habit and nutritional and dietary education programs. [26] Examples of interventions for reorientating health services may be training health professionals about preventive and

social components of oral health promotion and building knowledge for diagnosing early caries detection programs. [26]

The following are implementation guidelines for oral health prevention and promotion of the Ministry of Public Health, Thailand, according to age groups. [27]

Pregnant women and 0 to 2 years old children

To promote oral health literacy before and after the delivery.

- Before birth, oral health examination and plaque examination using dye coloring method by dental health personnel, tooth brushing hand on, and accessing dental service according to their need.
- After birth, advising mother for child oral cleaning, caries assessment for the child at 6, 9, 12, 18, 20, 30 to 36 months, children with risk to get fluoride varnish (FV), referring children with cavitated caries for treatment, tooth brushing hand on and advising proper diet to parents for children.

2 to 6 years old children

To promote oral health literacy of children.

- Tooth brushing with fluoride toothpaste after lunch.
- Provide healthy snacks (between meals), i.e., fruits and cereal, and set the campaign to promote plain milk, bottle feeding, and good diet among parents and caregivers.
- Oral health examination.
- FV for caries risk, sealing permanent teeth, and refer for cavitated caries.

School children and teenagers (5-15 years)

To increase access to dental services

- Support dental service unit/organization, tooth brushing campaign, decrease sugar diet and drinks, FV application, application of sealant to first and second permanent molars, referral for treatment need, and evaluation of sealant retention.

To develop an oral health literacy

- Oral health education, advising healthy food selection and tooth brushing behavior, and health promotion programs at schools via networks

To develop a school health system and environment

- Promoting all stakeholders to create an environment for good oral health, i.e., schools, families, and communities, supporting schools to set up a good policy for oral health, and developing surveillance systems for factors related to oral health

Working age (15-59 years old)

To increase oral health literacy and good oral health behavior.

- Proper access to dental service utilization

Elderly (Above 60 years)

To continuously receive oral health care by themselves or caregivers, integrate dental service delivery, receive treatment needs to maintain oral health, decrease tooth loss and access innovation and technology for elderly care.

- Self-care

  Tooth loss prevention, hyposalivation care, risk behavior care for CA, development of online communication, development of self-assessment of oral health care behavior, risk, and treatment need, integrated oral health care in care manager curriculum, develop an oral care plan and report in the information system, improvement of village health volunteer (VHV) performance to assess hyposalivation or dysphagia or other oral health problems and coordinate with service delivery
- Professional care
- Primary care (hospital at sub-district level) - Tooth brushing instructions and practice, plaque control, fluoride varnish for root caries prevention, scaling, oral cancer screening, risk behavior modification, non-communicable disease screening, service at home, and integrated with family medicine team

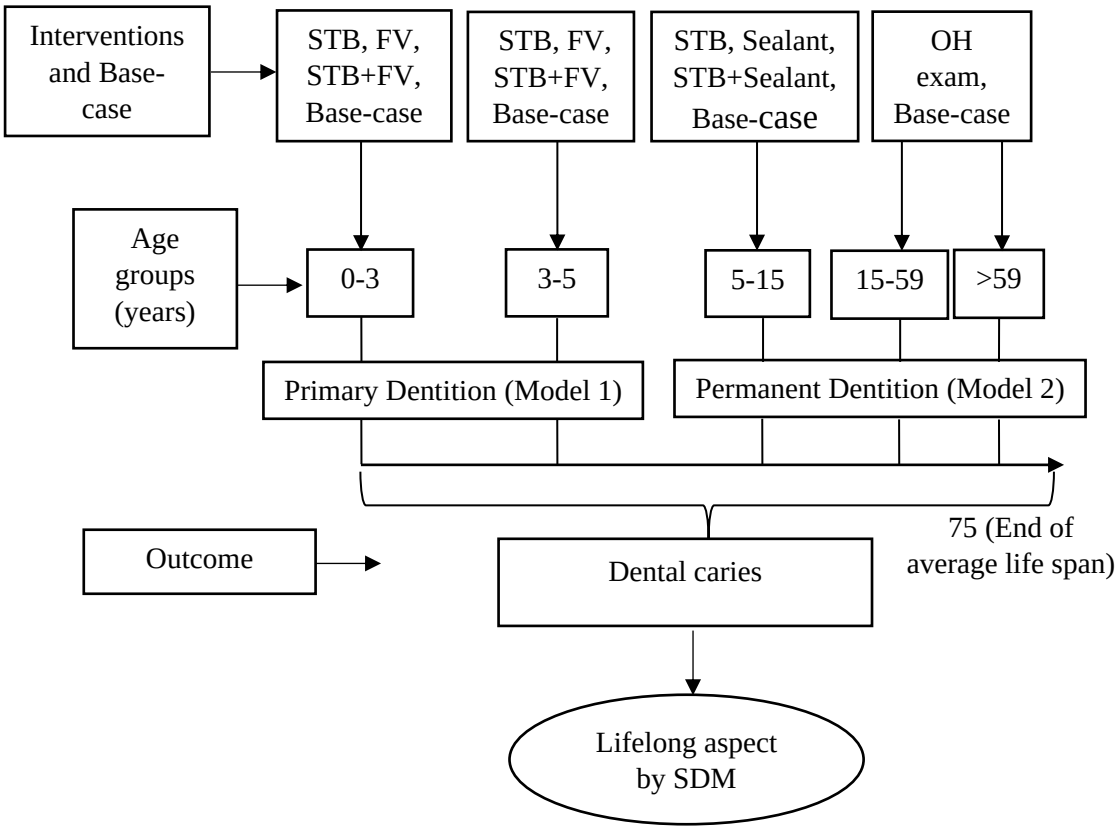
- Secondary care (community hospital, general hospital) - access to dentures for tooth loss cases, screening for pre-cancerous lesions, treatment for caries, root caries, periodontitis, and support health promotion hospital at sub-district level
- Tertiary care (Excellent center, central hospital) - provides services: implant, complex denture cases, biopsy, surgery, radiation therapy, and treatment for caries, root caries, and periodontitis

According to the review of guidelines of the oral health prevention and promotion programs in Thailand for each age group, the following caries preventive interventions for each respective age group shown in the conceptual framework were considered in SDM as intervention scenarios analysis for lifelong effects.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Conceptual Framework



Base-case = No intervention was given

STB = Supervised tooth brushing

Sealant = Sealant application

FV = Fluoride varnish

OH exam = Oral health examination

SDM = System dynamics model

3.2 Methodology for Objective 1

3.2.1 General Objective:

To identify the effectiveness or efficacy of primary prevention programs for dental caries among age groups (0-3, 3-5, 5-15, and 15-59) by conducting a Systematic Review and Meta-analysis.

3.2.2 Specific Objective:

To determine the effectiveness or efficacy of each primary preventive intervention-

- i.e., Supervised tooth brushing, fluoride varnish (FV), application of dental sealant, and oral health examination among each age group (0-3, 3-5, 5-15, and 15-59) compared to:
- Routine dental care or
- Another alternative intervention or
- No intervention
- for controlling the development or progression of dental caries by conducting a Systematic Review and Meta-analysis.

In this study, a Systematic Review and Meta-analysis were conducted for Supervised Toothbrushing (0-3, 3-5-, and 5-15-years age group) and Fluoride Varnish (0-3- and 0-5-years age group), but for FV, only latest five years period were searched and the studies from last years were retrieved from the previous systematic review of FV (2019). Searching for the dental sealant (5-15 age group) was not conducted, and retrieved studies from the previous Cochrane review. Also, the search for oral health examination (15-59) was not conducted, and retrieved the studies from other work.

Table 2. Provided interventions and outcomes for each age group according to specific objectives

Age groups Participants (P)	Interventions (I)	Comparison (C)	Outcome (O)
0-3 years	Supervised toothbrushing and fluoride varnish	Routine dental care or another alternative intervention or no intervention	Dental caries
3-5 years	Supervised tooth brushing and fluoride varnish	Routine dental care or another alternative intervention or no intervention	Dental caries
5-15 years	Supervised tooth brushing and application of sealant	Routine dental care or another alternative intervention or no intervention	Dental caries
15-59	Oral health examination	Routine dental care or another alternative intervention or no intervention	Dental caries

3.2.3 Inclusion criteria for included studies

Types of study design

Researchers introduced interventions and studied the effects, so the study designs looked more like experimental ones. The study designs of the included studies in the review were included as follows –

- Randomized Controlled Trial (individual or cluster) or
- Quasi-Randomized or
- Parallel or
- Comparative or
- Prospective or
- Interventional study

Follow up

The studies with a follow-up period of at least one year were considered included.

Type of participants

The review was considered for all studies that include participants within ages-groups of –

- 0-3 years
- 3-5 years
- 5-15 years
- 15-59 years

The age group intervals are classified and considered based on MOPH's intervention age groups, as mentioned above in section 2.3. No restrictions will be placed on participants' gender, ethnicity, or other demographic characteristics.

Type of interventions

The review of interventions of interest included those related to each preventive intervention's efficacy and/or effectiveness, i.e., supervised tooth Brushing, fluoride varnish, dental sealant, and oral health examination. Each intervention included in this study is described below. Since the preventive interventions included in this study aim to prevent the disease from occurring or progressing, they could be considered primary prevention.

Description of each intervention

Supervised Tooth Brushing

Supervised tooth brushing aims to control or prevent the progression of oral diseases such as dental caries, plaque, and gingival diseases and improve oral health literacy. The following facts are included in the supervised toothbrushing program [29, 30] –

- Use the correct toothbrushing technique.
- Brush twice daily with fluoride toothpaste (before bedtime and after breakfast).
- Choice of appropriate toothbrush design and amount of fluoride toothpaste
- Brushing time (minimum of two minutes)
- Spit out well after brushing, but minimize rinsing behaviors with water

All the above facts were demonstrated and supervised by responsible supervisors such as oral health professionals, health educational professionals, or trained persons: teachers or parents for children or caregivers to target groups.

Fluoride varnish

Fluoride varnish prevents dental caries, promotes tooth remineralization, and reduces dentine sensitivity in both primary and permanent teeth. The following facts are included in the application of fluoride varnish [31] –

- Professionally application of fluoride varnish to target age group by dental professionals

- Application of a thin layer of 5% or 0.1% fluoride varnish with a specific or unspecific brand to all surfaces of the teeth in both primary and permanent teeth
- Two or three or four or five, or six times application
- One month, four months, six months, or twelve months apart application.
- Application of fluoride varnish alone or supplying fluoride toothpaste together

Pit and fissure sealants application

Applying pit and fissure sealants aim to prevent dental caries in permanent teeth. The following facts are included in the application of pit and fissure sealants [32] –

- Professionally application of pit and fissure sealants to target age groups by dental professionals
- Applying Resin-based sealants to be placed on permanent teeth with deep pits and fissures, including teeth with initial enamel lesions that are considered at risk of caries

Oral health examination

The aim is to visit dentists for treatment needs of oral diseases to reduce oral diseases. The following facts are included in the oral health examination [33].

- Assessment of dentition status, i.e., the presence of untreated decay teeth, missing teeth, filling teeth, presence of periodontitis, or severe periodontal conditions
- Assessment of intraoral conditions, conditions of tongue and lips, i.e., the presence of abnormal changes in the oral cavity
- Assessment of treatment needs of the present conditions or diseases and referral for treatment needs

Type of comparison

The comparison groups to interventions interest of the included studies in the review included no intervention, routine dental care, or other alternative intervention.

Description of type of comparison

No intervention

No intervention means that the comparison group to the intervention group receives no intervention.

Routine care

In this study, routine dental care means that participants in the comparison group do their oral hygiene alone and do not receive any intervention.

Other alternative intervention

The alternative intervention means that the comparison group receives other alternative interventions in contrast to the primary intervention from the intervention group. For example, if the intervention is supervised tooth brushing and control is given oral hygiene instruction, oral hygiene instruction could be considered as another alternative intervention compared to the primary intervention.

Outcome

The outcome interest of the included studies in the review included –

Dental caries

The interest in the outcome (dental caries) among intervention and comparison groups is the proportion of participants with caries experience who were measured using the caries indexes such as mean decayed, missing, and filled at tooth level (DMFT) and tooth surface level (DMFS).

Type of settings

Settings contained in the review were community-based, home-based, nursery, and school-based interventions.

3.2.4 Exclusion criteria for included studies

The studies that were not relevant to the review's inclusion criteria were excluded according to the type of participants, type of intervention, type of comparison, type of outcome, and type of study design.

3.2.5 Search methods for identification of studies

The search strategy was designed to access published materials. There were language restrictions, and only the English language was used. Articles were searched in the English language. Published articles were searched as electronic searches. It was comprised of three stages:

An initial limited search of Medline via PubMed was undertaken to identify relevant keywords in the title and abstracts. Terms were identified this way, and the synonyms used by respective databases were used in an extensive literature search. Reference lists and bibliographies of the articles collected from those identified in the two stages mentioned above were searched.

All electronic searches included studies that started from 1990 to 2021. Articles published in English and indexed in the following databases were searched:

- Cochrane Central Register of Controlled Trials (CENTRAL)
- MEDLINE via PubMed
- Web of Science
- EMBASE
- SCOPUS

MeSH terms will be identified and used. MeSH is the National Library of Medicine's (NLM's) controlled vocabulary or subject heading list of

biomedical literature indexing journal articles for Index Medicus® and MEDLINE. [34] MeSH imposes uniformity and consistency to the indexing of biomedical literature and is arranged in a hierarchical categorized manner called MeSH tree structures which are updated annually. [34] MeSH terms were assessed through the search box on the main PubMed page. An initial search term was typed, and choose MeSH term that the system presented with a list of subject headings with definitions and then sent to the search box with AND or OR to broaden or narrow the search results. Once the MeSH terms are in the search box, finish searching the chosen MeSH term by clicking on “Search PubMed.” The search terms are shown in table 3 according to the type of intervention, age range, and outcome.

Table 3. Search terms for studies

No.		Interventions		Participants		Outcome
1.	Supervised Toothbrushing for 0-5 years old	(“Toothbrushing” [Mesh] OR “Education, Dental" [Mesh])	AND	(“Child” [Mesh] OR “Child, Preschool” [Mesh]) OR “Schools” [Mesh])	AND	(“Dental caries” [Mesh])
2.	Supervised Toothbrushing for 5-15 years old	(“Toothbrushing” [Mesh] OR “Education, Dental" [Mesh])	AND	(“Child” [Mesh] OR “Schools” [Mesh])	AND	(“Dental caries” [Mesh])
3.	Fluoride Varnish for 0-5 years old	("Fluorides, Topical" [Mesh] OR “Fluoride Varnish”)	AND	(“Child” [Mesh] OR “Child, Preschool” [Mesh]) OR “Schools” [Mesh])	AND	(“Dental caries” [Mesh])

3.2.6 Selection of studies

After searching studies, the results of searches in each electronic database were imported into the Endnote X7 record. The number of records retrieved from each database was kept. Duplicates were removed to create a core database. After removing duplicate studies, articles were scanned to meet the inclusion criteria based on their title, abstract, and keywords to eliminate irrelevant records. Potentially relevant studies meeting the eligibility criteria were selected as full-text records. Two review authors examined the full-text report to determine the included studies. They were not blinded to the potential influence to review authors, such as the authors, institutions, journals of publication, or results. An inclusion criteria template was developed to aid reviewers in identifying the included studies. Not blind because reviewers reviewed the full-text report according to the inclusion criteria, and each process was done independently and then discussed to develop an agreement for the final decision on included studies. Disagreements about the inclusion of studies were resolved by discussion. Excluded studies were entered into an excluded studies table, and reasons for exclusion were recorded.

The combined results of all searches, such as all records from all databases, duplicate studies, included studies meeting eligibility criteria, excluded studies and reasons for exclusion, and studies that were included in quantitative and qualitative synthesis, are presented as study flow diagrams in Figures 1, 2 and 3 according to the PRISMA statement. (Liberati 2009) [35]

Figure 1. PRISMA flow diagram for Supervised Toothbrushing (0-5 years age group)

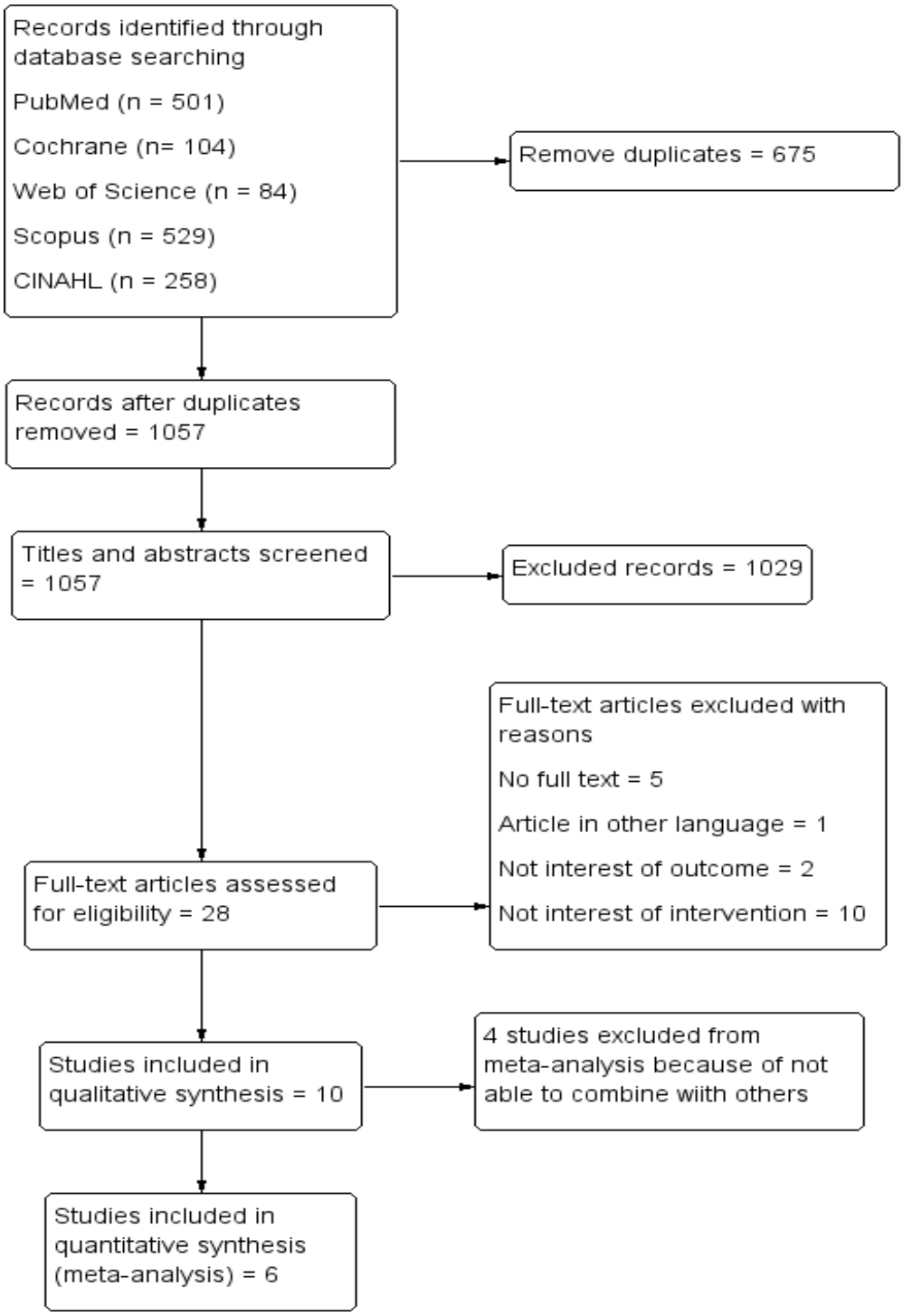


Figure 2. PRISMA flow diagram for Supervised Toothbrushing (5-15 years age group)

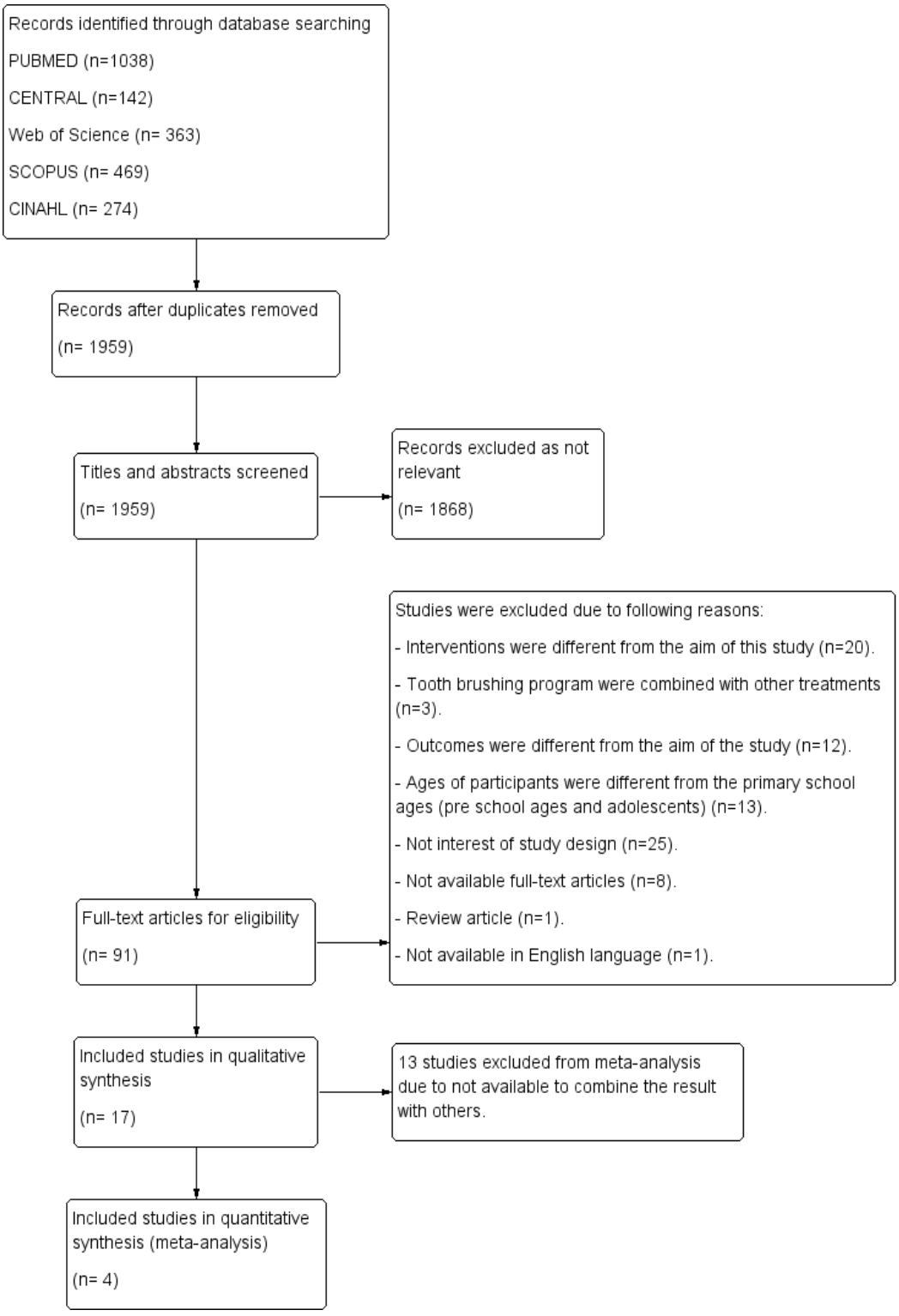
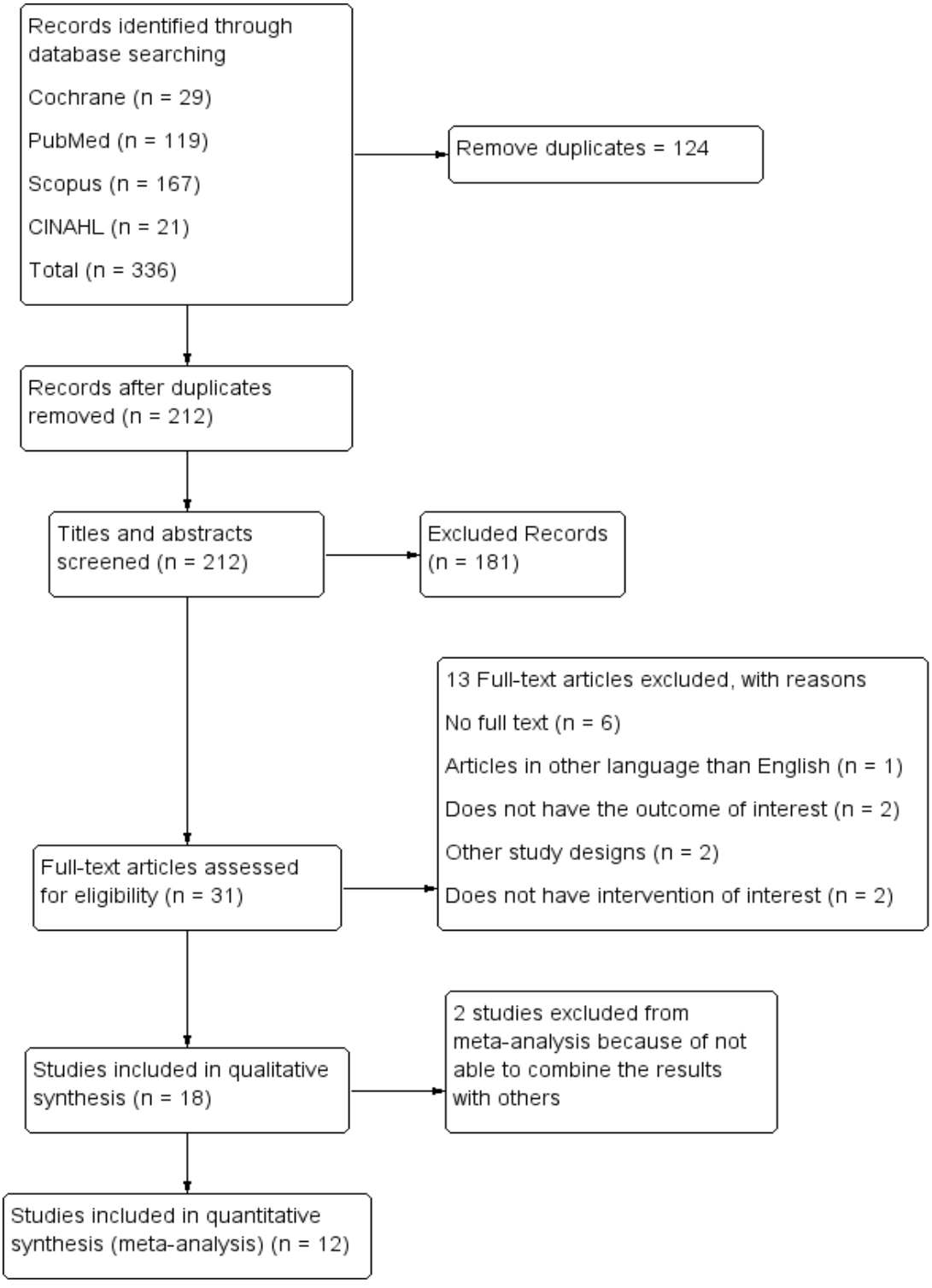


Figure 3. PRISMA flow diagram for Fluoride Varnish (0-5 years age group)



3.2.7 Data extraction

After included studies were defined, an excel spreadsheet was created to extract the required information and data from the studies with the following specified format.

- Author names with a year of publication
- Study design
- Duration of study
- Ages of participants
- Type of intervention
- Type of control or comparison group
- Number of participants in the intervention group
- Number of participants in the control group or comparison group
- Dental caries outcome data in the intervention group
- Dental caries outcome data in the control or comparison group

And then, data were input RevMan software, and meta-analyses were performed according to age groups.

3.2.8 Characteristics of the included studies

The following tables (4,5,6,7,8,9,10) showed the characteristics of included studies in the **meta-analyses** of supervised Toothbrushing, fluoride varnish, sealant, and oral health examination.

Table 4. Characteristics of included studies in the meta-analysis of Supervised Toothbrushing (0-3 years)

No	Author/ Publication years	Follow up	Age	Study design	Intervention	Control	Resource use	Outcome
1	Klaus Pieper, 2016 [36]	Two years	2-4-year-old	Interventional study	Specially trained dental nurses supervised daily Toothbrushing	Tooth brushing instructions (3 to 4 times a year)	500 ppm fluoride toothpaste in the intervention group	Dental caries (dmft, dmfs index)
2	Inger Wennhall, 2005 [37]	One year	Two year old	Interventional study	Toothbrushing instructions and training to guardians at each visit by two specially trained dental assistants and provided fluoride tablets	No intervention	Fluoride toothpaste with 1,000–1,100 ppm and 0.25 mg NaF in the intervention group	Dental caries (deft index)

Table. 4 (Continued)

3	Emily Ming Jiang, 2014 [38]	Two years	8–23 months old	RCT	Oral health education talk, parental hands-on training on brushing their child's teeth from a trained dental hygienist, reinforced every six months	Oral health education talks to parents (no reinforcement of OHE)	Fluoride toothpaste and printed materials for OHE	Dental caries (dmft index)

Table 5. Characteristics of included studies in the meta-analysis of Supervised Toothbrushing (3-5 years)

No	Author/ Publication years	Follow up	Age	Study design	Intervention	Control	Resource use	Outcome
1	Rong W. S, 2003 [39]	Two years	Three years old	RCT	Brushing the teeth with fluoride toothpaste twice a day under the supervision of teachers during school days	No intervention	Fluoride toothpaste with 1,100 ppm in the intervention group	Dental caries (dmfs index)
2	Vilija, 2008 [40]	Two years	Three years old	Interventional study	Supervised Toothbrushing was applied twice daily at the kindergarten in the morning and home in the evening	No intervention	Fluoride toothpaste with 500 ppm for STB	Dental caries (dmft, dmfs index)

Table. 5 (Continued)

3	Lena Natapov, 2021 [41]	Two years	Five years old	Interventional study	Brushed once daily at kindergartens, with fluoridated toothpaste, for two school years	No intervention	Fluoride toothpaste with 1,000 ppm in the intervention group	Dental caries (dmft index)

Table 6. Characteristics of included studies in the meta-analysis of Supervised Toothbrushing (5-15 years)

No	Author/ Publication years	Follow up	Age	Study design	Intervention	Control	Resource use	Outcome
1	Curnow, Mm 2002 [42]	Two years	5-6 - years old	RCT	Supervised Toothbrushing on school days by local mothers.	No intervention	1,000-ppm fluoride toothpaste, as well as being provided with toothbrushes for their home use	Dental caries (D1FS, D3FS index)
2	Al-Jundi 2006 [43]	Four years		Prospective study	30-min oral hygiene instructions sessions on school days by twice a year, and all children practiced tooth brushing	Same oral hygiene instructions sessions, but without practical demonstratio	500 and 1000 ppm fluoride toothpaste	Dental caries (DMFT index)

Table. 6 (Continued)

					using the horizontal scrub method under the supervision of the dental hygienist and the research assistant.	n and application of tooth brushing method		
3	Lai, HM 2016 [44]	Ten years		Prospective study	Flossing and brushing after lunch on every school day, under the detailed instruction of school nurses, for one semester (20 weeks)	Carried out their oral hygiene procedures in their ways	1,000 ppm fluoridated toothpaste	Dental caries (DMFT, DMFS index)

Table. 6 (Continued)

4	Poul Erik Petersen 2004 [45]	Three years		Interventional study	OHE (general and dental health), and daily oral hygiene instructions supervised by teachers in vertical short stroke brushing method	No intervention	Booklets, models, slides, posters for OHE, toothbrushes, and fluoride toothpaste	Dental caries (DMFT, DMFS index)

Table 7. Characteristics of included studies in the meta-analysis of Fluoride Varnish (FV) (0-3 years)

No	Author/ Publication years	Follow up	Age	Study design	Intervention	Control	Resource use	Outcome
1	M. Tickle, 2017 [46]	Three years	2-3 - year old	Randomized, 2-arm, parallel-group	FV to all primary teeth, toothbrush, and toothpaste were delivered at the child's dental check-up twice a year with standardized dental health advice on optimal use of fluoride toothpaste and restriction of sugar consumption	Did not receive professionally provided fluoride intervention but received the same standardized dental health advice	22,600 ppm of fluoride varnish, a toothbrush, and a 50-mL tube of 1,450 ppm of fluoride toothpaste in the intervention group	Dental caries (dmfs index)
2	Mahtab Memarpour, 2016 [47]	12 months	12-14 - months old	RCT	Oral health education and application of FV (every six months)	Placebo FV	FV = 5% sodium fluoride, educational pamphlet, and toothbrush	Dental caries (dmft index)

Table. 7 (Continued)

3	Emily Ming Jiang, 2014 [48]	Two years	8–23 - months old	RCT	Semi-annual application of fluoride varnish in addition to oral health education and hands-on toothbrushing training	Oral health education talks to parents (no reinforcement of OHE)	Fluoride toothpaste, printed materials for OHE, and 5% sodium fluoride varnish	Dental caries (dmft index)
4	J.A. Weintraub, 2006 [49]	Two years	6-44 - months old	RCT	Parental counseling plus FV twice/year with four intended applications	Counseling only, with no fluoride varnish, 0FV	FV (Duraphat®)	Dental caries (dfs index)
5	B.H. Oliveira, 2014 [50]	24 months	1-4 - year-old	Prospective, randomized-controlled, parallel-group clinical trial	Application of fluoride every six months + individual oral health counseling, including supervised Toothbrushing	OHC + Placebo varnish	5% sodium FV, toothbrush, and fluoride toothpaste containing 1,450 ppm	Dental caries (dmfs index)

Table. 7 (Continued)

6	Maria Anderson, 2016 [51]	Three years	One year old	RCT	Semi-annual applications of FV and standard preventive oral health programs, including toothbrushing instructions, twice daily with fluoride toothpaste, and dietary counseling	Standard preventive oral health program	FV (Duraphat ®, 22.6 mg of fluoride per ml), toothpaste (1,000–1,450 ppm fluoride)	Dental caries (Decay, d index)
7	Patricia Munoz-Mill, 2018 [52]	Two years	2-3-year-old	RCT	Biannual applications of FV	Placebo varnish	0.5 mL of FV Profluorid Varnish (Voco GmbH, Cuxhaven, Germany)	Dental caries (dmft index)

Table 8. Characteristics of included studies in the meta-analysis of Fluoride Varnish (FV) (3-5 years)

No	Author/ Publication years	Follow up	Age	Study design	Intervention	Control	Resource use	Outcome
1	P.A. Braun, 2016 [53]	Three years	3-5 years old	Cluster-randomized	Four times FV applications and oral health promotion (OHP) events	Did not receive OHP events or FVs but received toothbrushes and toothpaste.	FV, toothbrushes, and toothpaste	Dental caries (dmfs index)
2	Lars G. Petersson, 1998 [54]	Two years	Four & Five years old	Clinical study	Four times applications of the varnish	No varnish	FV	Dental caries (dfs index)
3	Lawrence HP, 2008 [55]	Two years	Five years old	Cluster-randomized	FV application twice a year + oral health counseling	Oral health counseling	FV (Duraflor, 5% sodium fluoride)	Dental caries (dmfs index)

Table. 8 (Continued)

4	A. Agouropoulos, 2014 [56]	Two years	2–5 years old	RCT	Dental professionals use biannual applications of FV + oral health education (OHE) in the classroom twice a year and supervised toothbrushing (STB) by teachers once a day at school	Biannual applications of a placebo varnish without fluoride + OHE + STB	FV (0.9% dichlorosilane), 1000 ppm fluoride toothpaste	Dental caries (dmfs index)
5	Alex D. McMahon, 2020 [57]	Two years	Three years old	RCT	FV + TAU (treatment as usual)	TAU only	FV (Duraphat 50 mg/mL)	Dental caries (dmft, dmfs index

Table 9. Characteristics of included studies in the meta-analysis of sealant (5-15 years)

No	Author/ Publication years	Follow up	Age	Study design	Intervention	Control	Outcome
1	Brooks, 1979 [58]	Three years	5-10 years old	Comparative study	Delton and Nuva Seal was applied to permanent first molars	No sealant	Dental caries (occlusal caries)
2	Charbeneau, 1979 [59]	18 months	5-8 years old	Half mouth design	BIS-GMA resin sealant was applied to the permanent first molars and primary second molars	No sealant	Dental caries (occlusal caries)
3	Sheykholeslan, 1978 [60]	24 months	6-10 years old	Experimental study	Delton sealant was applied to the first permanent molars	No sealant	Dental caries (occlusal caries)

Table. 9 (Continued)

4	McCune RJ, 1979 [61]	36 months	6-8 years old	Half mouth design	Bis GMA sealant was applied to the molars	No sealant	Dental caries (occlusal caries)
5	Richardson, 1978 [62]	Five years	Second grade aged	Clinical study	Bis-GMA sealant was applied to the first permanent molars	No sealant	Dental caries (occlusal caries)
6	Liu, 2012 [63]	24 months	Nine years	RCT	Resin sealant, single placement	No sealant (water as placebo)	Dental caries (occlusal caries)

Table 10. Characteristics of included studies in the meta-analysis of oral health examination (15-59 years)

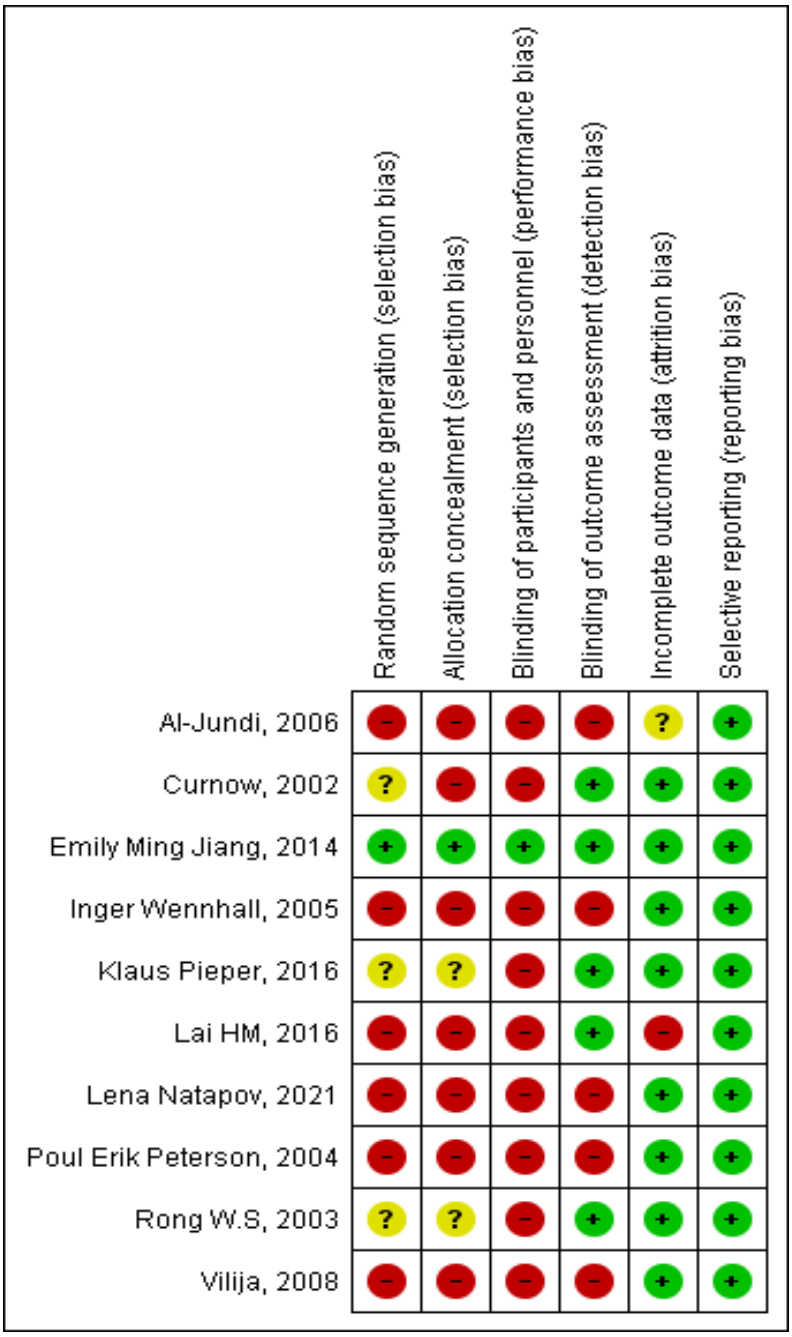
No	Author/ Publication years	Age	Study design	Intervention	Control	Outcomes
1	C HEN X, 2014 [64]	21-58 years old	Cross-sectional study	Presence of dental or oral health examination within six months	No oral health examination	Dental caries (DMFT index)
2	Kasper Rosing, 2016 [65]	25–40 years old	Retrospective register-based study	Dental examination 2005 to 2009	No oral health examination	Dental caries (DMFT index)

3.2.9 Risk of bias assessment

The risk of bias was assessed using the criteria of bias assessment as presented in the Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (updated March 2011, Higgins 2011). [66] Five sources of bias were assessed: selection bias, performance bias, attrition bias, detection bias, and reporting bias. They were assessed under six domains: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, and selective outcome reporting corresponding to the primary sources of bias. Judgment of risk of bias for each domain was accompanied by low risk, high risk, and unclear risk. This adjustment was made according to the risk of bias assessment criteria template. The process of bias assessment was done by RevMan software.

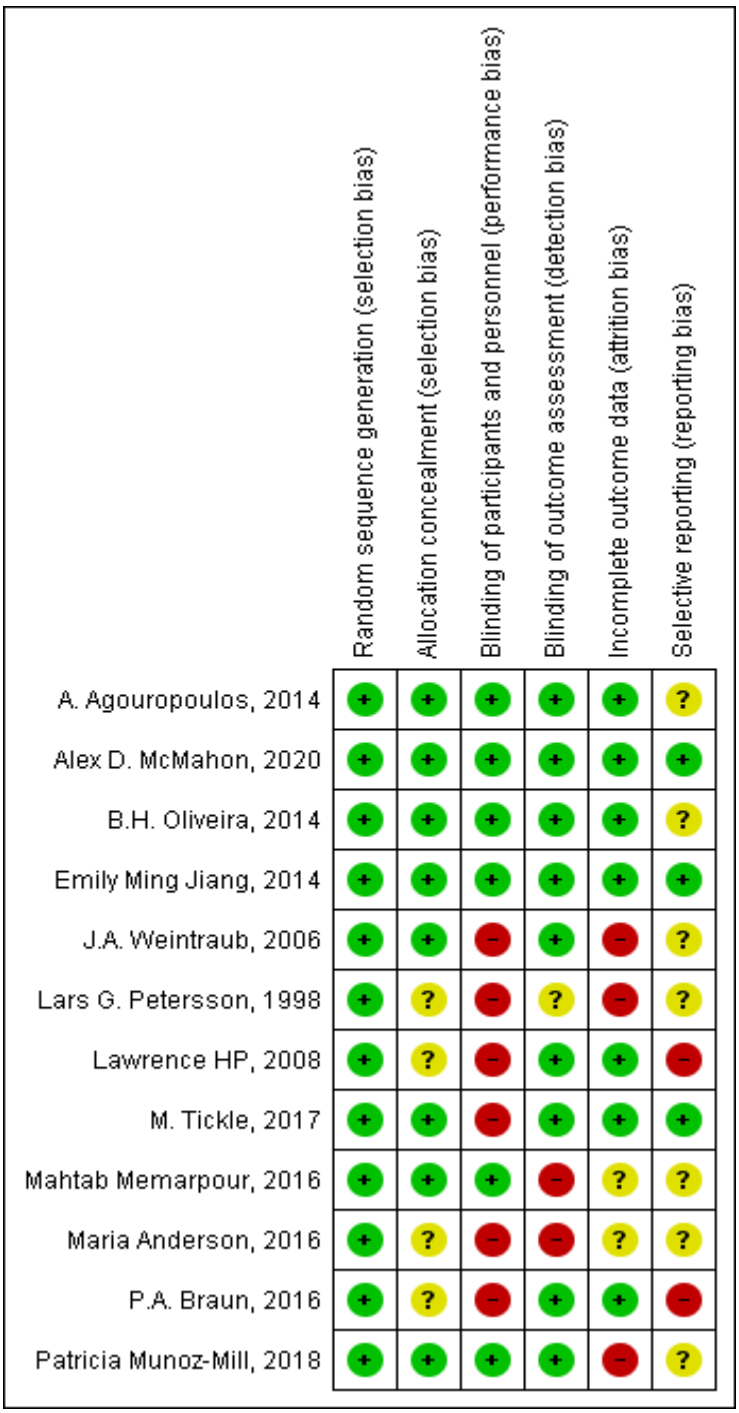
The risk of bias summary for included studies of each intervention was shown as shown in the following figures: (4,5,6)

Figure 4. Risk of bias summary of included studies in meta-analysis for Supervised Toothbrushing (0-15 years old)



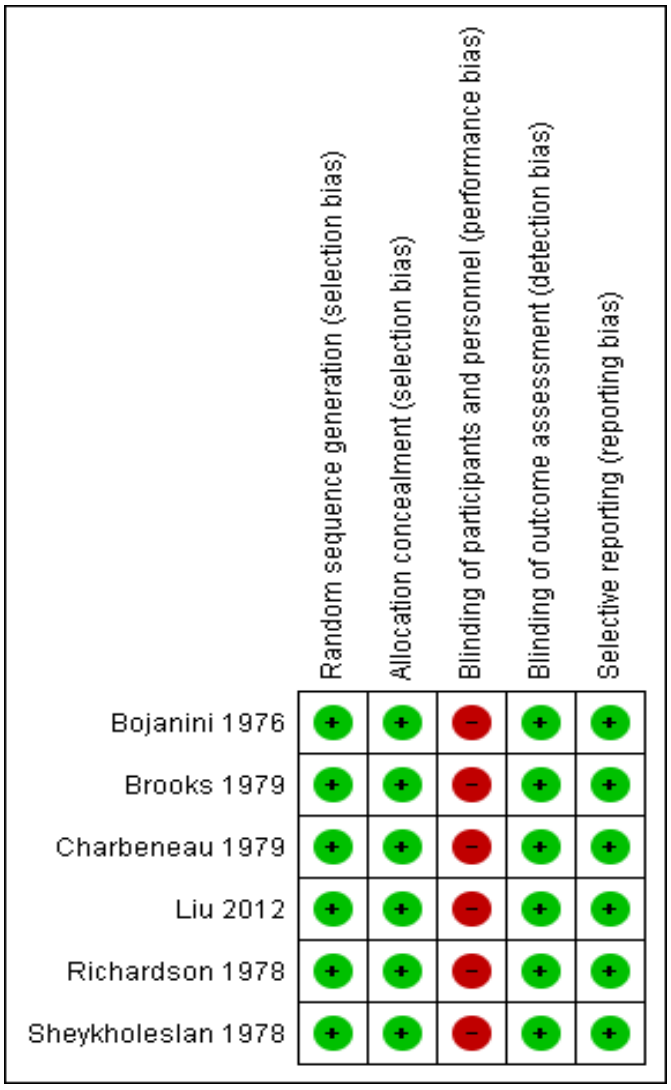
+ (low risk of bias), ? (unclear risk of bias), - (high risk of bias)

Figure 5. Risk of bias summary of included studies in meta-analysis for Fluoride Varnish (0-5 years old)



+ (low risk of bias), ? (unclear risk of bias), - (high risk of bias)

Figure 6. Risk of bias summary of included studies in meta-analysis for sealant (5-15 years old)



+ (low risk of bias), ? (unclear risk of bias), - (high risk of bias)

3.2.10 Meta-analysis for outcomes measures

Meta-analysis was carried out to assess the effect of interventions on reducing the risk of outcomes. It was conducted by Review Manager (RevMan) 5.3 software. The meta-analysis results for each intervention are shown in the results section. The following components were included in the meta-analysis-

Measurement of intervention effect

Estimated effect sizes were considered as the effectiveness of the included studies. It was performed for each study using risk ratio (RR) as effect size, and their 95% confidence intervals were considered. [66] Effect sizes were measured as risk ratio (RR) for the dental caries outcomes for the intervention and comparison groups.

In this study, risk ratio (RR) was considered an effect estimate to derive the prevented fraction from them. The information on prevented fractions was used in the SDM when running the intervention scenarios (Objective 2). The prevented fraction is when an exposure seems to reduce the risk and gives the percentage of cases that can be prevented if a population is exposed to intervention compared to an unexposed population. It can be derived from RR by calculating (1 − RR) and expressed as a percentage. [67]

The estimated effect was compared to whether it favors the intervention or control group among studies as a comparison. The analysis was done as comparisons of intervention and control for each age group, and the effect was single for each age group and not combined for all age groups.

Assessment of heterogeneity

Heterogeneity is the study's variations, such as study types, interventions, outcomes, and participants. Heterogeneity between studies was tested using the statistical approach, the standard chi-square test, and I^2 statistics. Heterogeneity was regarded when the I^2 value is substantial, which is greater than 50%, as interpreted in the Cochrane Handbook for Systematic Reviews of Interventions. [66] Heterogeneity was observed for all meta-analyses due to I^2 values being more significant than 50%. Therefore, meta-analyses were

performed using a random-effects model for weights of the effect sizes and overall effect sizes. [66] The random effect model gives the summary effect, which is the mean estimate of all relevant actual effects across all studies to avoid overestimated or underestimated effects. [66] Furthermore, study weights are balanced. So, extensive sample-size studies are less likely to dominate the analysis, and small studies are less likely to be trivialized. [66]

Subgroup analysis

Variations among the studies, such as study types, intervention, outcomes, and participants, were identified, and subgroup analysis was conducted according to variations of the included studies. Interventions were different from the studies of fluoride varnish (FV). Some studies compared FV alone, and others compared FV with package health promotion. Therefore, subgroup analysis was performed in fluoride varnish analysis by splitting interventions into subgroups, often to compare them.

Presenting of study results

Effect sizes for each study, overall effect size, confidence interval intervals (95%), and weights of studies of all interventions for each respective age group are presented using forest plots to assess the magnitude of the intervention effect on a particular outcome. The forest plots are shown in the results section.

3.3 Methodology for Objective 2

3.3.1 Objective

To conduct the System Dynamics Model (SDM) to estimate the lifelong outcomes (dental caries and their related events such as treated cases and tooth loss) under the caries preventive programs based on the effectiveness information from objective 1.

3.3.2 Design

System Dynamics Model (SDM) was constructed to analyze and compare the different scenarios: caries preventive interventions for lifelong outcomes. SDM involves two aspects: qualitative and quantitative.

The qualitative aspect included mapping the causal relationships between the outcome of interest (dental caries) and their related events and identifying feedback loops among them. The modeling processes in this part included problem articulation and developing a dynamics hypothesis.

The quantitative aspect included developing the mathematical simulation models representing stocks and flows diagram showing the interaction among a set of variables related to outcome interests identified from the qualitative part. The simulation model, model testing, and scenario analysis were involved in this modeling process.

3.3.3 Study population

The Thai population was set and simulated in the model. The population started from 0 years old (born in 2021) in the model, and the total population was 678,243. The model simulated the population to 75 years old to estimate the outcomes of the population in each age group interval, such as 0-3 years, 3-5 years, 5-15 years, 15-59 years, and above 59 years.

3.3.4 Modeling process

Modeling was built with such steps: **problem articulation: identifying the time horizon, identifying key behaviors, identifying the behaviors of the critical variables, developing dynamics hypothesis, and formulating the simulation model by group model building, model testing, and scenarios analysis.** [68,69] To respond to the established goal, the system dynamics model was consulted by specialists in the expert field, and all the required adjustments were conducted. Vensim: 9.0.1 software was used to run the SDM model.

3.3.4.1 Problem articulation

The problem to be considered was to estimate lifelong outcomes: dental caries and their related events among the Thai population under different scenarios, i.e., different oral health preventive and promotion interventions and base-case, which is assumed that no intervention was given. The effectiveness data were used from the systematic review and meta-analysis. Other required data were from secondary data and literature reviews of studies/documents.

Group Model Building (GMB)

GMB session

A session for group model building was established three times. There were three sessions. The purpose of the GMB was to determine critical variables and their behavior for a causal relationship, conduct a stocks and flows diagram and have reliable database uses. Five experts from the Ministry of Public Health (MOPH), two from the Provincial Health Authority, two professors from the Preventive Department, Faculty of Dentistry (Prince of Songkla University), two professors who are experts in SDM, one from Community Hospital, WCC, one from Sirindhorn College of Public Health, one from Faculty of Dentistry, Naresuan University and one from Chulalongkorn University with well-working experience in their respective fields included as participants in the GMB sessions. Details of experts are shown in the appendix. In the first and second GMB sessions, the researchers engaged about the

system dynamics model with its uses according to system dynamics literature, how we could apply the model in our study, the concept of our model, and the aim of the model to be used in the study. The researchers prepared some relevant input data as a dummy table for the SDM model to provide in the discussion.

Then, five main activities, such as

1. Identifying the time horizon
2. Identifying key variables
3. Identifying the behavior of the key variables
4. Developing the final causal loop diagram
5. Developing the final stocks and flows diagrams were included in the sessions.

Activity 1: Identifying the time horizon

The time horizon is firstly considered a lifelong aspect. The years for lifelong aspects to run in the model depended on expected life expectancy among males and females. An agreement for the time horizon was developed between the participants.

Activity 2: Identifying key variables

The names of all variables with an actual quantity were used. The variables were dental caries and their related events occurring over time. The researcher leads the participants to identify possible variables related to outcomes. The following variables were identified as included vital variables in the model.

The variables for dental caries-related events were as follows –

- No caries activity
- Developing caries
- Untreated caries
- Untreated caries to the treated case with restoration

- Treated caries with restorative treatment
- Treated caries with restorative treatment to recurrent caries
- Untreated caries to the treated case with endodontic treatment
- Treated caries with endodontic treatment
- Treated caries with endodontic treatment to recurrent caries
- Developing caries in primary teeth to permanent teeth
- Caries in permanent teeth
- Untreated caries to missing teeth
- Missing teeth

Activity 3: Identifying the behavior of the key variables

It focuses on understanding and describing the critical variables of how to behave. For example, it should change up or down depending on what external events affect the system. The participants discussed the occurrence of the variables in the model that would change over time depending on different scenarios, i.e., the effects of the interventions and base-case or current.

Activity 4: Formulation of dynamic hypothesis (Developing the causal loop diagram (CLD))

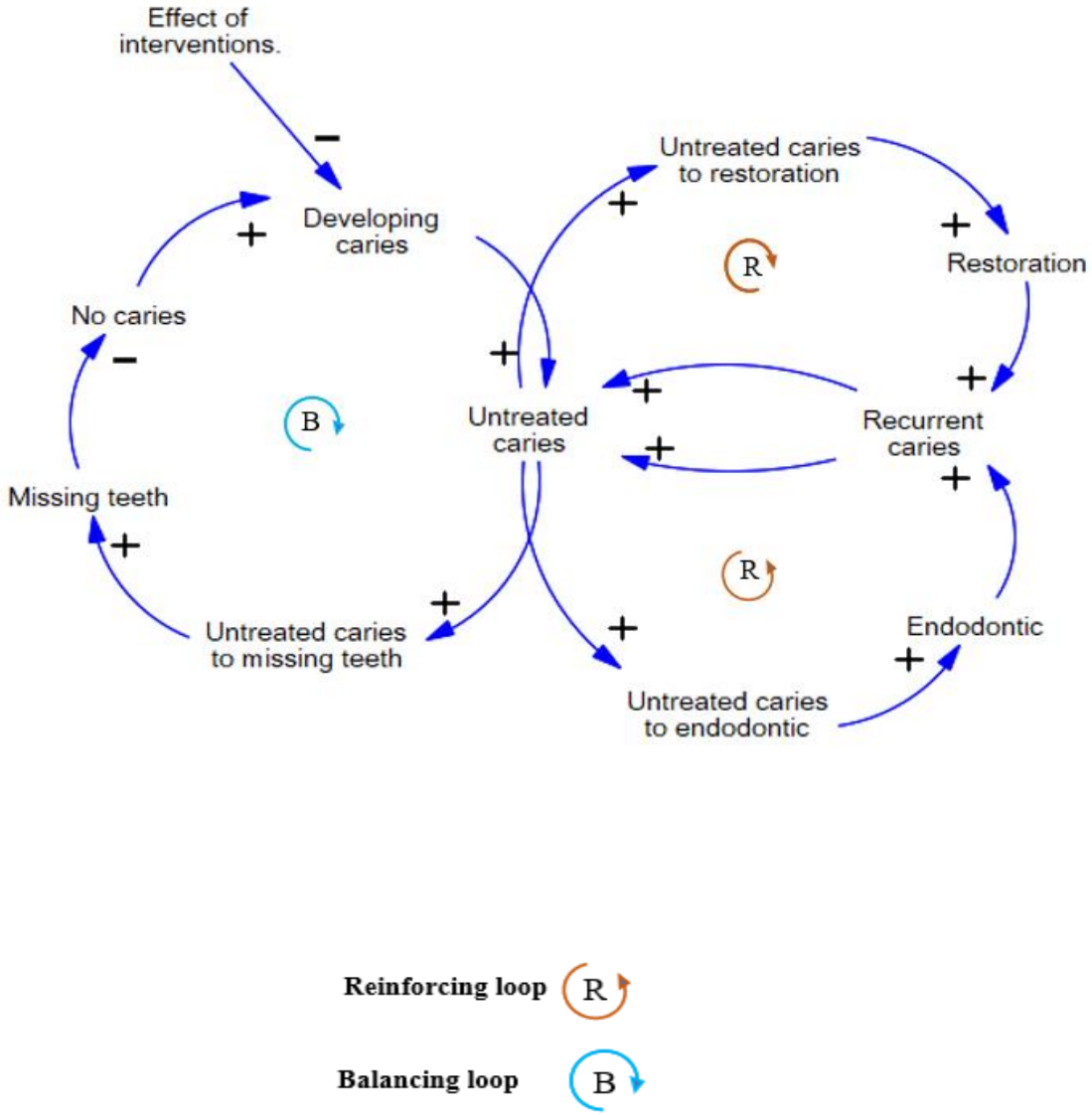
It focuses on developing a dynamic hypothesis that explains the dynamic relationships of dental caries-related events in the feedback structure. It is identified by the **causal loop** or feedback loop diagrams as a qualitative aspect showing relationships among variables that have the potential to change over time. [14,15]

The causal loop for dental caries and disease-related events was developed. The draft causal loop diagram was provided, and the final

causal relationship was consulted and conducted based on the draft by participants in the GMB session after an agreement was developed among the participants. In the causal loop diagram, the causal link from one element to another is a positive (+) sign if either one adds to another or a change in one produces a change in another in the same direction. If either one subtracts from another or a change in one produces a change in another in the opposite direction, the causal link from one to another is a negative (-) sign. [15] Balancing loops contains an odd number of "–" signs, whereas reinforcing loops contain an even number of "–" signs or all "+" signs.

Based on the draft causal loop diagram, participants discussed the natural history of the outcomes and their disease state progression. This progression focused on a seed question: "What are the states of diseases, including treated states, and how do they relate?" and "How does the intervention affect the disease?". The draft causal loop was modified to the final one when variables were adjusted or modified by consulting between participants. The final causal loop diagram is shown in Figure (7). This causal loop presented the general relationship between no caries, dental caries, treated cases, and missing teeth. After identifying the causal relationship, it was decided to separate two models in the following stock and flow diagrams, such as the primary and permanent dentition age models. Some required variables were also added to the models. And then, the stocks and flows diagrams of the two models were converted from the identified causal loop diagram to estimate the outcomes.

Figure 7. Causal loop diagram (CLD)



Activity 5: Formulation of a simulation model (Developing the stocks and flows diagram)

It is a quantitative aspect of formulating a mathematical model by setting and inputting the parameter values into the model. It was identified by converting the causal loop diagram from the qualitative part to the stocks and flows diagrams.

The stocks and flows diagrams for dental caries and related events were developed based on the draft stocks and flows diagram. There were two models for the final stocks and flows diagrams: the primary dentition age model and the permanent dentition age model. The updated causal loop diagram from activity four was turned into stocks and flows diagrams, and conducted the final ones based on the draft ones after approving an agreement between participants.

The stocks and flows diagrams for two dentition ages are shown in Figures (8,9) as model 1 for primary dentition age and model 2 for permanent dentition age. They are presented as follows –

Model 1 (Primary dentition age)

Stocks - The stocks in the models are denoted as squares which represent the caries-related events such as –

- No caries activity
- Untreated caries
- Treated caries with restorative treatment
- Treated caries with endodontic treatment
- Caries in permanent teeth
- Missing teeth

Flows – The rate of flows that affect the stocks in the models represent symbols with two triangles touching at their vertices called “valves,” indicating –

- Developing caries

- Untreated caries to the treated case with restoration
- Untreated caries to the treated case with endodontic
- Treated with restoration to recurrent caries
- Treated with endodontic to recurrent caries
- Developing caries from primary teeth to permanent teeth
- Untreated caries to missing teeth

Model 1 represents the primary dentition age where the population in the model was from 0 years old and ran the model for 6 years until the population reaches 6 years old. The six years old age was assumed that all populations would change to permanent dentition, and input the simulation results from during this age to model 2 (permanent dentition age). The concept of the model is shown in Figure (10).

Model 2 (Permanent dentition age)

Stocks - The stocks in the models are denoted as squares which represent the caries-related events such as –

- No caries activity
- Untreated caries
- Treated caries with restorative treatment
- Treated caries with endodontic treatment
- Missing teeth

Flows – The rate of flows that affect the stocks in the models represent symbols with two triangles touching at their vertices called “valves,” indicating –

- Developing caries
- Untreated caries to the treated case with restoration
- Untreated caries to the treated case with endodontic
- Treated with restoration to recurrent caries
- Treated with endodontic to recurrent caries
- Untreated caries to missing teeth

The simulation results from model 1 after six years at the age of 6 were input to model 2. Model 2 represents the permanent dentition age where the population in the model started from 6 years old and ran the model for 69 years until the population reached 75 years old. The concept of the model is shown in Figure (10).

Other required additional variables were input into two models, such as

- Caries development fraction that affects the rate of developing caries
- Fraction of restorative treatment that affects the rate of restoration from untreated caries
- Fraction of endodontic treatment that affects the rate of endodontic treatment from untreated caries
- Fraction of recurrent caries from the restoration that affects the rate of recurrent caries from restoration
- Fraction of recurrent caries from endodontic treatment that affects the rate of recurrent caries from restoration
- Fraction of missing teeth from untreated caries that affects the rate of missing teeth from untreated caries

In addition,

- Fraction of caries development in permanent teeth that affects the rate of caries developing in permanent teeth (risk of caries development in permanent teeth from primary caries teeth)

The risk of caries development in permanent teeth from caries in primary teeth was considered a variable due to most interventions being provided during younger age and focusing on primary teeth. Therefore, the connection between primary and permanent teeth is regarded as a variable representing the effect of the primary teeth' caries on the development of caries in permanent teeth. That is the link between the

primary dentition model (model 1) and the permanent dentition model (model 2).

The fractions affect the flows in the models, and the flows in the models identify the changes in the stocks. The fractions that affect the rate of flows were influenced by factors including biological variables such as standard rates of disease development and effects of interventions, e.g., fluoride varnish slows the rate of caries progression by reducing the caries development fraction. In models, the interventions influenced the caries development fraction that affects the rate of caries development. The relevant equations in both models defined the flows.

We also consulted with participants in the first and second sessions about which database was appropriate for the required parameter values and how can we get them to conduct the models. The leading questions were “What are the required parameter values for the quantitative part of the model?” and “Which database should be used for the required parameter values?”. We did the third session to finalize the models by confirming model structures, variables, valid parameters, and the database used.

Figure 8. Model 1 (Primary dentition age)

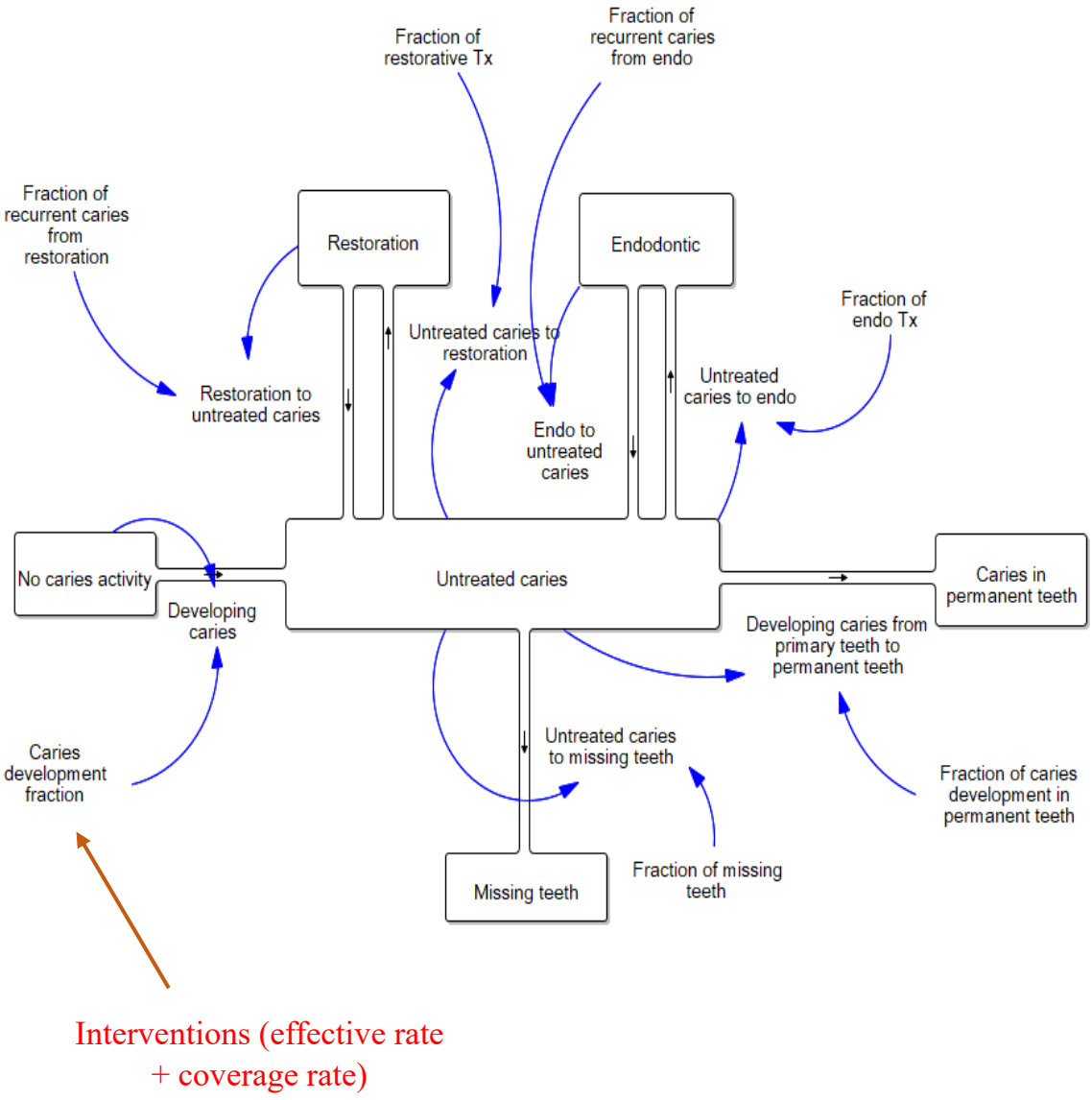


Figure 9. Model 2 (Permanent dentition age)

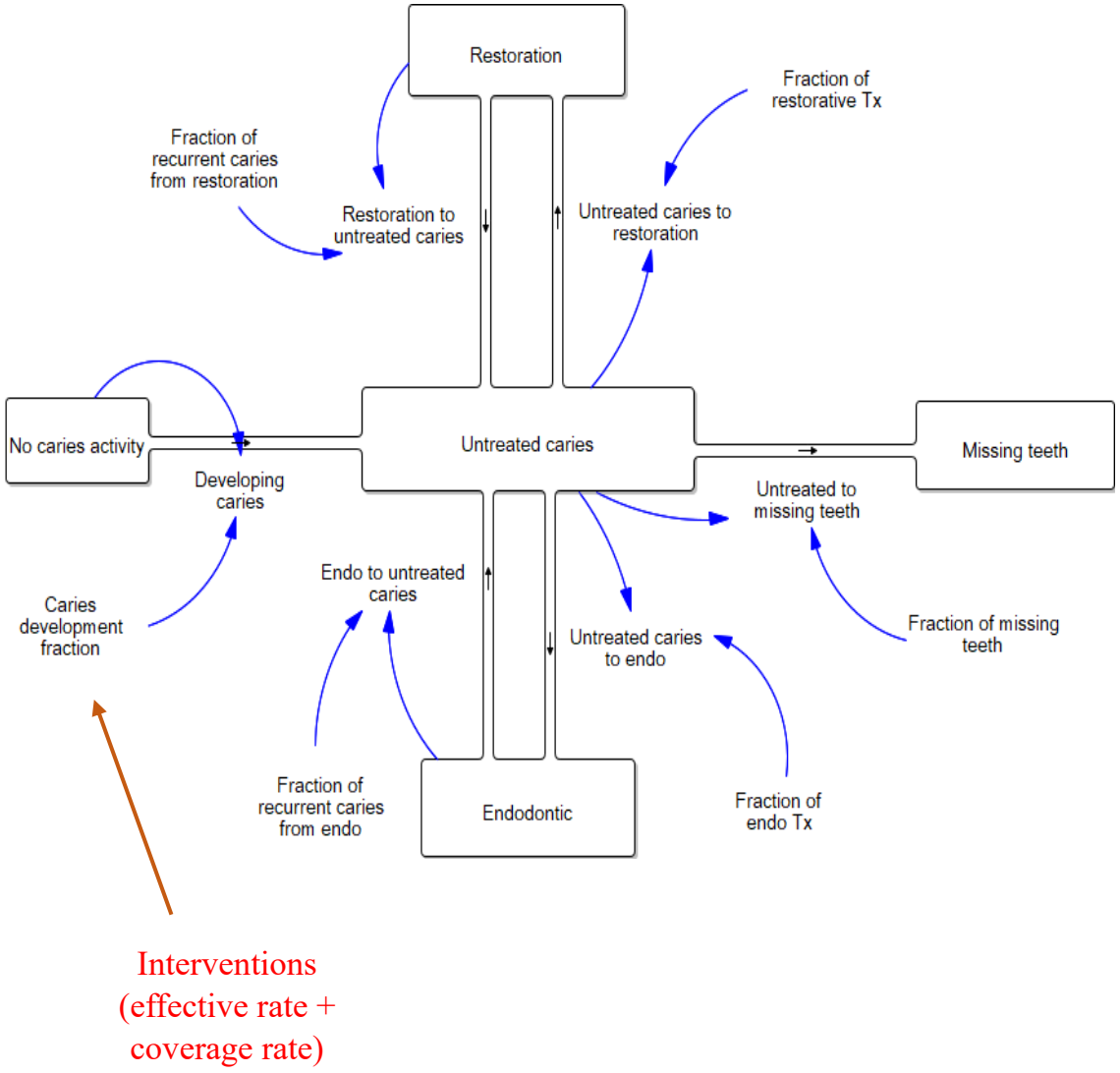
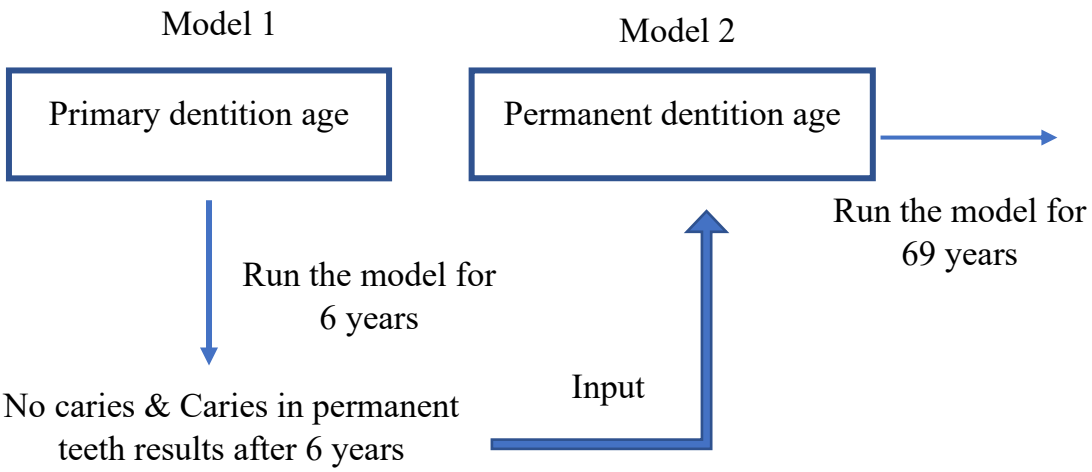


Figure 10. Concept of the models



* Model 1 (Primary dentition age) – start from 0 years old and run the model for six years until the population reaches six years old.
* Model 2 (Permanent dentition age) – start from 6 years old and run the model for 69 years until the population reaches 75 years old.

Data collection and source for the model

The data used and the source of the data for the model are as follows:

- For the effectiveness data of the intervention, published data were retrieved from the systematic review and meta-analysis (objective 1).
- For all required parameter values to be used in the models, available data from the 8th National Oral Health Survey, Health Data Center, National Statistical Office, and literature were collected.
- When no data were available, experts' opinions were consulted. In the models, the effectiveness data for combined interventions (Supervised Toothbrushing and Sealant) among 5-15 years old age were retrieved from the experts' opinions. The experts are dentists with good knowledge and experience in clinical and dental public health fields and who can express their opinion. Experts gave opinions on data used in the models depending on their available data and literature. The experts were the same as some participants in GMB.

Data used in the model were validated in the GMB session by experts. Tables (11,12) showed parameter values to be used in the models, data sources for each parameter value, and the ways of data extraction. Table (11) showed the parameter values for model 1, and table (12) showed the parameter values for model 2.

The outcome of the model

Outcomes such as Dental caries, treated cases (restoration and endodontic), and tooth loss (missing teeth) were attributed to the stocks in the model that change over time. Therefore, the stocks are the healthy, disease, and treated state of the outcome. All these states from the stocks were considered as study outcomes of the SDM in this study, and life outcomes in age intervals were estimated from the model. They are described below.

Dental caries

- The population with no carious activity
- The population with caries experience
- The population with restorative treatment
- The population with endodontic treatment
- The population with missing teeth

The models ran lifelong, estimated outcomes under base-case conditions, and provided intervention. All outcomes under different conditions according to age intervals are presented in the results section.

Table 11. Required parameters to be used in the primary dentition model (Model 1)

No	Model parameter	Unit	Parameter initial value	Source	Assumption	Extracted data
1.	Population with no caries	Person	678,243	National Statistical Office (NSO) [70]	The 0-year-old population who are assumed as a caries age group	0-year-old population (2021) = 678,243 (NSO)
2.	Population with untreated caries	Person	0	-	No caries cases in the 0-year-old population	-
3.	Population with missing teeth	Person	0	-	No missing teeth cases in the 0-year-old population	-
4.	Population with restoration	Person	0	-	No restorative treated cases in the 0-year-old population.	-
5.	Population with endodontic treatment	Person	0		No endodontic treated cases in the 0-year-old population	-

Table. 11 (Continued)

6.	Fraction of caries developing	Dmnl/ Year	0.14 Base-case	Literature [71]	Used the % of caries development from the control group after a 1-year follow-up from the literature and converted it to a fraction divided by 100	Population with caries development = 14% (Literature)
		Dmnl/ Year	0.124 (STB for 0-3 age intervals)	Meta-analysis, Health Data Centre (HDC) [72]	Meta-analysis is done to retrieve caries prevented fraction for STB in the 0-3 years age group and calculate the caries development fraction depending on the prevented fraction of STB and coverage of intervention.	Coverage = 60% (HDC) Preventive rate = 19% (Meta-analysis) The preventive rate in coverage is 60% = 11.4% (Due to the not full coverage, the preventive rate is reduced from 19%) So, 11.4% in 100% and 1.6% of caries development is reduced from 14% per year.

Table. 11 (Continued)

		Dmnl/ Year	0.123 (STB for 3-5 age intervals)	Meta-analysis, Health Data Centre (HDC) [72], Literature [73]	Meta-analysis is done to retrieve caries prevented fraction for STB in the 3-5 years age group and calculate the caries development fraction depending on the prevented fraction of STB and coverage of intervention.	Coverage = 78% (HDC) Preventive rate = 15% (Meta-analysis) The preventive rate in coverage is 78% = 12% (Due to the not full coverage, the preventive rate is reduced from 15%) So, 12% in 100% and 1.7% of caries development is reduced from 14% per year.
		Dmnl/ Year	0.128 (FV for 0-3 age intervals)	Meta-analysis, Health Data Centre (HDC) [72]	Meta-analysis is done to retrieve caries prevented fraction for FV in the 0-3 years age group and calculate the caries development fraction depending on the prevented	Coverage = 50% (HDC) Preventive rate = 17% (Meta-analysis) The preventive rate in coverage is 50% = 8.5% (Due to the not full coverage, the preventive rate is reduced from 17%)

Table. 11 (Continued)

					fraction of FV and coverage of intervention.	So, 8.5 % in 100% and 1.2% of caries development is reduced from 14% per year.
		Dmnl/ Year	0.133 (FV for 3-5 age intervals)	Meta-analysis, Health Data Centre (HDC) [72]	Meta-analysis is done to retrieve caries prevented fraction for FV in the 3-5 years age group and calculate the caries development fraction depending on the prevented fraction of FV and coverage of intervention.	Coverage = 60% (HDC) Preventive rate = 8% (Meta-analysis) The preventive rate in coverage is 60% = 4.8% (Due to the not full coverage, the preventive rate is reduced from 8%) So, 4.8% in 100% and 0.7% of caries development is reduced from 14% per year.
		Dmnl/ Year	0.119 (STB+FV for 0-3 and 3-5 age intervals)	Meta-analysis, Literature [74]	Retrieved caries prevented fraction for FV+STB from subgroup analyses of	Coverage = 42.7% (Literature) Preventive rate = 34% (Meta-analysis) The preventive rate in coverage

Table. 11 (Continued)

					FV, 0-3 years old age group and used for both 0-3 and 3-5 years old. Calculate the caries development fraction depending on the prevented fraction of FV and coverage of intervention.	is 42.7% = 15% (Due to the not full coverage, the preventive rate is reduced from 34%) So, 15% in 100% and 2.1% of caries development is reduced from 14% per year.
7.	Fraction of restorative treatment	Dmnl/ Year	0.04 (for both base-case and interventi on scenarios)	Health Data Centre (HDC) [72], National Statistical Office (NSO) [70]	Used the number of populations by filling in the 2562 Buddhist years from the HDC source and calculated the fraction divided by the total number of populations in 2021from from the NSO source.	Population with filling = 2,561,786 (HDC)
						Total population (2021) = 66,171,439 (NSO)

Table. 11 (Continued)

8.	Fraction of recurrent caries from restorative case	Dmnl/ Year	0.036 (for both base-case and intervention scenarios)	Literature [75]	Used the % of secondary caries from different types of restoration from the literature and converted it to a fraction divided by 100	% of secondary caries = 3.6% (Literature)
9.	Fraction of endodontic treatment	Dmnl/ Year	0.003 (for both base-case and intervention scenarios)	Health Data Centre (HDC) [72], National statistical office (NSO) [70]	Used the number of populations with endodontic treatment in the 2562 Buddhist years from the HDC source and calculated the fraction divided by the total number of populations in 2021 from the NSO source.	Population with endodontic treatment = 163,419 (HDC) Total population (2021) = 66,171,439 (NSO)

Table. 11 (Continued)

10.	Fraction of recurrent caries from endodontic case	Dmnl/ Year	0.006 (for both base-case and intervention scenarios)	Literature [76]	Used the % of the failure rate of RCT treatment, assumed that it is prone to recurrent caries from the literature, and converted it to a fraction divided by 100.	% of failure rate = 0.6% (Literature)
11.	Fraction of missing teeth	Dmnl/ Year	0.05 (For both base-case and intervention scenarios)	Health Data Centre (HDC) [72], National statistical office (NSO) [70]	Used the number of populations with extraction in the 2562 Buddhist years from the HDC source and calculated the fraction divided by the total number of populations in 2021 from the NSO source.	Population with extraction = 3,525,836 (HDC) Total population (2021) = 66,171,439 (NSO)

Table. 11 (Continued)

12.	Fraction of caries development in permanent teeth	Dmnl/ Year	0.45 (for both base-case and intervention scenarios)	Literature [77]	Used the risk of caries to permanent teeth	0.45 (Literature)

Table 12. Required parameters to be used in the permanent dentition model (Model 2)

No	Model parameter	Unit	Parameter initial value	Source	Assumption	Extracted data
1.	Population with missing teeth	Person	44,086	8th National oral health survey (NOHS) [3], National statistical office (NSO) [70]	Used the % of the 5-year-old population with untreated caries from the NOHS source and calculated the initial parameter value based on the 0-year-old population of 2021 from model 1 (NSO source).	Five years old with missing teeth = 6.5% (8th NOHS) Population of 0-year-old (2021) from model 1 = 678,243 (NSO)
2.	Population with restoration	Person	59,685	8th National oral health survey (NOHS) [3], National	Used the % of the 5-year-old population with filling from the NOHS source and	Five years old with filling = 8.8% (8th NOHS) Population of 0-year-old (2021) from

Table. 12 (Continued)

				statistical office (NSO) [70]	calculated the initial parameter value based on the 0-year-old population of 2021 from model 1 (NSO source).	model 1 = 678,243 (NSO)
3.	Population with endodontic treatment	Person	6782	Literature [78], National statistical office (NSO) [70]	Used the % of the >6-year-old population with endodontic from the literature and calculated the initial parameter value based on the 0-year-old population of 2021 from model 1 (NSO source).	>6 years old with endodontic treatment = 1% (Literature)
						Population of 0-year-old (2021) from model 1 = 678,243 (NSO)

Table. 12 (Continued)

4.	Fraction of caries developing	Dmnl/ Year	0.14 (Base case)	Literature [71]	Used the % of caries development from the control group after a 1-year follow-up from the literature and converted it to a fraction divided by 100.	Population with caries development = 14% (Literature)
			0.126 (STB for 5-15 age intervals)	Meta-analysis, Literature [79]	Meta-analysis is done to retrieve caries prevented fraction for STB in the 5-15 years age group and calculate the caries development fraction depending on the prevented fraction of STB and coverage of intervention.	Coverage = 95% (Literature) Preventive rate = 10% (Meta-analysis) The preventive rate in coverage is 95% = 9.5 % (Due to the not full coverage, the preventive rate is reduced from 10%) So, 9.5% in 100% and 1.33% of caries development is

Table. 12 (Continued)

						reduced from 14% per year.
			0.118 (Sealant 5-15 age intervals)	Meta-analysis, Health Data Centre (HDC) [72], Literature [79]	Meta-analysis is done to retrieve caries prevented fraction for sealant in the 5-15 years age group. Nevertheless, it is only for molar teeth and calculates the preventive rate for all teeth by multiplying the prevalence of molar and other teeth. And then, calculate the caries development fraction depending on the sealant's preventive rate and	Caries % of molars = 82% (Literature) PF for molars = 0.71 (Meta-analysis) Caries % of other teeth = 18% (Literature) Preventive rate for molars = 0.71*82% = 58% The preventive rate for other teeth = 0% Preventive rate for all teeth = 58% + 0% = 58% Coverage rate = 27% (HDC) The preventive rate in coverage is 27% = 15.66% (Due to the not

Table. 12 (Continued)

					intervention coverage.	full coverage, the preventive rate is reduced from 58%) So, 15.66% in 100% and 2.2% of caries development is reduced from 14% per year.
			0.1 (STB + Sealant 5-15 age intervals)	Meta-analysis, Literature [79]	Meta-analysis is done to retrieve caries-prevented fraction (PF) for STB and sealant in the 5-15 age group. Then, multiply the preventive fraction of sealant with the caries rate of molars teeth and the preventive fraction of STB with the caries rate of other teeth to find each	Caries % for molars = 82% (Literature) PF for molars = 0.71 (Meta-analysis) Preventive rate = 82%*0.71= 58.22% Caries % for other teeth = 18% (Literature) PF of STB for other teeth = 0.1 (Meta-analysis) Preventive rate = 18%*0.1 = 1.8%

Table. 12 (Continued)

					preventive rate for respective teeth. (Caries rate of molar and other teeth were retrieved from the literature on the Thailand situation) And then, combine the two preventive rates and calculate the caries development fraction depending on the combined prevented rate of sealant and STB.	Coverage = 33% (Literature) Combined Preventive rate % = 58.22% + 1.8% = 60.02% The preventive rate in coverage is 33% = 19.8% (Due to the not full coverage, the preventive rate is reduced from 60.02%) So, 19.8% in 100% and 2.8% of caries development is reduced from 14% per year.
		Dmnl/ Year	0.133 (FV for 5-15 age intervals)	Effectiveness from 3-5 age	FV is assumed to provide at 0-5 years of age and did not provide after age five.	The caries fraction after effectiveness rate is used = 0.13 (from 3-5 years old)

Table. 12 (Continued)

					Therefore, the effectiveness rate does not change after five years. So, the same effectiveness rate from 3-5 years old is used, and the caries fraction is also the same.	
		Dmnl/ Year	0.119 (STB + FV for 5-15 age intervals)	Effectiveness from 0-5 age	Combined STB+FV is assumed to be provided at 0-5 years of age and did not provide after five years old age. Therefore, the effectiveness rate does not change after five years. So, the same effectiveness rate from 0-5 years old is used, and the caries fraction	The caries fraction after the preventive rate is used = 0.119 (from 0-5 years old)

Table. 12 (Continued)

					is also the same.	
		Dmnl/ Year	0.139 (OH exam for 15-59 age intervals)	Meta-analysis, Health Data Centre (HDC) [72]	Meta-analysis is done to retrieve caries prevented fraction for the OH exam in the 15-59 age group and calculate the caries development fraction depending on the detected fraction of the OH exam and coverage of intervention.	Coverage (40-59 years old) = 7% (HDC) Preventive rate = 7% (Meta-analysis) The preventive rate in coverage is 7% = 0.49% (Due to the not full coverage, the preventive rate is reduced from 7%) So, 0.49% in 100% and 0.07% of caries development is reduced from 14% per year.
		Dmnl/ Year	0.138 (OH exam for 59 and above age intervals)	Meta-analysis, Health Data Centre (HDC) [72]	A prevented fraction from the OH exam in the 15-59 years age group (meta-analysis) is used and calculated the	Coverage (>60 years old) = 23% (HDC) Preventive rate = 7% (Meta-analysis) The preventive rate in coverage is

Table. 12 (Continued)

					caries development fraction is calculated depending on the prevented fraction of the OH exam and coverage of intervention.	23% = 1.61% (Due to the not full coverage, the preventive rate is reduced from 7%) So, 1.61% in 100% and 0.23% of caries development is reduced from 14% per year.
5.	Fraction of restorative treatment	Dmnl/ Year	0.04 (for both base-case and interventi on scenarios)	Health Data Centre (HDC) [72], National statistical office (NSO) [70]	Used the number of populations by filling in the 2562 Buddhist years from the HDC source and calculating the fraction divided by the total number of populations in 2021 from the NSO source.	Population with filling = 2,561,786 (HDC)
						Total population (2021) = 66,171,439 (NSO)
6.	Fraction of recurrent caries from	Dmnl/ Year	0.036 (for both base-case	Literature [75]	I used the % of secondary caries from	% of secondary caries = 3.6%

Table. 12 (Continued)

	restorative case		and intervention scenarios)		different types of restoration from the literature and converted it to a fraction divided by 100.	(Literature)
7.	Fraction of endodontic treatment	Dmnl/ Year	0.003 (for both base-case and intervention scenarios)	Health Data Centre (HDC) [72], National statistical office (NSO) [70]	Used the number of populations with endodontic treatment in the 2562 Buddhist years from the HDC source and calculated the fraction divided by the total number of populations from the 2021from NSO source.	Population with endodontic treatment = 163,419 (HDC) Total population (2021) = 66,171,439 (NSO)
8.	Fraction of recurrent caries from	Dmnl/ Year	0.006 (for both base-case and	Literature [76]	Used the % of the failure rate of RCT treatment,	% of failure rate = 0.6% (Literature)

Table. 12 (Continued)

	endodontic case		interventi on scenarios)		assumed that it is prone to recurrent caries from the literature, and converted it to a fraction divided by 100.	
9.	Fraction of missing teeth	Dmnl/ Year	0.05 (For both base-case and interventi on scenarios)	Health Data Centre (HDC) [72], National statistical office (NSO) [70]	Used the number of populations with extraction in the 2562 Buddhist years from the HDC source and calculated the fraction divided by the total number of populations from the 2021from NSO source.	Population with extraction = 3,525,836 (HDC)
						Total population (2021) = 66,171,439 (NSO)

3.3.4.2 Model testing

Model testing was conducted to verify the model's validity. In a practical sense, the model's usefulness is more concerned than the validity in which it would serve and help establish the purpose. [80] For validity, we think of models as valid when they can be used confidently. [81]. Face validity was conducted by researchers and experts in the GMB session for the model's structure as structure-based validation [82], as below. Known-case validity compared with historical data was conducted by researchers as behavior-based validation for the model's behavior [82] as below.

Structure-based validation [82]

It was conducted to determine whether the model was suitable for its purpose and consistent with the actual situation. It was checked as follows:

Boundary adequacy

It was checked whether the crucial concepts and structures for addressing the policy issue were included in the model to pass the purpose. Therefore, dental caries with related issues and interventions to set in the model were checked with the conceptual framework and objective of the study.

Structure verification

It was checked whether the model structure was consistent with the existing system of dental caries-related issues by comparing the structure of the model directly with the structure of the factual system that the model represents. The progression of dental caries states or variables in the model were checked to determine whether it is relevant to the natural history of the disease.

Parameter verification

It was checked whether the parameters in the model were consistent with the information from the existing system. Parameters in

the model were checked with whether it is relevant, i.e., caries population from NOHS or treated cases from HDC.

Dimensional consistency

It was checked whether each equation in the model dimensionally corresponds to the natural system. For example, whether a model contains a rate of developing caries per year on the left side of the equation, a fraction of caries per year falls out from the right side.

Behavior-based validation [82]

It was conducted to test the accuracy of the system behavior. It was checked as follows:

Extreme conditions

It was checked whether the plausibility of the model rate equations was reasonable on extreme values by setting the imaginary implication of maximum or minimum (minus infinity, zero, plus infinity). For example, the untreated caries population was zero when the developing untreated caries rate was zero).

Behavior Replication Test

It was checked whether the model's behavior was typical of the behavior of the modeled system. The simulated behavior of the primary variable (dental caries disease-related events) was checked to determine whether it was familiar with the historical reference data. Checking some parameters with the previous study is shown in the appendix.

Behavior Sensitivity Test

It was checked whether the model's behavior was seriously affected or not by plausible parameter variations. Sensitivity analysis is shown in the results section.

3.3.4.3 Scenarios analysis

Different intervention scenarios were developed for this study. All intervention scenarios were explored according to age groups and the base-case (current). Lifelong outcomes were estimated from the model under different scenarios.

Effectiveness information for intervention scenarios

Assume that different interventions were implemented according to age group intervals and were run as intervention scenario analyses in SDM. The effectiveness information or disease reduction rate was used from the meta-analysis in objective 1. The effective rate differed according to different age group intervals in intervention scenarios analysis. E.g., Assume that an intervention was given in 0-3 years age interval and a 45% effectiveness rate was considered. After three years, when they reach the 3-5 year age interval, this intervention was continuous, and the constant or increasing or decreasing effective rate was considered. When combined interventions, SDM cannot check whether its interaction is additive, multiplicative, synergistic, or antagonistic. However, we can check the “what if” scenario by setting additive, multiplicative, or other conditions. In this study, the effectiveness rate for combined intervention scenarios to be run in the model was retrieved from experts’ opinions in the GMB session.

Base-case scenario

The base-case simulation assumed that all model parameters remained unchanged over the simulation run. This simulation was a reference point for comparing different intervention scenarios, as mentioned below.

Intervention scenarios

Supervised toothbrushing (STB)

Description

Supervised tooth brushing aims to control or prevent the progression of dental caries, and the following facts are included in the supervised toothbrushing program [29, 30] –

- Use the correct toothbrushing technique
- Brush twice daily with fluoride toothpaste (after breakfast and before bedtime)
- Choice of appropriate toothbrush design and amount of fluoride toothpaste
- Brushing time (minimum of two minutes)
- Spit out well after brushing, but minimize rinsing behaviors with water

All the above facts were demonstrated and supervised by responsible supervisors such as oral health professionals, health educational professionals, or trained persons: teachers or parents for children or caregivers to target groups.

Scenario analysis in model

Assumed that the intervention was provided to the population within the age group interval of 0-3, 3-5, and 5-15 years old. The effectiveness rate varied between 0-3, 3-5, and 5-15 years old according to variation of effectiveness changes in age group intervals. In model 1, the population started from 0 years old and assumed that intervention was provided at their age intervals of 0-3 years old and 3-5 years. In model 2, the population was started from 6 years old and assumed that intervention was provided at their age intervals of 6-15 years old. After 15 years old age, it assumed that the intervention was not provided, and the effective rate remained unchanged.

Fluoride varnish (FV)

Description

Fluoride varnish prevents dental caries and promotes tooth remineralization in both primary and permanent teeth. The following facts are included in the application of fluoride varnish [31] –

- Professionally application of fluoride varnish to target age groups by dental professionals.
- Application of a thin layer of 5% or 0.1% fluoride varnish with a specific or unspecific brand to all surfaces of the teeth in both primary and permanent teeth.
- Application at 6, 12, 18, 24, and 36 months according to the MOPH vaccination program in Well Child Clinic (WCC). It is assumed that biannual apart applications from at least two times to more than five times.
- Application of fluoride varnish alone or supplying fluoride toothpaste together.

Scenario analysis in model

Assuming that the intervention was provided to the population within the age group interval of 0-3 and 3-5 years old. The effectiveness rate varied between 0-3 and 3-5 years old according to variation of effectiveness changes in age group intervals. In model 1, the population started from 0 years old and assumed that intervention was provided at their age intervals of 0-3 years old and 3-5 years. After five years old age, it assumed that the intervention was not provided, and the effective rate remained unchanged. Therefore, in model 2, the effective rate to use has remained unchanged from model 1.

Dental sealant application

Description

The application of sealants aims to prevent dental caries in permanent teeth. The following facts are included in the application of pit and fissure sealants [32] –

- Professionally application of pit and fissure sealants to target age groups by dental professionals.
- Applying Resin-based sealants to be placed on permanent teeth with deep pits and fissures, including teeth with initial enamel lesions that are considered at risk of caries.

Scenario analysis in model

Assumed that the intervention was provided to the population within the age group interval of 5-15 years old. Therefore, in model 2, the population was started from 6 years old and assumed that intervention was provided at their age intervals of 6-15 years old. After 15 years old age, it assumed that the intervention was not provided, and the effective rate remained unchanged. (The experts in the GMB session suggested using existing data to assume the effective rate of sealant for all teeth. Therefore, multiply the preventive fraction (PF) of sealant for molar teeth by the caries rate of molar and for the other teeth by the caries rate of other teeth. Then, combine them to find the effective rate for all teeth. Caries rate was retrieved from the document of Thailand situation.

Oral health examination

Description

The aim is to visit dentists for treatment needs of dental caries and other oral diseases to reduce the diseases. This intervention is proposed to be in the benefits package of the Universal Coverage Benefit Scheme this year by MOPH. It is in the process of reviewing. This study

was to investigate the result of this intervention as proposed by MOPH. The following facts are included in the oral health examination [33].

- Assessment of dentition status, i.e., the presence of untreated decay teeth, missing teeth, filling teeth, presence of periodontitis, or severe periodontal conditions
- Assessment of intraoral conditions, conditions of tongue and lips, i.e., the presence of abnormal changes in the oral cavity
- Assessment of treatment needs of the present conditions or diseases and referral for treatment needs
- Providing at least once a year

Scenario analysis in model

Assumed that the intervention was provided to the population within the age group interval of 15-59 and >59 years old. Therefore, in model 2, the population was started from 6 years old and assumed that intervention was provided at their age intervals of 15-19 years and above 59 years. The effectiveness rate varied during the age of 15-19 and above 59 years old according to variation of effectiveness changes in age group intervals.

Combined intervention scenarios

In this study, STB and FV interventions are combined as a combined intervention for 0-3 years and 3-5 years old age since both of them are implemented during 0 to 5 years old according to MOPH. Besides, STB and dental sealant are combined for 5-15 years old as the two interventions are provided between the ages of 5 to 15 years old. There are no other interventions to combine with oral health examination because only oral health examination is provided among the adult and the elderly age. If more than two or three interventions are implemented among the same age intervals, they could be combined as a combined intervention scenario for these age groups.

Combined supervised toothbrushing (STB) and fluoride varnish (FV)

Description

The description of each intervention (STB and FV) in the combined one is the same procedure mentioned above.

Scenario analysis

Assumed that the intervention was provided to the population within the age group interval of 0-3 and 3-5 years old. The effectiveness rate was the same from 0 to 5 years old, as retrieved from a sub-group analysis of fluoride varnish. In model 1, the population started from 0 years old and assumed that intervention was provided at their age intervals of 0-3 years old and 3-5 years. After five years old age, it assumed that the intervention was not provided, and the effective rate remained unchanged. Therefore, in model 2, the effective rate to use has remained unchanged from model 1.

Combined supervised toothbrushing (STB) and sealant

Description

The description of each intervention (STB and sealant) in the combined one is the same procedure mentioned above.

Scenario analysis

Assumed that the intervention was provided to the population within the age group interval of 5-15 years old. Therefore, in model 2, the population started from 6 years old and assumed that intervention was provided at their age intervals of 6-15 years old. After 15 years old age, it assumed that the intervention was not provided, and the effective rate remained unchanged. (The experts in the GMB session suggested using existing data to combine the effectiveness rate of STB and sealant. Therefore, multiply the preventive fraction (PF) of sealant for molars by the caries rate of molars teeth and the PF of STB by the caries rate of

other teeth to find each preventive rate for respective teeth. And then, the two preventive rates were combined. Caries rate of molar and other teeth were retrieved from the documents on Thailand's situation).

3.3.4.4 Uncertainty analysis

The uncertainty analysis was done by multivariate sensitivity analysis with random uniform distribution in Vensim DSS version 6.4 software. The parameters were changed by ±10 percent. The outcome of mean values with a 95 percent confidence interval under the base case scenario and intervention scenarios is shown for the robustness of the model. The outcome of uncertainty analysis for a population with untreated caries at five years old, 15 years old, and 59 years old are presented in the result section, tables (22,23,24).

CHAPTER IV
RESULTS

4.1 Meta-analysis

Meta-analyses of interventions were done for dental caries outcomes. Figures (11,12,13) show supervised toothbrushing for 0-3, 3-5, and 5-15 years old. It is seen that the risk ratio (RR) of dental caries was 0.81 in 0-3 years old, 0.85 in 3-5 years old, and 0.90 in 5-15 years old. All of the studies favored the intervention. Therefore, it is regarded that children taking supervised toothbrushing have a 19%, 15%, and 10% decreased risk of caries developing at 0-3, 3-5, and 5-15 years old, respectively.

Figures (14,15) show the fluoride varnish for 0-3 and 3-5 years old. It was found that the RR of dental caries was 0.83 and 0.92 at 0-3 years old and 3-5 years. Even six studies in the figure (14, 0-3 years old) favored the intervention. One study [48] did not show the favor for intervention. This study said that the area was water fluoridated, and the provision of oral health education is sufficient for preventing ECC. Fluoride varnish applications and training in parental toothbrushing may not affect caries prevention among young children in this area. Overall, it is exposed that children having fluoride varnish have a 17% and 8 % caries reduction in 0-3- and 3-5-years old children. Where some of the interventions were combined with toothbrushing, it is considered that combined fluoride varnish and supervised toothbrushing have a 34% caries prevention according to a sub-group analysis for 0-3 years old.

Figure (16) presents dental sealant for 5-15 years old. It shows that the RR of dental caries was 0.29, and it is interpreted that dental sealant has a 71% in caries reduction for molar teeth in 5-15 years old. Besides, according to experts' opinions, a dental sealant can have a 58% decreased risk of caries for all teeth, and combined dental sealant and supervised toothbrushing has a 60% caries reduction for 5-15 years old age.

Figure (17) shows the oral health examination for the adult age group (15-59). It was found that the RR of dental caries was 0.93, and it is considered that people

taking oral health examinations have only a 7% decreased risk of caries during adult age.

According to meta-analyses, there are pretty low effective rates in supervised toothbrushing and fluoride varnish. It can be assumed that oral health examination has a shallow effective rate. Nevertheless, combined interventions and dental sealants have quite good effective rates.

Figure 11. Supervised Toothbrushing (0-3 years old)

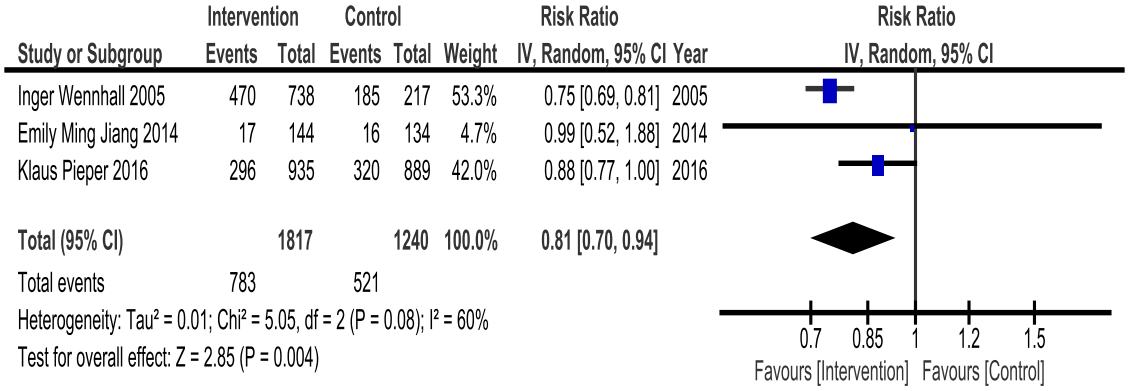


Figure 12. Supervised Toothbrushing (3-5 years old)

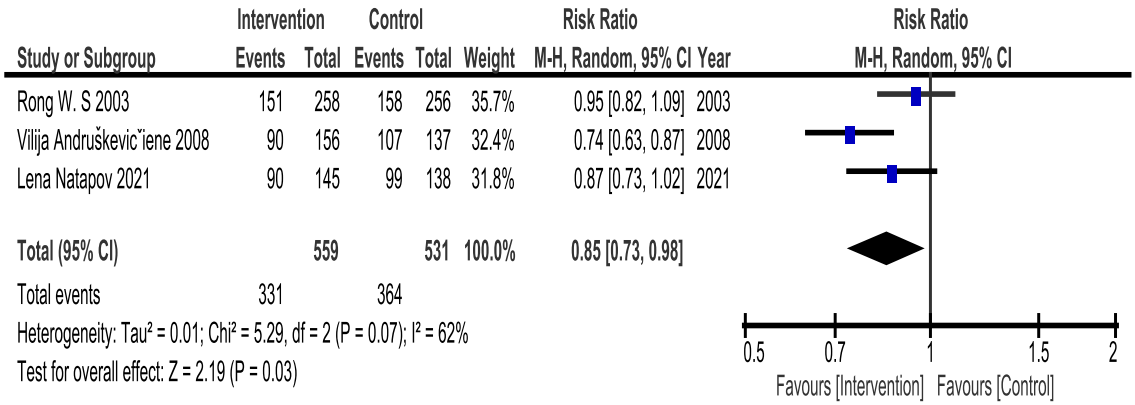


Figure 13. Supervised Toothbrushing (5-15 years old)

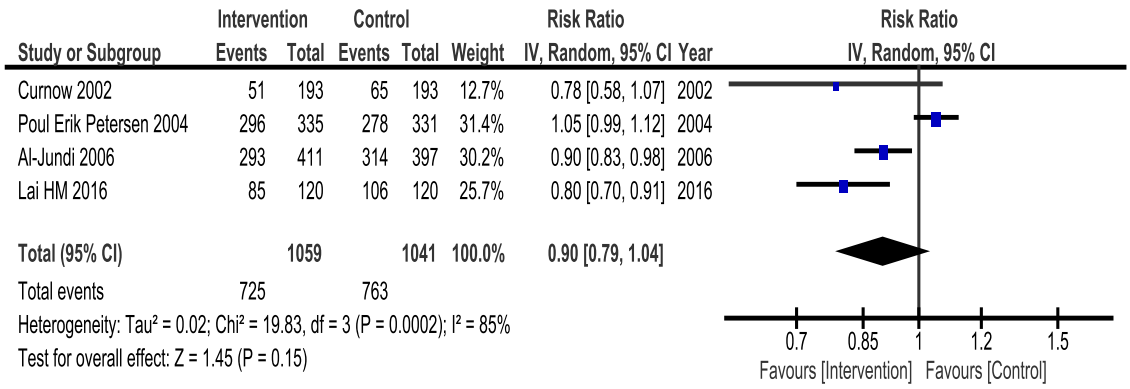


Figure 14. Fluoride FV (0-3 years old)

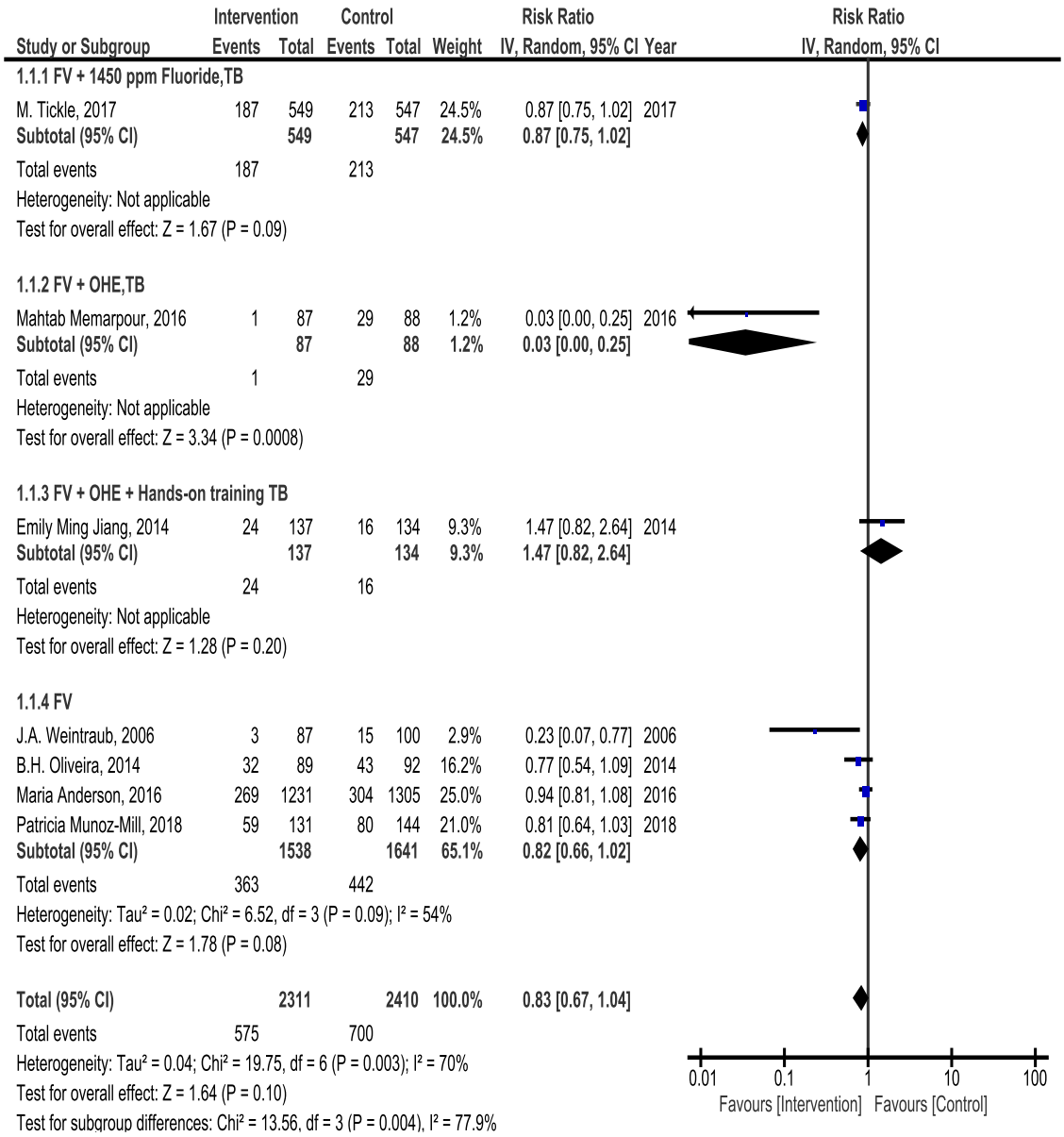


Figure 15. Fluoride varnish FV (3-5 years old)

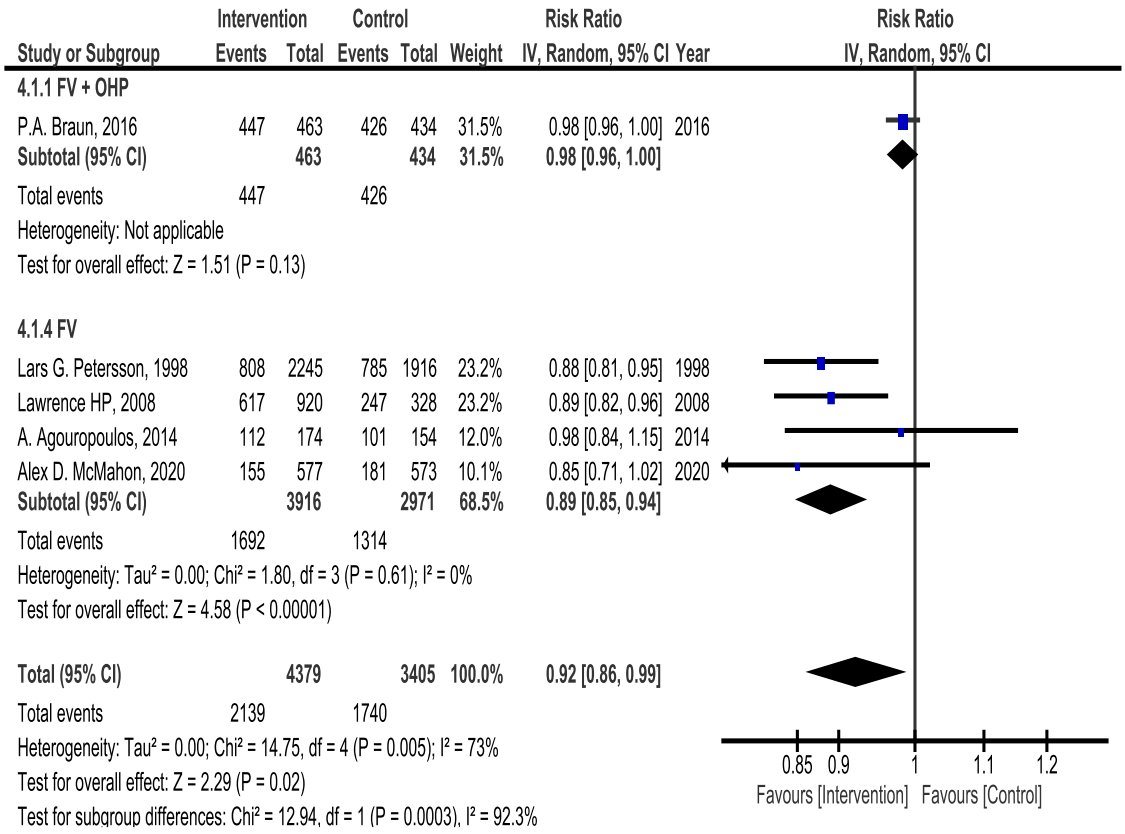


Figure 16. Sealant (5-15 years old)

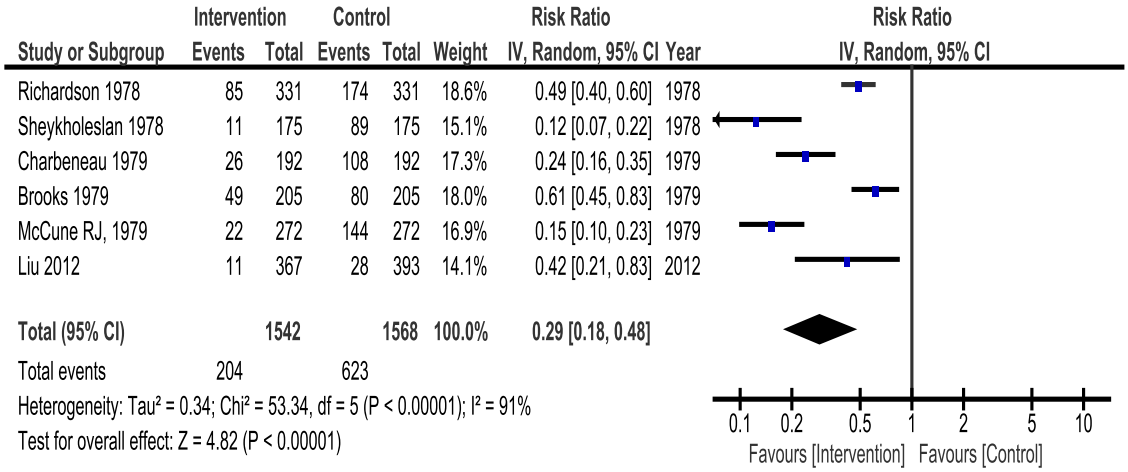
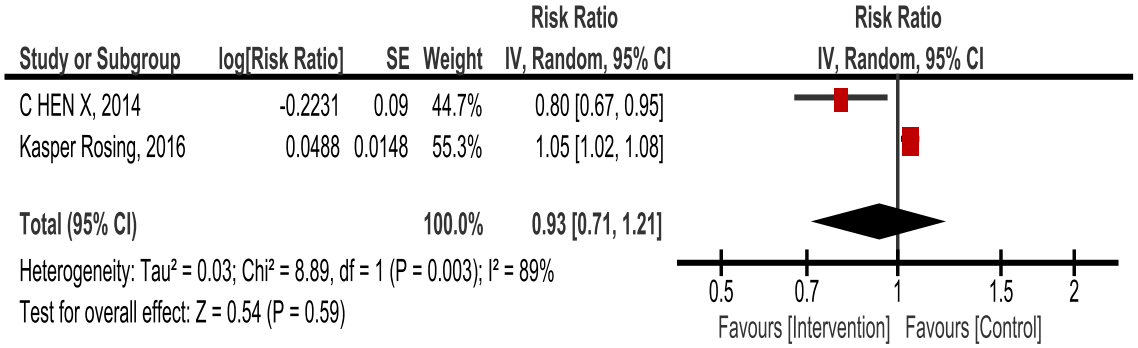


Figure 17. Oral health examination (15-59 years old)



4.2 SDM model

Assumption of the model

Causal loop relationship

The causal loop diagram was developed for the relationship of dental caries-related events in the feedback structure. After identifying the final causal loop from the GMB session, two reinforcing feedback loops and one balancing feedback loop were found in the diagram. When the direction of influence of elements keeps going in the same direction, it is a reinforcing loop. Where a positive change in one element leads to a pushback in the opposite direction, it is a balancing loop.

The balancing loop in the diagram operated the relationship of variables, i.e., no caries, developing caries, untreated caries, untreated caries to missing teeth, and missing teeth. It is understood that when the no caries population is increased, it leads to an increase in the population with caries and missing teeth, but on one side, an increase in the population with caries and missing teeth leads to a decrease in the no caries population. The missing teeth are not only due to the cause of dental caries but also may be due to the cause of periodontal diseases such as periodontitis and poor periodontal condition perspective to root caries and so on during elderly ages. Therefore, the variables of the rate of missing teeth and the population with missing teeth are assumed due to the cause of dental caries among younger ages and both the cause of dental caries and periodontal diseases among the middle adult and the elderly, assumed that when the intervention is set, it tends to reduce the rate of developing caries that would change to an untreated caries state. It means that when the no-caries population is increased, developing caries, the population with untreated caries, changing to missing teeth and missing teeth population are reduced, and on the other hand, it leads to an increase in the no-caries population. In this study, most interventions focus on dental caries, not periodontal diseases, although the STB and oral health examination could affect the gingival and periodontal disease.

Nevertheless, we did not include the STB and oral health examination focusing on periodontal disease as a study limitation. Therefore, the reduced number of missing teeth population could be less than if interventions focus and have a greater effective

rate on dental caries and periodontal diseases. If not, it would not be different from focusing on dental caries alone. Overall, it can be considered that the balancing feedback loop changes to a reinforcing feedback loop since the positive change in one keep a pushback in the same direction. The operated reinforcing loop by the effect of the intervention is seen to increase the no-caries population and reduce the population with caries and missing teeth.

One reinforcing loop in the diagram established the relationship of variables, i.e., untreated caries, untreated caries to restoration, restoration, and recurrent caries from the restoration to untreated caries. It is understood that when the untreated caries population is increased, it leads to an increase in the population with restoration, recurrent caries from restoration to untreated caries, and on one side, the population with untreated caries is also increased. Assuming that when the intervention is set, it tends to reduce the rate of developing caries that would change to an untreated caries state. It means that when the untreated caries population is decreased, untreated caries to restoration, the population with restoration, and recurrent caries from the restoration to untreated caries are reduced. On the other hand, it leads to a decrease in the untreated caries population. Therefore, it can be considered that the reinforcing feedback loop changes to another good reinforcing loop since the direction of influence of elements keeps going in the same direction. The operated reinforcing loop by the effect of the intervention is seen to reduce the untreated caries population and the population with restoration.

Another reinforcing loop in the diagram established the relationship of variables, i.e., untreated caries, untreated caries to endodontic, endodontic, and recurrent caries from the endodontic to untreated caries. It is understood that when the untreated caries population is increased, it leads to an increase in the population with endodontic and recurrent caries from endodontic to untreated caries. On one side, the population with untreated caries is also increased. Assuming that when the intervention is set, it tends to reduce the rate of developing caries that would change to an untreated caries state. It means that when the untreated caries population is decreased, untreated caries to endodontic, the population with endodontic and recurrent caries from endodontic to untreated caries is reduced.

On the other hand, it leads to a decrease in the untreated caries population. Therefore, it can be considered that the reinforcing feedback loop changes to another good reinforcing loop since the direction of influence of elements keeps going in the same direction. The operated reinforcing loop by the effect of the intervention is seen to reduce the untreated caries population and the population with endodontics.

The causal loop diagram explained the causal relationship between the state of the disease and showed that it is likely to change to a good condition when intervention is provided. It was translated into the quantitative model that evaluates how long the intervention effect keeps the condition quantitatively.

Quantitative approach

The stock and flow diagram represents the quantitative approach to estimating the long-term outcomes from the simulation model. After translating from the CLD to the stocks and flows diagram and confirming in the GMB, the model is separated into two approaches: model 1, which represents the primary dentition age, and model 2, which represents the permanent dentition age.

In model 1, the population started from 0-year-old age. The initial parameter values that were input to the stocks of the model were retrieved from reliable data sources of 0 years old. Set the initial parameter values remained unchanged until the model was simulated for six years, but the caries development rate was changed according to the setting of the scenarios. The scenarios set in this model were base-case (no intervention given), supervised toothbrushing (STB), fluoride varnish (FV), and combined STB+FV interventions. In the base-case scenarios, the caries development rate represented the normal disease development without the effects of interventions and was set as a reference point to compare with other scenarios. In intervention scenarios, it assumed that the implemented interventions affected the rate of caries development, which was changed depending on the effective rate of interventions. After the model was run for six years, input the simulation results at six years to model 2 (permanent dentition age). At six years old age was assumed that all populations would change to permanent dentition.

In model 2, the population started from 6 years old age. The simulation results of the no caries population and population with caries in permanent teeth from model 1 were input to the stocks of model 2 as initial parameter values. Other initial parameter values that were input were retrieved from reliable data sources. Set the initial parameter values remained unchanged until the model was simulated for 69 years, which means the population reaches 75 years old, but the caries development rate was changed according to the setting of the scenarios like model 1. The scenarios set in this model were base-case (no intervention given), supervised toothbrushing (STB), fluoride varnish (FV), combined STB+FV, dental sealant, combined STB+sealant, and oral health examination interventions. Like model 1, in the base-case scenarios, the caries development rate represented the normal disease development without the effects of interventions and was set as a reference point to compare with other scenarios. In intervention scenarios, it assumed that the provided interventions affected the rate of caries development, and the rate was changed depending on the effective rate of interventions.

Both models quantitatively evaluated how long the intervention affects dental caries by simulating base-case and intervention scenarios.

Primary dentition model (Model 1)

The 0-year-old population was started in model 1 and simulated model until the population reached six years old (permanent dentition age) under different scenarios such as base-case, supervised toothbrushing (STB), fluoride varnish (FV), and combined supervised toothbrushing (STB) and fluoride varnish (FV) intervention scenarios. Base-case was set as a reference point to compare other scenarios and assumed as no intervention was provided. The tables (13,14) show the results of no population, populations with caries, restoration, and endodontic treatment under four scenarios. Table (13) shows the results at three years old, and table (14) shows the results at the age of 5.

In table (13), at three years old, among the no caries populations, the population under combined STB+FV is the highest, 463,781 (68.38 %), then in the other scenarios,

supervised toothbrushing, fluoride varnish, and base-case. Supervised toothbrushing is the second highest, 455,929 (67.22 %). Population with caries experienced is the highest in base-case, 222,546 (32.81 %) than under the other intervention scenarios where the caries population under combined intervention STB+FV is the lowest, 193,653 (28.55 %) followed by supervised toothbrushing, 200,669 (29.59 %), and fluoride varnish, 206,220 (30.41 %). Population with missing teeth is the lowest in the combined STB+FV scenario, 11,251 (1.66 %), followed by supervised toothbrushing, fluoride varnish, and the highest under base-case, 13,137 (1.94 %) where the treated case, populations with restoration and endodontic treatment, are also the highest in the base-case scenario and lowest in the combined STB+FV followed by supervised toothbrushing and fluoride varnish.

In the table below (14), at the age of 5 years old, the no caries population is the highest under combined intervention STB+FV, 359,969 (53.07 %), followed by supervised toothbrushing, 350,669 (51.70 %), and fluoride varnish, 338,044 (49.84 %) where the base case is the lowest in the no caries population. Caries experienced population is the highest under the base-case scenario, 290,829 (42.88 %). The other intervention scenarios where the combined STB+FV is the lowest, 258,876 (38.17 %), followed by supervised toothbrushing, 266,049 (39.23 %) and fluoride varnish, 276,703 (40.79 %). Population with missing teeth under the combined STB+FV is the lowest, 32,492 (4.79 %), followed by supervised toothbrushing and fluoride varnish, and the highest under base-case, 37,395 (5.51 %). The populations with treated cases such as restoration and endodontic treatment are also the highest under the base-case scenario than the other intervention scenarios. Among intervention scenarios, it is the lowest in combined STB+FV.

Figure (18) shows the no-caries population of 0 to 6 years old. It is seen that the no caries population is the highest under combined intervention STB+FV followed by STB and FV and lowest under base-case along the 0-6 years old age. Figures (19,20,21,22,23) show the population with caries in deciduous teeth, permanent teeth, restoration, endodontic, and missing teeth of 0 to 6 years old. It seems they are lowest in combined STB+FV, followed by STB and FV, and highest under base-case along this age.

According to the simulation of scenarios in model 1, it seems that combined supervised toothbrushing (STB) and fluoride varnish (FV) is the most effective intervention compared to separately and base-case around the age of 0-5 years old where the interventions, supervised toothbrushing, fluoride varnish, and combined STB+FV are provided.

Table 13. Simulation results from primary dentition model at the age of 3 years old

States	At the age of 3 years old			
	Base-case	STB	FV	Combined STB+FV
No caries	431401	455929	449712	463781
	63.61 %	67.22 %	66.31 %	68.38 %
Untreated caries	222546	200669	206220	193653
	32.81 %	29.59 %	30.41 %	28.55 %
Restoration	10373	9241	9525	8885
	1.53 %	1.36 %	1.40 %	1.31 %
Endodontic	787	701	722	674
	0.12 %	0.10 %	0.11 %	0.099 %
Missing teeth	13137	11703	12063	11251
	1.94 %	1.73 %	1.78 %	1.66 %

Table 14. Simulation results from primary dentition model at the age of 5 years old

States	At the age of 5 years old			
	Base case	STB	FV	Combined STB+FV
No caries	319064	350669	338044	359969
	47.04 %	51.70 %	49.84 %	53.07 %
Untreated caries	290829	266049	276703	258876
	42.88 %	39.23 %	40.79 %	38.17 %
Restoration	28726	25862	26692	24970
	4.23 %	3.81 %	3.93 %	3.68 %
Endodontic	2229	2006	2070	1936
	0.33 %	0.29 %	0.31 %	0.29 %
Missing teeth	37395	33657	34734	32492
	5.51 %	4.96 %	5.12 %	4.79 %

Figure 18. No caries population, primary dentition model

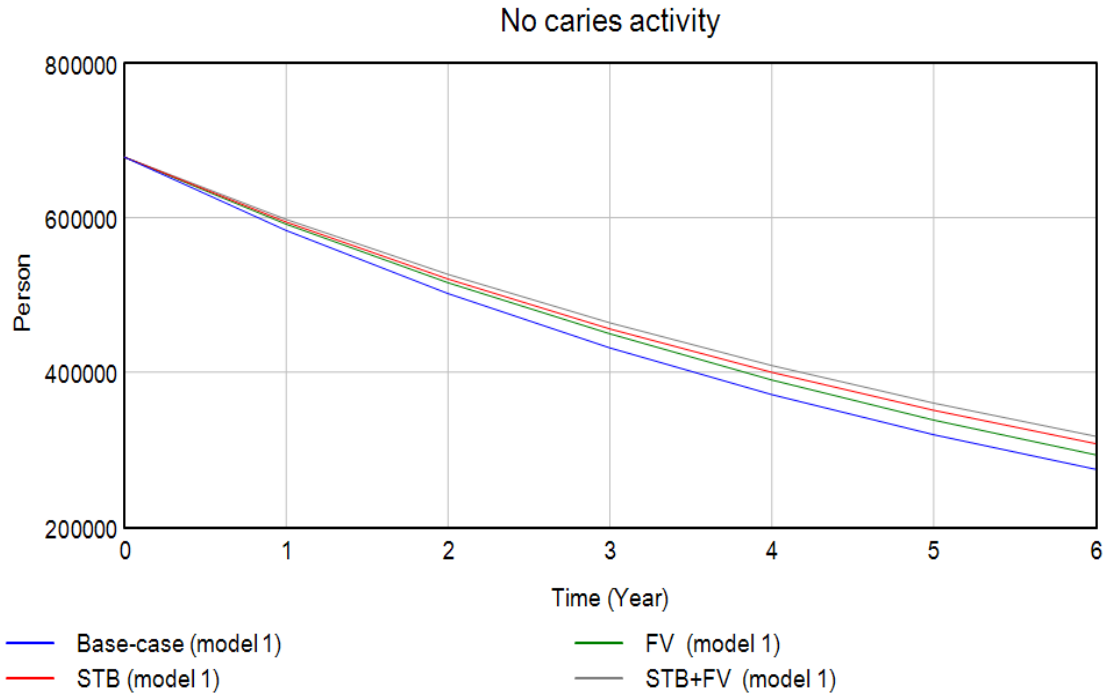


Figure 19. Caries population (deciduous teeth), primary dentition model

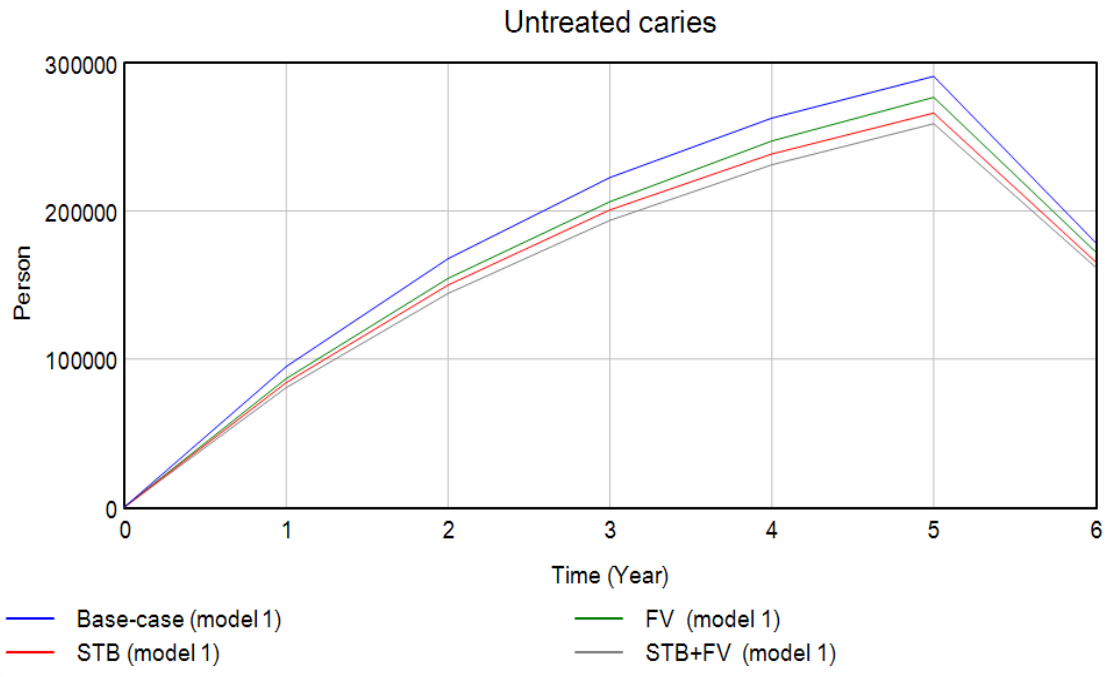


Figure 20. Caries population (permanent teeth), primary dentition model

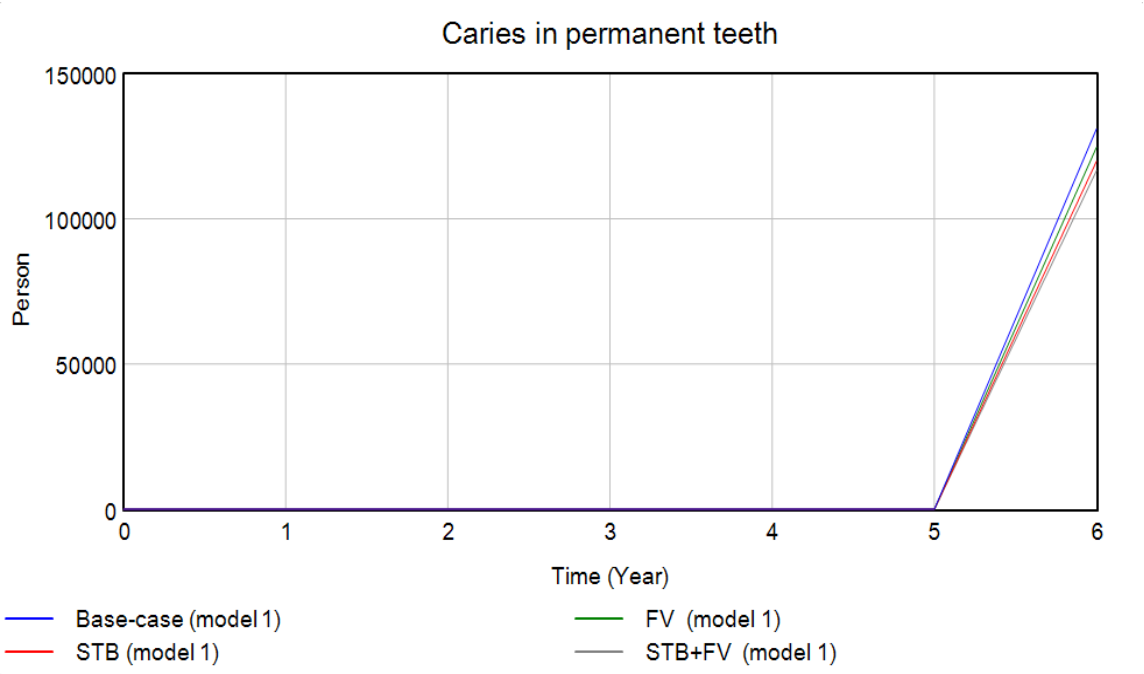


Figure 21. Population with restoration, primary dentition model

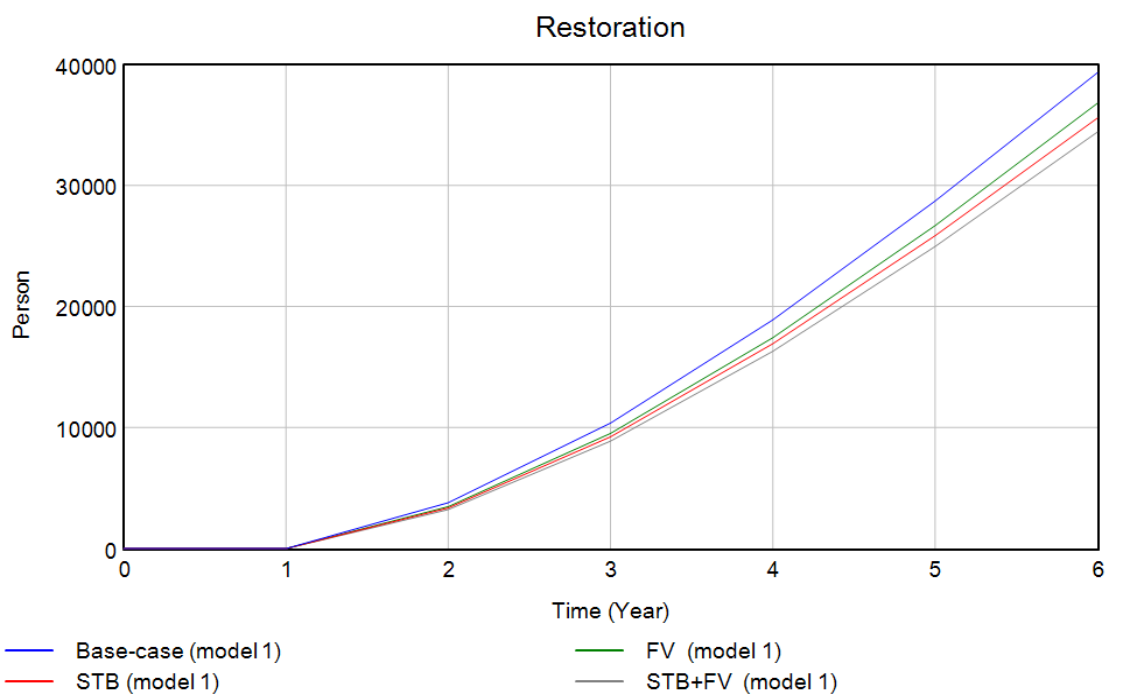


Figure 22. Population with endodontic, primary dentition model

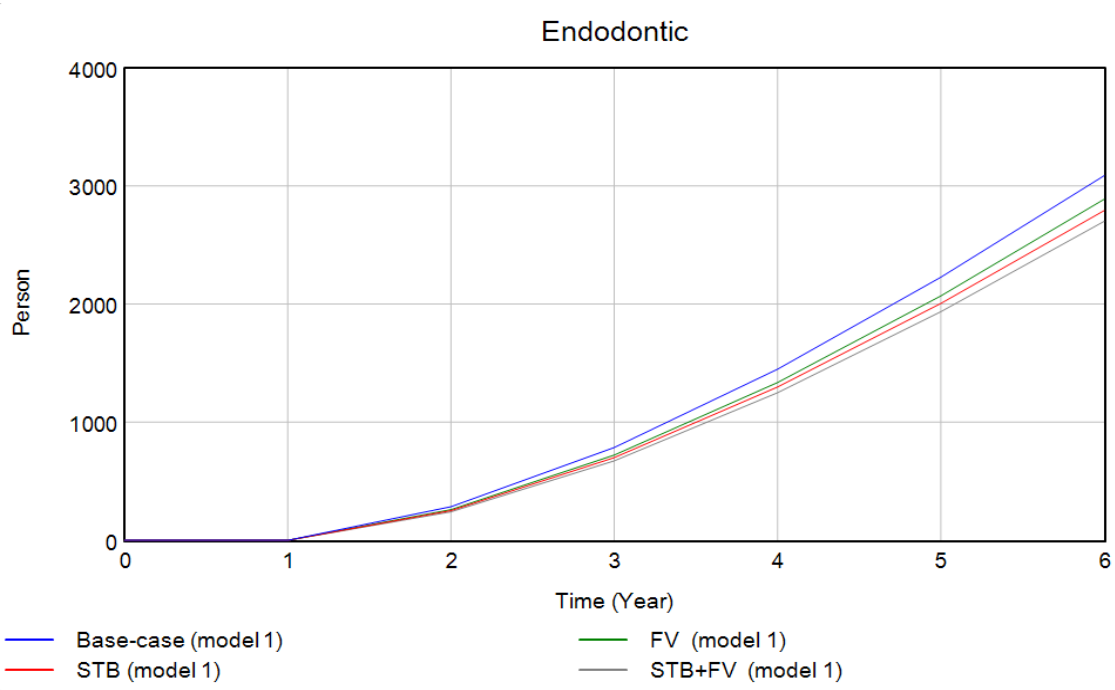
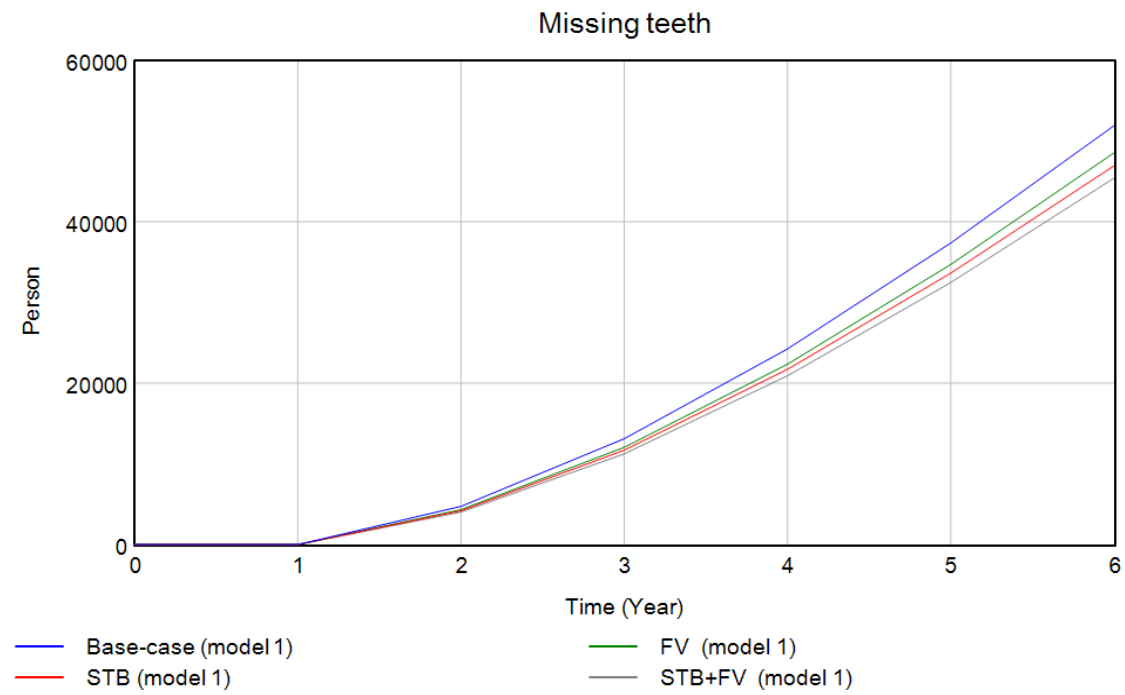


Figure 23. Population with missing teeth, primary dentition model



Permanent dentition model (Model 2)

Six years old population is started in model 2 and simulated model until the population reaches 75 years old under different scenarios such as base-case, supervised toothbrushing (STB), fluoride varnish (FV), combined STB+FV, dental sealant, combined STB+sealant, and oral health examination intervention scenarios. Base-case was set as a reference point to compare other scenarios and assumed as no intervention was provided. The tables (15,16,17) present the results of the no caries population, populations with caries, restoration, endodontic treatment, and missing teeth under scenarios. Table (15) presents the results at the age of 15 years old; table (16) presents at the age of 23 years old; table (17) shows at the age of 59 years old.

In table (15), at the age of 15 years old, for the no caries populations, the population under combined STB+sealant and combined STB+FV are the highest, 153,042 (22.56 %) and 144,261 (21.27 %), respectively, than in the other intervention scenarios: dental sealant supervised toothbrushing and fluoride varnish, and base-case. Caries experienced population is the highest in base-case, 280,244 (41.32 %), followed by the fluoride varnish, 275,849 (40.67 %), and supervised toothbrushing, 270,870 (39.94 %), where the caries population is the lowest under combined STB+sealant, 257,655 (37.99 %) followed by sealant, 264,507 (38.99 %), and combined STB+FV, 265,319 (39.12 %). Population with missing teeth is the lowest under combined STB+sealant and combined STB+FV, 142,777 (21.05 %) and 143,301 (21.13 %), respectively, followed by sealant, supervised toothbrushing, and fluoride varnish. It is the highest under base-case, 152,959 (22.55 %). The treated populations with restoration and endodontic are the highest in the base-case scenario and lowest in the combined STB+sealant and STB+FV.

In table (16), at the age of 23 years old, in the no caries population, the population under combined interventions, STB+sealant and STB+FV are the highest, 60,246 (8.88 %) and 52,355 (7.72 %) respectively than in the other intervention scenarios: sealant, supervised toothbrushing, fluoride varnish, oral health examination, and base-case. The population with caries experienced is the lowest under combined STB+sealant, 210,411 (31.02 %), and sealant, 211,498 (31.18 %). There are no differences in effects in other intervention scenarios: STB, FV, STB+FV, and oral

health examination from base-case in the caries population. Population with missing teeth is the lowest under combined STB+sealant, 238,843 (35.21 %), and STB+FV, 241,669 (35.63 %), respectively, followed by sealant, supervised toothbrushing, fluoride varnish, and oral health examination. The treated populations with restoration and endodontic are the highest in the base-case scenario and lowest in the combined STB+sealant and STB+FV.

In table (17), at the age of 59 years old, although the population with no caries is the highest under combined STB+sealant, 908 (0.13 %), there are no very differences among other intervention scenarios: sealant, STB+FV, STB, FV, and oral health examination from base-case. Also, the population with caries and the treated population are not different between interventions and base-case. The population with missing teeth is the lowest in STB+sealant, 457,036 (67.39 %), followed by combined STB+FV, and there are no differences among other interventions from base-case.

Figure (24) presents the no-caries population of 6 to above years old age. It shows that the no caries population is the highest under combined interventions: STB+sealant and STB+FV followed by sealant, STB, FV, oral health examination, and lowest in base-case until above 20 years old age. It is not very different after this age. Figures (25) show the population with caries from 6 years to above. It is the lowest under combined STB+sealant followed by sealant, STB+FV, STB, FV, and highest under base-case until above 15 years old age. However, STB, FV, STB+FV, and oral health examination are not different from the base case or have no effects during the age of above 20 years old except for the interventions: STB+sealant and sealant. Around the age of 59 and above 59, there are also no differences between all interventions and base-case. Figure (26, 27, 28) show the population with restoration, endodontic treatment, and missing teeth 6 to above years old. It shows that they are lowest under STB+sealant, STB+FV, and sealant and highest in base-case until between above 20 years old and 30 years old. From above this age to 59 years old and above 59 years old, all interventions are not different from the base case or have no effectiveness. Generally, over the years, the figures showed that the no caries population and the caries population slightly decreased, and on the other hand, the population with treated cases and missing teeth gradually increased under all scenarios

in the model. It is due to the transmission states from no caries to caries state and caries state to treated and missing teeth states.

According to the simulation of scenarios in model 2, combined supervised toothbrushing (STB) and sealant is the most effective intervention compared to providing alone and base-case around the age of 6-15 years old, where the interventions, combined STB+sealant, supervised toothbrushing, and sealant are provided. Besides, combined STB+sealant and sealant are still effective for caries reduction until 23 years old, and STB is still effective until 19 years old. Oral health examination has a shallow effect on caries reduction compared to base-case, even though it is provided among 15-59 and above 59 years old. Although combined STB+FV and FV are not implemented after five years old, it is still effective in reducing caries until above 15 years old.

After the age of above 20 years old, the caries populations under intervention scenarios are not significantly different or slightly increased than the reference point, a base-case scenario. It means that the interventions provided among the younger ages are no longer effective in reducing caries beyond those above 20 years old or from middle adulthood. Therefore, the interventions could reduce the population with caries by about 15 years from they started. Nevertheless, the populations with treated cases and missing teeth are reduced until 30 and 40 years old compared to the base case, whereas the caries population is reduced until above 20 years old. It would be because the treated states and missing teeth state are consequences of dental caries. It concerns that transitioning back from treated cases to the caries state has to take time depending on treatment conditions or qualities, and it also affects the changing to missing teeth. After these ages, the treated cases and missing teeth are also not different or slightly increased than the reference point, a base-case scenario.

Table 15. Simulation results from permanent dentition model at the age of 15 years old

States	At the age of 15 years old					
	Base-case	STB	FV	STB+FV	Sealant	STB + Sealant
No caries	112405	133306	122672	144261	141097	153042
	16.57%	19.65%	18.09%	21.27%	20.80%	22.56%
Untreated caries	280244	270870	275849	265319	264507	257655
	41.32%	39.94%	40.67%	39.12%	38.99%	37.99%
Restoration	119813	115259	117499	113107	114601	112547
	17.67%	16.99%	17.32%	16.68%	16.89%	16.59%
Endodontic	12821	12436	12625	12255	12391	12222
	1.89%	1.83%	1.86%	1.81%	1.83%	1.80%
Missing teeth	152959	146372	149598	143301	145648	142777
	22.55%	21.58%	22.06%	21.13%	21.47%	21.05%

Table 16. Simulation results from permanent dentition model at the age of 23 years old

States	At the age of 23 years old						
	Base-case	STB	FV	STB+FV	Sealant	STB + Sealant	OH exam
No caries	33634	45388	39165	52355	51673	60246	33948
	4.96%	6.69%	5.77%	7.72%	7.62%	8.88%	5.01%
Untreated caries	212063	213396	212963	213299	211498	210411	211877
	31.27%	31.46%	31.39%	31.45%	31.18%	31.02%	31.24%
Restoration	160303	155857	158136	153466	154133	151456	160251
	23.64%	22.98%	23.32%	22.63%	22.73%	22.33%	23.63%
Endodontic	18154	17694	17928	17454	17547	17288	18150
	2.68%	2.61%	2.64%	2.57%	2.59%	2.55%	2.68%
Missing teeth	254089	245908	250051	241669	243393	238843	254018
	37.46%	36.26%	36.87%	35.63%	35.89%	35.21%	37.45%

Table 17. Simulation results from permanent dentition model at the age of 59 years old

States	At the age of 59 years old						
	Base-case	STB	FV	STB+FV	Sealant	STB + Sealant	OH exam
No caries	148	356	230	547	563	908	155
	0.022%	0.052%	0.034%	0.081%	0.083%	0.13%	0.023%
Untreated caries	64261	65698	64937	66560	66394	67473	64293
	9.47%	9.69%	9.57%	9.81%	9.79%	9.95%	9.48%
Restoration	125432	126536	125984	127081	126808	127347	125442
	18.49%	18.66%	18.58%	18.74%	18.69%	18.78%	18.49%
Endodontic	25661	25585	25625	25537	25543	25480	25659
	3.78%	3.77%	3.78%	3.77%	3.77%	3.76%	3.78%
Missing teeth	462742	460068	461467	458518	458935	457036	462694
	68.23%	67.83%	68.04%	67.60%	67.67%	67.39%	68.22%

Figure 24. No caries population, permanent dentition model

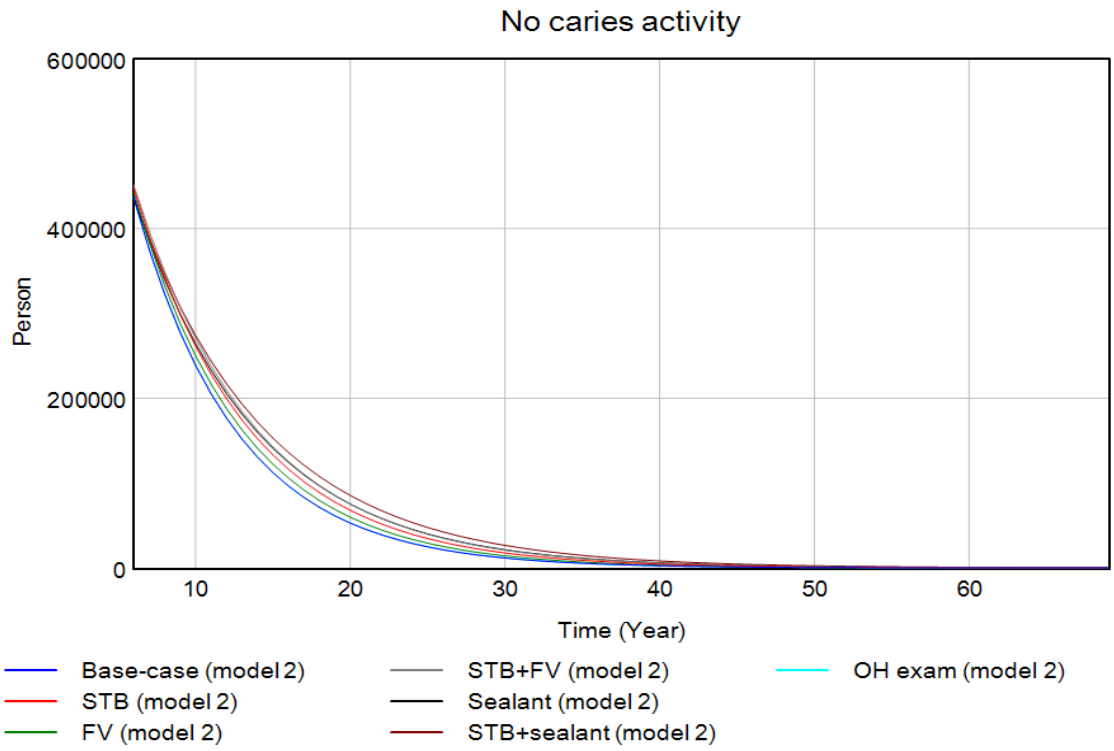


Figure 25. Caries population, permanent dentition model

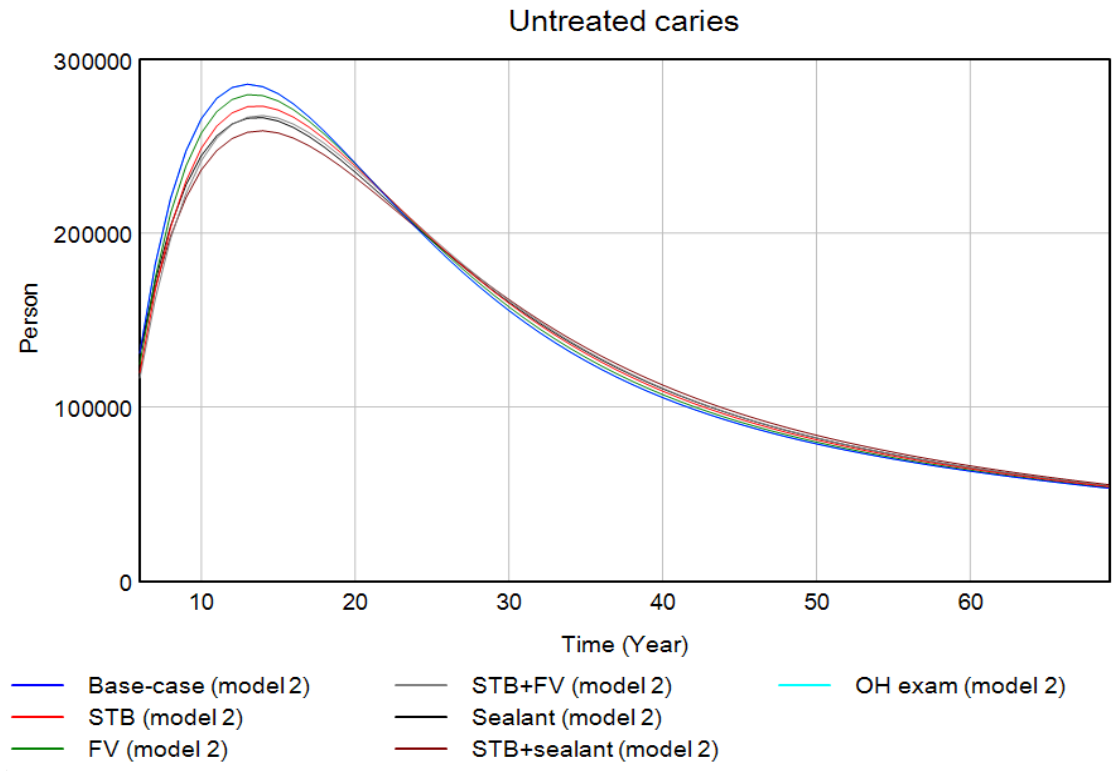


Figure 26. Population with restoration, permanent dentition model

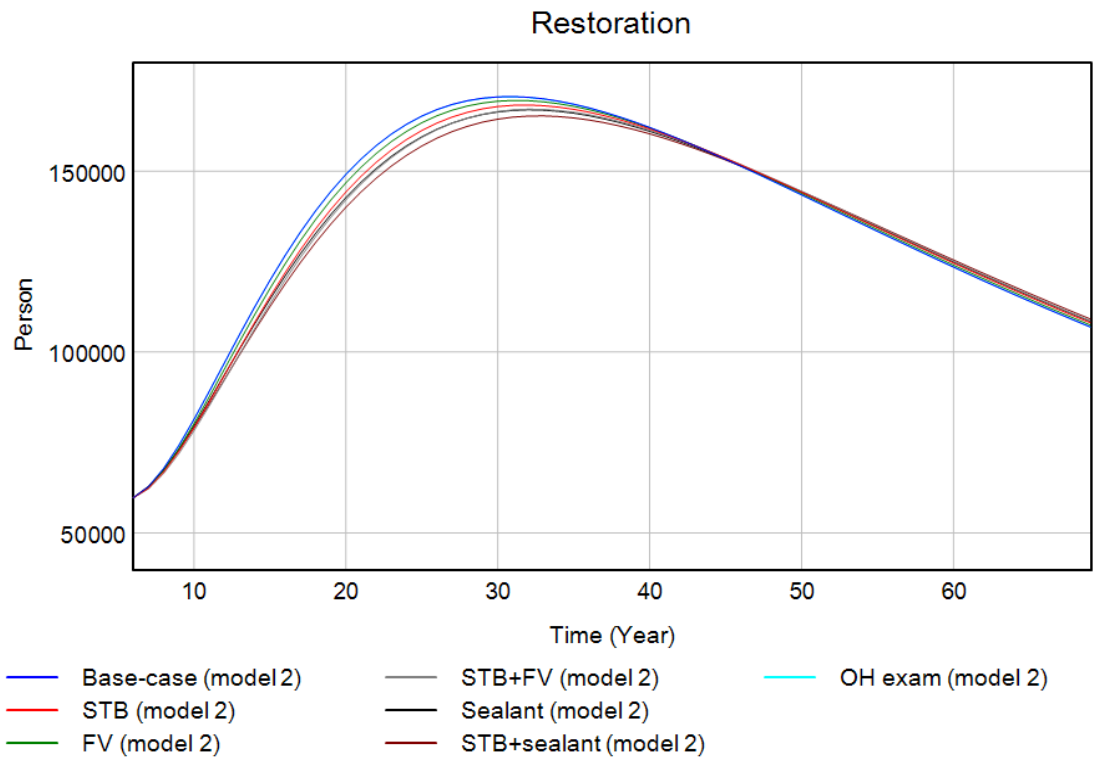


Figure 27. Population with endodontic, permanent dentition model

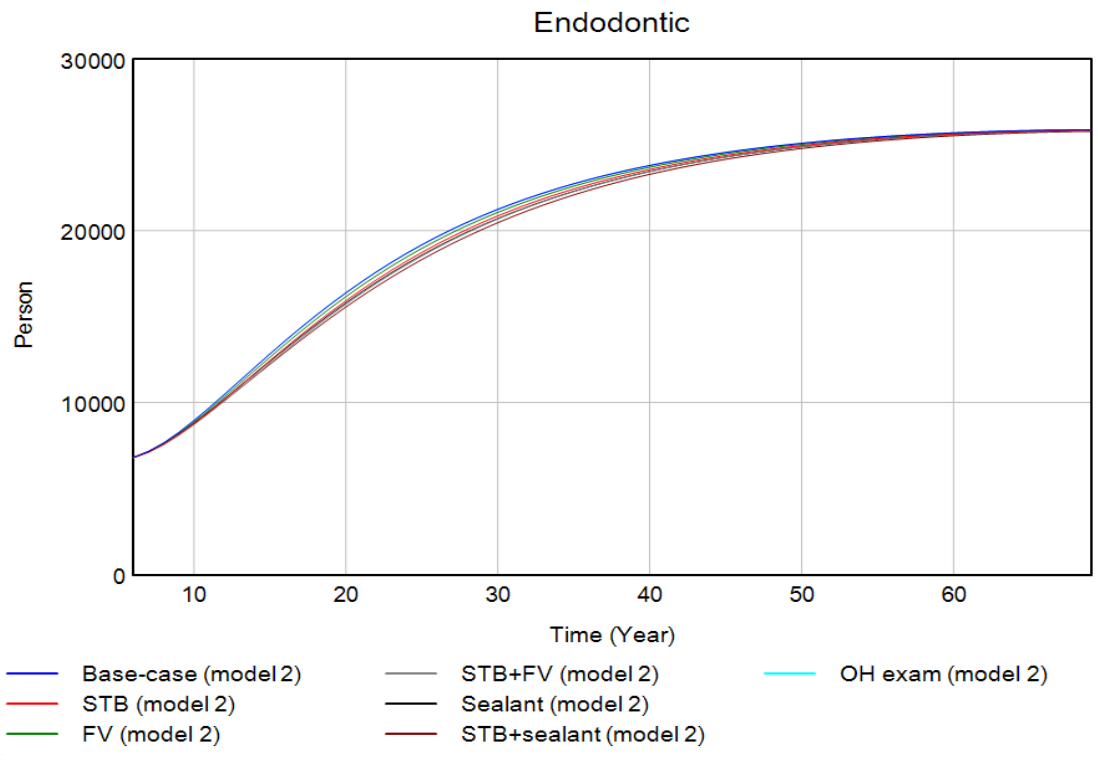
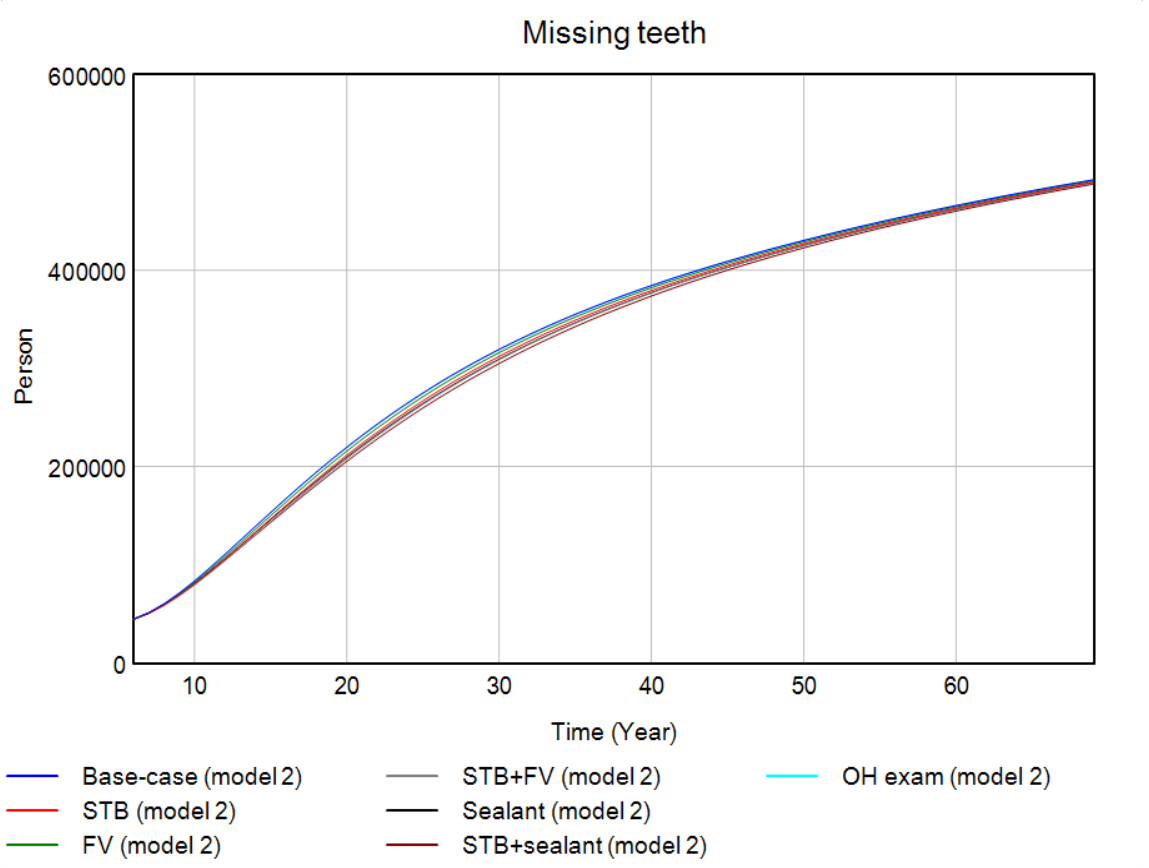


Figure 28. Population with missing teeth, Model 2



Sensitivity analysis (Coverage change)

Sensitivity analysis was done by changing some coverage rates of interventions. In table 18, the coverage rate of the combined supervised toothbrushing (STB) and fluoride varnish (FV) is 42.7% and changed to 55%. In table 19, the sealant is 27% and changed to 50%. In tables 20 and 21, the coverage rates of both interventions are changed by 20%. The effective rates have remained unchanged. It is seen that it is not very different in results after changing the coverage rate. Nevertheless, it is found that when coverage rates of interventions are higher, the no-caries population is increased, and on the other hand, the caries population, the population with treated cases and missing teeth, decreases. The model's behavior is not changed even though the coverage rate changes.

Table 18. Sensitivity analysis (coverage change in combined STB+FV)

States	5 years old		
	STB+FV (coverage 42.7%)	STB+FV (coverage 55%)	28% Change
No caries	359969	378735	+2.77 (5.2%)
	53.07 %	55.84 %	
Untreated caries	258876	244079	-2.18 (5.71%)
	38.17 %	35.99 %	
Restoration	24970	23304	-0.24 (6.5%)
	3.68 %	3.44 %	
Endodontic	1936	1807	-0.02 (6.8%)
	0.29 %	0.27 %	
Missing teeth	32492	30319	-0.32 (6.7%)
	4.79 %	4.47 %	

Table 19. Sensitivity analysis (coverage change in sealant)

States	15 years old		
	Sealant (coverage 27%)	Sealant (coverage 50%)	85% Change
No caries	141097	169232	+4.15 (19.9%)
	20.80%	24.95%	
Untreated caries	264507	248139	-2.4 (6.2%)
	38.99%	36.59%	
Restoration	114601	109853	-0.7 (4.1%)
	16.89%	16.19%	
Endodontic	12391	12001	-0.06 (3.3%)
	1.83%	1.77%	
Missing teeth	145648	139019	-0.98 (4.6%)
	21.47%	20.49%	

Table 20. Sensitivity analysis (coverage change in combined STB+FV) (20% change)

States	5 years old		
	STB+FV (coverage 42.7%)	STB+FV (coverage 51.24%)	20% Change
No caries	359969	366969	+1.03 (1.94%)
	53.07 %	54.1%	
Untreated caries	258876	253366	-0.82 (2.15%)
	38.17 %	37.35%	
Restoration	24970	24345	-0.09 (2.4%)
	3.68 %	3.59%	
Endodontic	1936	1888	-0.02 (6.89%)
	0.29 %	0.27%	
Missing teeth	32492	31676	-0.12 (2.5%)
	4.79 %	4.67%	

Table 21. Sensitivity analysis (coverage change in sealant) (20% change)

States	15 years old		
	Sealant (coverage 27%)	Sealant (coverage 32.4%)	20% Change
No caries	141097	153042	+1.76 (8.4%)
	20.80%	22.56%	
Untreated caries	264507	257655	-1.01 (2.5%)
	38.99%	37.98%	
Restoration	114601	112547	-0.3 (1.7%)
	16.89%	16.59%	
Endodontic	12391	12222	-0.03 (1.6%)
	1.83%	1.80%	
Missing teeth	145648	142777	-0.42 (1.95%)
	21.47%	21.05%	

Table 22. Uncertainty analysis outcome at five years old

Scenarios	Population with untreated caries		
	Mean	Lower bound (95% CI)	Upper bound (95%CI)
Base-case	291,148	268,783	308,481
STB	265,571	244,773	281,879
FV	273,334	251,401	290,523
STB+FV	260,816	239,778	277,387

Table 23. Uncertainty analysis outcome at 15 years old

Scenarios	Population with untreated caries		
	Mean	Lower bound (95% CI)	Upper bound (95%CI)
Base-case	280,498	262,192	293,187
STB	270,554	252,731	284,542
FV	275,965	257,205	289,351
STB+FV	266,288	247,473	279,325
Sealant	264,508	244,817	278,669
STB + sealant	257,958	239,682	270,984

Table 24. Uncertainty analysis outcome at 59 years old

Scenarios	Population with untreated caries		
	Mean	Lower bound (95% CI)	Upper bound (95%CI)
Base-case	64,581	54,546	72,841
STB	66,028	55,725	74,525
FV	65,262	55,098	73,680
STB+FV	66,770	56,340	75,303
Sealant	66,725	56,315	75,243
STB + sealant	67,806	57,233	76,366
OH exam	64,736	54,672	73,032

CHAPTER V

DISCUSSION

In Thailand, the prevalence of dental caries was still high according to the 8th National Oral Health Survey, detected at 52.9% at three years old, 75.6% at five years old, 52% at 12 years old, 62.7% at 15 years old, 91.8% in 35–44 years old, 98.5% in 60–74 years old and 99.5% in 80-85 years age groups respectively [3]. Due to the high trend of caries prevalence, preventive interventions are implemented in different age group intervals according to the Ministry of Public Health (Thailand) guidelines. Nevertheless, the coverage of interventions is different among the age groups. It is higher in younger age groups than in the adult age groups. According to a literature review of some studies, conducting or using the System Dynamics Model (SDM) is seen to assist in evaluating the long-term assessment of caries preventive interventions. Depending on the coverage and effective rate of some preventive interventions implemented in Thailand, this study planned to conduct dental caries and related events outcomes under the intervention conditions among the simulated population in the System Dynamics Model (SDM). In this study, it is projected possibly see the lifelong effect of interventions depending on the coverage rate and effective rate, which is different from some previous studies [10,11] that conducted SDM to estimate the effect of interventions on reducing caries experience and costs mostly ten years projecting.

Therefore, the objective of the study is to estimate the lifelong outcomes (no caries, dental caries experience, and their related events such as restorative treatment, endodontic treatment, and tooth loss) under different conditions such as base-case and preventive interventions (supervised toothbrushing, fluoride varnish, combined supervised toothbrushing and fluoride varnish, dental sealant application, combined supervised toothbrushing and sealant and oral health examination) by conducting the System Dynamics Model (SDM). It also aims to compare the interventions to the base case, a reference point for lifelong outcomes. The population represented in the model was fixed and started from 0 years old. The model was simulated for 75 years until the population reached 75. The model assumed that different interventions mentioned

above were implemented in this population according to age group intervals recommended by the Ministry of Public Health (Thailand) and established the outcomes. The effectiveness rates of each intervention used in the model were retrieved from the systematic review and meta-analysis. The model was divided into qualitative and quantitative parts. The qualitative (causal loop) showed the relationship between dental caries and their related events, and the quantitative part (stock and flow) was approached to conduct the number of outcomes under different scenarios.

5.1 Dental caries and related events under scenario analysis

The population with no caries, untreated caries, restorative treatment, endodontic treatment, and missing teeth were explored under different scenarios by comparing the intervention scenarios to the base-case scenario.

When establishing the interventions, effective rates were considered based on the meta-analysis results and coverage rate of interventions in Thailand. According to systematic reviews and meta-analyses, the effective rates of supervised toothbrushing and fluoride varnish were not very high and were just around 10% and above 10%. where the combined STB+FV was above 30%. However, the dental sealant and combined STB+sealant were good, around 50% and above 50%. Here, meta-analysis and expert opinions assume the effective rate of combined STB+sealant. Oral health examination has only 7%. In the coverage rate, the coverage rates of supervised toothbrushing and fluoride varnish were above 50%, and others were below them. After adjusting the effective rate and coverage rate, the intervention scenarios were analyzed, and the estimated outcomes populations were compared to the base-case scenario.

Supervised toothbrushing (STB)

According to systematic reviews and meta-analyses of supervised toothbrushing, the effective rates of the intervention were 19% in 0-3 years old, 15% in 3-5 years old, and 10% in 5-15 years old, respectively. Where the coverage rates were 60% in 0-3 years old age, [72], 78% in 3-5 years old age [73], and 95% in 5-15 years old age [79], respectively. Depending on coverage rates, the effective rates were adjusted as 11.4 % in 60% coverage of the 0-3 years old age group, 12 % in 78% coverage of the 3-5 years

old age group, and 9.5% in 95% coverage of 5-15 years old age group. Therefore, it is considered that the preventive rates were not very high in addition to the not full coverage of the interventions. Due to low preventive rates, the reduction of the caries development rate was not significantly different from the base-case scenario. Assumed that the intervention was provided to the population within the age group interval of 0-3, 3-5, and 5-15 years old age according to the guideline of the Ministry of Public Health, Thailand, and set the interventions in model 1 and model 2 with maintaining the same effective rate from the last age group provided.

According to the model 1 simulation, the population with no caries was higher above 20,000 and 30,000 in number than in the base-case scenario at three and five years age group intervals. On the other hand, the population with caries experienced was lower than 20,000 in number than in the base case at 3 and 5 years old. The populations with restoration, endodontic, and missing teeth were also lower in number compared to the base case. However, the percentages were not significantly different.

In the model 2 simulation, at the age group intervals of 15 years old, no caries population was higher above 20,000 in number than in the base case, and around 9,000 in number was lower in the caries population compared to the base case where the populations with restoration, endodontic, and missing teeth were also still lower in number compared to the base case. Nevertheless, the percentages were not significantly different. However, at 23 years old, the caries population was not different from the base case even though the treated population and missing teeth population were lower and the no caries population was higher than the base case. From the age of above 23 years old, there were no differences between all population statuses and the base case scenario.

It seems that the intervention does not affect caries reduction after being above 15 years old. It can be considered that the supervised toothbrushing intervention can affect reducing dental caries by above 15 years from the intervention started. If the effective rate and coverage were higher than the rates set in the model, the intervention could reduce the caries population more than the current result in the model.

Fluoride varnish (FV)

According to systematic reviews and meta-analyses of fluoride varnish, the effective rates of the intervention were 17% in 0-3 years old and only 8% in 3-5 years old. The coverage rates were 50% at 0-3 years old and 60% at 3-5 years old [72]. Depending on coverage rates, the effective rates were adjusted as only 8.5% in coverage, 50% of the 0-3 years old group, and 4.8% in coverage, 60% of the 3-5 years old age group. Therefore, it is considered that the preventive rates were relatively low in addition to the not full coverage of the interventions. Due to relatively low preventive rates, the reduction of the caries development rate was not significantly different from the base-case scenario. According to the implemented intervention guideline of the Ministry of Public Health (Thailand), it was assumed that the population was provided by the intervention within the age group interval of 0-3 and 3-5 years old and set the intervention in model 1 and model 2 with maintaining the same effective rate from the last age group provided.

From the model 1 simulation, at the age of 3 and 5 years old, above 10,000 was higher in the population with no caries and lower in the caries population than in the base-case scenario. On the other hand, the populations with missing teeth, restoration, and endodontic treatment were also lower in number compared to the base case. Nevertheless, the differences in the percentages were not significantly different.

According to the model 2 simulation, although the intervention was not provided later than five years old, no caries population was above 10,000 in number, and around 4,000 in number was lower in the caries population compared to the base case at the age of 15 years old. The populations with restoration, endodontic, and missing teeth were also still lower in number than in the base case. The percentages were not significantly different. Nevertheless, at 23 years old, even though the population with missing teeth and treated population were lower and no caries population was higher than the base case, the caries population was not different from the base case. After being above 23 years old, there were no differences for all populations compared to the base case scenario.

It seems that fluoride varnish is not effective in caries reduction after being above 15 years old. It can be assumed that the intervention can reduce dental caries by over 15 years from the intervention's start. The intervention could reduce the caries

population by more than the predicted result in the model if the effective rate and coverage were higher than the rates set in the model.

Combined supervised toothbrushing (STB) and fluoride varnish (FV)

According to a subgroup analysis of combined STB+FV from systematic reviews and meta-analyses of fluoride varnish, the effective rate of the combined intervention was 34% in 0-3 years, while the coverage rate was 42.7% [74]. Depending on this coverage rate, the effective rate was adjusted as 15% for both 0-3 and 3-5 years old. Therefore, it is considered that the preventive rate was not relatively high in addition to the not full coverage of the combined intervention. Due to not being exceptionally high, the caries development reduction rate was not significantly different from the base-case scenario. According to the established intervention guideline of the Ministry of Public Health (Thailand), it was assumed that the population was implemented by the combined intervention at the age interval of 0-3 and 3-5 years old and set the intervention in model 1 and model 2 with maintaining the same effective rate from the last age group provided.

From the model 1 simulation, the no caries population was higher above 30,000 and 40,000 in number than in the base case at 3 and 5 years old, respectively. At these ages, the caries population was lower, above 20,000 and 30,000 compared to the base case. Besides, the populations with missing teeth, restorative and endodontic treatment were also lower in number than in the base case. Nevertheless, the percentage differences were not significantly different.

In the model 2 simulation, even though the combined intervention was not provided after five years old, no caries population was higher above 30,000 and above 10,000 in number was lower in the caries population than in the base case at the age of 15 years old. The populations with missing teeth, restoration, and endodontic treatment were also still lower. The percentages were not significantly different. However, at 23 years old, although the treated population and missing teeth population were lower and the no caries population was higher than the base case, the caries population was not different from the base case. From above 23 years old age, there were no differences compared to the base case scenario.

It is seen that combined intervention does not affect caries reduction after being above 15 years old. It can be determined that the combined intervention can reduce dental caries by over 15 years from the intervention's start. If there are higher effective and coverage rates, the intervention could reduce the caries experienced population more than the expected value in the model.

Dental sealant

According to systematic reviews and meta-analyses of dental sealant, the effective rate of the intervention was 71% in molars and 58% in all teeth during the 5-15 years old age groups. However, the coverage rate of the intervention was only 27% during this age group. [72] The effective rate was adjusted depending on the coverage rate. Therefore, 12% in 27% coverage of the 5-15 age group. Even though the effective rate was relatively high, the intervention coverage was not very high. It is considered that the preventive rate was not very high due to the meager rate of coverage. The reduction of the caries development rate was not very different from the base-case scenario due to the low preventive rate. It is assumed that the intervention was implemented to the population within the age group interval of 5-15 years old as per the Ministry of Public Health, Thailand guideline, and set the intervention in model 2 with maintaining the unchanged effective rate from the last group provided.

In the model 2 simulation, the population with no caries was above 20,000 and 10,000 higher than in the base-case scenario at 15 and 23 years old, respectively. The population with caries experienced was lower at around 10,000 than in the base case at 15 years old, and only around 500 was lower at 23 years old. The populations with restoration, endodontic treatment, and missing teeth were still lower in number compared to the base case during these ages. From later above 23 years old, there were no quite differences from the base case in all population statuses.

Dental sealant application seems to have no efficacy in caries reduction after being over 23 years old. It can be regarded that the intervention could reduce dental caries by above 15 years from the intervention started. If the coverage rate and effective rate are higher, even though the effective rate is relatively high, the sealant intervention could keep reducing of caries population for more than the estimated number in the model.

Combined supervised toothbrushing and sealant

According to systematic reviews and meta-analyses, the effective rate of the sealant was 71% in molars, and the supervised toothbrushing was 10% during the 5-15 age group. It was considered that the combined intervention effective rate was 60% based on the experts' opinions. Nevertheless, the coverage rate of the intervention was only 33%. [79] The effective rate was adjusted depending on the coverage rate. Therefore, 19.8% in the 33% coverage of the 5-15 age group. Even though the effective rate was relatively high, the intervention coverage was not very high. Therefore, it is considered that the preventive rate was not very high due to the relatively low coverage rate. The reduction of the caries development rate was not very different from the base-case scenario due to the low preventive rate. It is assumed that the intervention was provided within the age interval of 5-15 years old according to the Ministry of Public Health, Thailand guideline, and set the intervention in model 2 with keeping the unchanged effective rate from the last group provided.

From the model 2 simulation, at 15 and 23 years old, the no-caries population was higher than 40,000 and 20,000 in the base-case scenario, respectively. Caries experienced population was lower at around 10,000 than in the base case at 15 years old, and only above 1,000 was lower at 23 years old. The populations with restoration, endodontic treatment, and missing teeth were still lower in number compared to the base case during these ages. From above 23 years old, there were no differences from the base case.

Combined STB+sealant does not affect caries reduction from above 23 years old. It can be established that the combined intervention could reduce dental caries by above 15 years from the intervention started. If the combined intervention has a higher effective rate and coverage rate, even though the effective rate is relatively high, the intervention could affect on reduction of the caries population for more than the expected number in the model.

Oral health examination

According to systematic reviews and meta-analyses of oral health examination, the effective rate of the intervention was only 7% in 15-59 years old. The coverage rates were only 7% for 40-59 years old and 23% for those above 60 years old [72]. The effective rates were adjusted with coverage rates as only 0.49% for adults aged (15-59 years old) and 1.61% for elderly aged (above 59 years old). Therefore, it showed that oral health examination has no effect during these ages in addition to meager coverage rates. The reduction of the caries development rate was not different from the base-case scenario due to the shallow preventive rate. It is assumed that the intervention was provided to the population within the age group interval of 15-59 and above 59 years old as per the Ministry of Public Health, Thailand guideline, and set the intervention in model 2 even though there is not relatively high effectiveness.

According to the model 2 simulation, very few amounts were lower than the base case, as around 100 or <100 in the population with caries, missing teeth, and treated cases statuses at 23 years old, and there were no differences from the base case after that. It can be considered that oral health examination has very low or no efficacy in caries reduction due to the meager preventive rate.

This study estimated the dental caries outcome under intervention scenarios comparing the base-case scenario mentioned above. The findings evaluate the long-term effects of interventions belonging to previous studies. One study (Splieth et al., 2008) [9] estimated combination of fluoride regimes was the most effective caries preventive intervention and cost-effective as a lifetime aspect. The study (Hirsch et al., 2012) [10] found that combined early childhood caries (ECC) interventions have the most significant potential for cavity reduction and costs as ten years project. Another study (Edelstein et al., 2015) [11] also projected ten years for nine preventive interventions and said that disease reductions and net savings from three different interventions. The study (Urwannachotima et al., 2019) [13] regarded the combined health promotion policies increased the affordability of dental health services with the reduction in the population with high DMFT as 40 years prediction. According to previous studies, [9,10,13] estimating combined one was better is consistent with the present study. Moreover, the studies [10,11] targeting disease reduction for ten years

projected is analogous to the present study where the reduction of disease is above 15 years.

However, the present study concerned not only the preventive or effective rate of the interventions but also the coverage rate of interventions in Thailand's situation when simulating the SDM for long-term assessment. In contrast, some previous studies mentioned only the preventive rate. On the other hand, the previous studies developed SDM for both effects and costs, such as costs of treatment and cost-savings for mostly ten years, whereas this study focuses only on effect as a lifelong aspect.

5.2 Strengths and limitations of the model

When conducting the model, consideration of behavior to the progression of dental caries and related events allows for the natural history of dental caries. The model structure is convenient to a similar previous study [10]. The setting interventions in the model are interventions that are implemented in Thailand. The effective rate to be used in the model comes from systematic reviews and meta-analysis and is adjusted with the coverage rate of the interventions in Thailand. The model may be used as a long-term assessment to estimate how long the intervention keeps efficiency when projecting the intervention for improving the population's oral health.

Although we engaged the SDM model with experts in the GMB session, there are limitations to the model and study as follows. The study is based on the secondary database and may not be able to use specific single data for analysis even though reliable secondary data was used in the model. The representation of the population in the model is fixed. Therefore, the population changes as birth and death conditions were not considered in the model, and the model was set as average lifespan time duration. Although the birth and death rates were not considered, it would have a low impact on the model results, whereas it could change in number, but the represented percentage would not be affected. Another limitation is factors that can relate to dental caries. Adding each risk factor as a variable in the model is complex and challenging. Therefore, it is assumed that the caries development rate is considered a natural disease development rate that may be influenced by risk factors when interventions are not provided. It is also assumed that the rate of disease development is reduced by

preventing risk factors that can be affected by interventions when implementing interventions.

The following limitation is the causes of loss of teeth or missing teeth that influence the rate of missing teeth. Depending on the available data source (HDC), the number of missing teeth cannot be separated due to the cause of dental caries, periodontal disease, and other causes. Therefore, the data on loss of teeth due to all causes (both dental caries and periodontal disease) from HDC was used and assumed that the variables with missing teeth may be primarily due to dental caries among the younger ages, and due to both dental caries and most common periodontal disease during the middle adult ages and elderly ages. Therefore, the reduced number of the population with missing teeth could be less than if interventions focus and have a greater effective rate on dental caries and periodontal diseases. However, if there is no better efficiency on periodontal disease, it would not be different from one focusing on dental caries alone.

When wondering about other oral health promotion programs and policies improving not only by targeting an individual level but also by taking an approach comprehensively to address a broad spectrum of health determinants and factors, it would impact the interventions of the present study. There were considerations about whether they have great approaches that have to impact. If the policies significantly impact the reduction of the incidence of dental caries disease, the disease may be reduced than the estimated ones. In comparison, the low impact could not have changed the estimated ones.

Therefore, due to the limitations mentioned above, this study may require generating a more distinct model system and quantitative predictions.

5.3 Implication and further suggestions

Evidence, resources used, and value are considered the decision drivers. As evidence of this study, combined interventions are more effectively implemented than other interventions provided separately according to the model simulation. Besides, the interventions provided during younger ages have no efficiency in adult age. Even though the oral health examination is implemented in adult age, it has a meager effective rate on disease development because it only focuses on examining the oral cavity. Therefore, it has to consider providing some effective interventions in adult life, for example, combining the oral health examination with other preventive interventions or replacing the oral health examination with another preventive intervention.

Although it is said that combined interventions are more effective, it has to consider the coverage rate of the intervention. It is because the effective rates of the interventions are pretty low even though they have higher effective rates evidence due to their low coverage rates. Therefore, the coverage of the interventions should be expanded. The sensitivity analysis showed that when coverage rates of interventions are higher, i.e., when the coverage (42.7%) of FV changes to 55% (KPI) and 27% of sealant to 50% (KPI), the no-caries population was increased, and the caries population was decreased. Therefore, it has to concern getting a coverage rate above 55% if possible. When expanding the coverage, the resource use or efforts for interventions would be needed to consider. For example, more resources would be needed in dental sealant application than supervised toothbrushing or fluoride varnish. According to previous studies in Thailand, the unit cost of applying pit and fissure sealant per case was 243 baht and 180 baht for fluoride varnish, respectively. [83] The unit cost for the oral health examination with oral hygiene instruction per case was 109 baht. [84] The available resource is crucial when considering the expanding coverage rate of interventions. Therefore, it has to establish how to use the resource to get a better effective rate. It may be shifting the resource use from one to one or adding the resource use.

This study informed based on evidence and would help as an implication for further considerations such as resource use and value in decision-making. In addition, the SDM may help in comparing the cases as scenarios to predict the best-case

condition or better and what is poor in terms of other policies or services. According to the study's objectives, this study focused on estimating the long-term effects of the interventions by model simulation. The resource used and costs of treated cases and interventions were not retrieved and estimated. Therefore, the interventions' cost-effectiveness or cost savings have to be regarded as a further suggestion of the study. Moreover, since it is necessary to contemplate resource use in decision-making, the use of resources is another option to appraise beyond this study.

CHAPTER VI
CONCLUSION

It is found that supervised toothbrushing, fluoride varnish, and oral health examination have a low effective rate for caries prevention, whereas dental sealant, combined supervised toothbrushing and fluoride varnish, and combined sealant and supervised toothbrushing have pretty good according to meta-analyses and experts' opinions. Although supervised toothbrushing and fluoride varnish have low preventive rates, the coverage rates are pretty good. The sealant and combined interventions are low in coverage rates, although the effective rates are reasonable. The oral health examination is low in both effective rate and coverage rate. After adjusting with effective rate and coverage rate for all interventions, they were set as scenarios in the SDM model. According to the model simulation results, among the interventions: supervised toothbrushing, fluoride varnish, and combined supervised toothbrushing and fluoride varnish provided during the age of 0-5 years old, the combined one is the most effective. Besides, among the interventions: dental sealant, supervised toothbrushing, and combined sealant and supervised toothbrushing implemented between 5-15 years old, the combined intervention is the most effective. In contrast, oral health examination has very low efficacy among the ages 15-19 and above 59. All the interventions could reduce the population with caries by about 15 years from their start.

Therefore, overall, according to SDM simulation, combined interventions are more effective than other interventions. Each intervention can reduce the caries population by about 15 years compared to the base case. The interventions that are implemented among the younger ages of the population do not affect caries reduction when they are adults and the elderly aged. If the interventions have better effective coverage rates, the caries population could be reduced for more than the estimated results.

REFERENCES

1. WHO | The burden of oral disease: challenges to improving oral health in the 21st century. https://www.who.int/bulletin/volumes/83/1/editorial20105/en/
2. Nazir MA. Prevalence of periodontal disease, its association with systemic diseases and prevention. Int J Health Sci (Qassim). 2017;11(2):72–80.
3. Bureau of Dental Health. Department of Health, Ministry of Public Health. The 8th Thailand National Oral Health Survey Report 2017. Bangkok: Bureau of Dental Health; 2018.
4. Mielczarek B. Review of modelling approaches for healthcare simulation. Operations Research and Decisions. 2016;26(1):55–72.
5. Mustafee N, Katsaliaki K, Taylor S. Profiling Literature in Healthcare Simulation. SIMULATION. 2010;86:543–58.
6. Almagooshi S. Simulation modelling in healthcare: Challenges and trends. Procedia Manufacturing. 2015;3:301–7.
7. Tsoi B, O'Reilly D, Jegathisawaran J, Tarride JE, Blackhouse G, Goeree R. Systematic narrative review of decision frameworks to select the appropriate modelling approaches for health economic evaluations. BMC research notes. 2015;8(1):1–15.
8. Homer JB, Hirsch GB. System Dynamics Modeling for Public Health: Background and Opportunities. Am J Public Health. 2006 Mar;96(3):452–8.
9. Splieth CH, Flessa S. Modelling lifelong costs of caries with and without fluoride use. Eur J Oral Sci. 2008 Apr;116(2):164–9.
10. Hirsch GB, Edelstein BL, Frosh M, Anselmo T. A simulation model for designing effective interventions in early childhood caries. Preventing Chronic Disease. 2012;9.
11. Edelstein BL, Hirsch G, Frosh M, Kumar J. Reducing early childhood caries in a Medicaid population: a systems model analysis. J Am Dent Assoc. 2015 Apr;146(4):224–32.

12. Umeda JE, Chichakly K, Passos GF, Terada RSS, Pascotto RC, Fujimaki M. System dynamics modeling for tooth decay treatment in Brazilian children. Braz Oral Res. 2020;34:e017.
13. Urwannachotima N, Hanvoravongchai P, Ansah JP, Prasertsom P. System dynamics analysis of dental caries status among Thai adults and elderly. Journal of Health Research. 2019;
14. Brailsford SC. System dynamics: What's in it for healthcare simulation modelers. In: 2008 Winter simulation conference. IEEE; 2008. p. 1478–83.
15. Siebers P-O. Lecture 06 Simulation Methods: System Dynamics Simulation.
16. Institute for Transport Studies (ITS). A system dynamics approach to transport modelling [Internet]. Available from: https://www.slideshare.net/ITSLeeds/a-system-dynamics-approach-to-transport-modelling.
17. Introduction to Stock Flow Diagrams. The Creative Learning Exchange at http://www.clexchange.org.
18. Qu Z, Zhang S, Krauth C, Liu X. A systematic review of decision analytic modeling techniques for the economic evaluation of dental caries interventions. PLoS One. 2019;14(5):e0216921.
19. Shanahan M, Shukla N, Perez P, Farrell M, Ritter A. A systematic review of modelling approaches in economic evaluations of health interventions for drug and alcohol problems. BMC health services research. 2016;16(1):1–14.
20. Naorungroj S. Oral Health-Related Quality of Life in the Elderly: A Review and Future Challenges in Thailand. Siriraj Medical Journal [Internet]. 2015 Oct 5 [cited 2021 Jun 7];67(5). Available from: https://he02.tcithaijo.org/index.php/sirirajmedj/article/view/55227
21. Olatosi O, Sote E. Causes and pattern of tooth loss in children and adolescents in a Nigerian tertiary hospital. Nigerian quarterly journal of hospital medicine. 2014 Feb 26;22:258–62.
22. Nithila A, Bourgeois D, Barmes DE, Murtomaa H. WHO Global Oral Data Bank, 1986-96: an overview of oral health surveys at 12 years of age. Bull World Health Organ. 1998;76(3):237–44.

23. Davahli MR, Karwowski W, Taiar R. A System Dynamics Simulation Applied to Healthcare: A Systematic Review. International Journal of Environmental Research and Public Health. 2020;17(16):5741.
24. Ungchusak C. Oral health promotion and prevention of Early Childhood Caries. Thai Dental Public Health Journal. 2017;22(พิเศษ):44–61.
25. Watt R, Fuller S, Harnett R, Treasure E, Stillman-Lowe C. Oral health promotion evaluation–time for development. Community Dentistry and Oral Epidemiology: Commentary. 2001;29(3):161–6.
26. Niranjan VR, Kathuria V, Venkatraman J, Salve A. Oral Health Promotion: Evidences and Strategies. In: Insights into Various Aspects of Oral Health. IntechOpen; 2017.
27. Bureau of Dental Health. Department of Health, Ministry of Public Health, Dental public health implementation guidelines; 2564.
28. Stein C, Santos NML, Hilgert JB, Hugo FN. Effectiveness of oral health education on oral hygiene and dental caries in schoolchildren: Systematic review and meta-analysis. Community Dent Oral Epidemiol. 2018;46(1):30–7.
29. Protocol for the Implementation of the Supervised Tooth Brushing Programme in Primary Schools [Internet]. [cited 2020 Jan 28].
30. Dos Santos APP, de Oliveira BH, Nadanovsky P. A systematic review of the effects of supervised toothbrushing on caries incidence in children and adolescents. Int J Paediatr Dent. 2018 Jan;28(1):3–11.
31. Health CA for D and T in. Fluoride varnishes for dental health: a review of the clinical effectiveness, cost-effectiveness, and guidelines. Summary of evidence. Ottawa, ON, Canada: Canadian Agency for Drugs and Technologies in Health; 2016. 2018.
32. Cvikl B, Moritz A, Bekes K. Pit and Fissure Sealants—A Comprehensive Review. Dent J (Basel). 2018 Jun 12;6(2):18.
33. Alyafei NA, Gibreel S. Exceptional Design for an Adult Oral Health Screening Program, Qatar.
34. Literature Search, Vorasith Sornsrivichai M.D. Ph.D. FETP Cert. Epidemiology Unit, Faculty of Medicine, Prince of Songkla University

35. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Journal of Clinical Epidemiology. 2009 Oct 1;62(10):e1–34.
36. Pieper K, Winter J, Krutisch M, Völkner-Stetefeld P, Jablonski-Momeni A. Prevention in kindergartens with 500 ppm fluoride toothpaste—a randomized clinical trial. Clinical oral investigations. 2016 Jul;20(6):1159-64.
37. Wennhall I, Mårtensson EM, Sjunnesson I, Matsson L, Schröder U, Twetman S. Caries-preventive effect of an oral health program for preschool children in a low socio-economic, multicultural area in Sweden: results after one year. Acta Odontologica Scandinavica. 2005 Jan 1;63(3):163-7.
38. Jiang EM, Lo EC, Chu CH, Wong MC. Prevention of early childhood caries (ECC) through parental toothbrushing training and fluoride varnish application: a 24-month randomized controlled trial. Journal of dentistry. 2014 Dec 1;42(12):1543-50.
39. Rong WS, Bian JY, Wang WJ, De Wang J. Effectiveness of an oral health education and caries prevention program in kindergartens in China. Community dentistry and oral epidemiology. 2003 Dec;31(6):412-6.
40. Andruškevičienė V, Milčiuvienė S, Bendoraitienė E, Saldūnaitė K, Vasiliauskienė I, Slabšinskienė E, Narbutaitė J. Oral health status and effectiveness of caries prevention programme in kindergartens in Kaunas city (Lithuania). Oral health & preventive dentistry. 2008 Sep 1;6(4).
41. Natapov L, Dekel D, Pikovsky V, Zusman SP. Dental health of preschool children after two-years of a supervised tooth brushing program in Southern Israel. Israel Journal of Health Policy Research. 2021 Dec;10(1):1-6.
42. Curnow MM, Pine CM, Burnside G, Nicholson JA, Chesters RK, Huntington E. A randomised controlled trial of the efficacy of supervised toothbrushing in high-caries-risk children. Caries research. 2002;36(4):294-300.
43. Al-Jundi SH, Hammad M, Alwaeli H. The efficacy of a school-based caries preventive program: a 4-year study. International journal of dental hygiene. 2006 Feb;4(1):30-4.

44. Lai H, Fann JC, Yen AM, Chen LS, Lai MH, Chiu SY. Long-term effectiveness of school-based children oral hygiene program on oral health after 10-year follow-up. Community Dentistry and Oral Epidemiology. 2016 Jun;44(3):209-15.
45. Petersen PE, Peng B, Tai B, Bian Z, Fan M. Effect of a school-based oral health education programme in Wuhan City, Peoples Republic of China. International dental journal. 2004 Feb 1;54(1):33-41.
46. Tickle M, O'Neill C, Donaldson M, Birch S, Noble S, Killough S, Murphy L, Greer M, Brodison J, Verghis R, Worthington HV. A randomized controlled trial of caries prevention in dental practice. Journal of dental research. 2017 Jul;96(7):741-6.
47. Memarpour M, Dadaein S, Fakhraei E, Vossoughi M. Comparison of oral health education and fluoride varnish to prevent early childhood caries: a randomized clinical trial. Caries research. 2016;50(5):433-42.
48. Jiang EM, Lo EC, Chu CH, Wong MC. Prevention of early childhood caries (ECC) through parental toothbrushing training and fluoride varnish application: a 24-month randomized controlled trial. Journal of dentistry. 2014 Dec 1;42(12):1543-50.
49. Weintraub JA, Ramos-Gomez F, Jue B, Shain S, Hoover CI, Featherstone JD, Gansky SA. Fluoride varnish efficacy in preventing early childhood caries. Journal of dental research. 2006 Feb;85(2):172-6.
50. Oliveira BH, Salazar M, Carvalho DM, Falcão A, Campos K, Nadanovsky P. Biannual fluoride varnish applications and caries incidence in preschoolers: a 24-month follow-up randomized placebo-controlled clinical trial. Caries Research. 2014;48(3):228-36.
51. Anderson M, Dahllöf G, Twetman S, Jansson L, Bergenlid AC, Grindefjord M. Effectiveness of early preventive intervention with semiannual fluoride varnish application in toddlers living in high-risk areas: a stratified cluster-randomized controlled trial. Caries research. 2016;50(1):17-23.
52. Muñoz-Millán P, Zaror C, Espinoza-Espinoza G, Vergara-Gonzalez C, Muñoz S, Atala-Acevedo C, Martínez-Zapata MJ. Effectiveness of fluoride varnish in preventing early childhood caries in rural areas without access to fluoridated

drinking water: A randomized control trial. Community dentistry and oral epidemiology. 2018 Feb;46(1):63-9.

53. Braun PA, Quissell DO, Henderson WG, Bryant LL, Gregorich SE, George C, Toledo N, Cudeii D, Smith V, Johs N, Cheng J. A cluster-randomized, community-based, tribally delivered oral health promotion trial in Navajo Head Start children. Journal of dental research. 2016 Oct;95(11):1237-44.
54. Petersson LG, Twetman S, Pakhomov GN. The efficiency of semiannual silane fluoride varnish applications: a two-year clinical study in preschool children. Journal of public health dentistry. 1998 Mar;58(1):57-60.
55. Lawrence HP, Binguis D, Douglas J, McKeown L, Switzer B, Figueiredo R, Laporte A. A 2-year community-randomized controlled trial of fluoride varnish to prevent early childhood caries in Aboriginal children. Community dentistry and oral epidemiology. 2008 Dec;36(6):503-16.
56. Agouropoulos A, Twetman S, Pandis N, Kavvadia K, Papagiannoulis L. Caries-preventive effectiveness of fluoride varnish as adjunct to oral health promotion and supervised tooth brushing in preschool children: a double-blind randomized controlled trial. Journal of dentistry. 2014 Oct 1;42(10):1277-83.
57. McMahon AD, Wright W, Anopa Y, McIntosh E, Turner S, Conway DI, Macpherson LM. Fluoride Varnish in Nursery Schools: A Randomised Controlled Trial–Protecting Teeth@ 3. Caries Research. 2020;54(3):274-82.
58. Brooks JD, Mertz-Fairhurst EJ, Della-Giustina VE, Williams JE, Fairhurst CW. A comparative study of two pit and fissure sealants: three-year results in Augusta, Ga. Journal of the American Dental Association (1939). 1979 Jul 1;99(1):42-6.
59. Charbeneau GT, Dennison JB, Ryge G. A filled pit and fissure sealant: 18-month results. Journal of the American Dental Association (1939). 1977 Aug 1;95(2):299-306.
60. Sheykholeslam Z, Houpt M. Clinical effectiveness of an autopolymerized fissure sealant after 2 years. Community dentistry and oral epidemiology. 1978 Aug;6(4):181-4.
61. McCune RJ, Bojanini J, Abodeely RA. Effectiveness of a pit and fissure sealant in the prevention of caries: three-year clinical results. The Journal of the American Dental Association. 1979 Oct 1;99(4):619-23.

62. Richardson AS, AS R, GB G. THE EFFECTIVENESS OF A CHEMICALLY POLYMERIZED SCALANT IN PREVENTING OCCLUSAL CARIES: TWO YEAR RESULTS.
63. Liu BY, Lo EC, Chu CH, Lin HC. Randomized trial on fluorides and sealants for fissure caries prevention. Journal of dental research. 2012 Aug;91(8):753-8.
64. Chen X, Liu Y, Yu Q, Zheng L, Hong X, Yan F, Yu H. Dental caries status and oral health behavior among civilian pilots. Aviation, Space, and Environmental Medicine. 2014 Oct 1;85(10):999-1004.
65. Rosing K, Hede B, Christensen LB. A register-based study of variations in services received among dental care attenders. Acta Odontologica Scandinavica. 2016 Jan 2;74(1):14-35.
66. Higgins JPT, Green S (editors). (2011): "Cochrane Handbook for Systematic Reviews of Interventions" Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.handbook.cochrane.org.
67. Prevented fraction of disease [Internet]. 2020. Available from: https://med.libretexts.org/@go/page/13736.
68. Modeling Exercises Section 1 [Internet]. Prepared for MIT System Dynamics Education Project Under the Supervision of Dr. Jay W. Forrester by Joseph G. Whelan May 1994.
69. Nipaporn Urwannachotima, System Dynamis Analysis of Sugar-Sweetened Beverage Taxing Effect on Sugar Consumption, Dental Health Service Utilization and Oral Health for Thai Adults and Elderly, 2018.
70. National statistical office thailand [Internet]. [cited 2022 Sep 18]. Available from: http://www.nso.go.th/sites/2014en.
71. Thai Health Promotion Foundation. "S-E-L-F C-A-R-E" project, Kirimas district; Sukhothai Province. Bangkok: Thai Health Promotion Foundation; 2018.
72. Health Data Center (HDC) [Internet]. [cited 2022 Sep 18]. Available from: http://www.pcko.moph.go.th/hdc.html.
73. Chomphon Provincial Health Office. Situation of oral health promotion service for pregnant woman and preschool children during 2017-2022. Chumphon: Provincial Health Office; 2022.

74. Ungchusak C, Promma S, Chettaprin S, Sukanwaranil S, Bangkertsing W. (2009). Brushing habit and oral health care utilization of pre-school children age 6-36 months. Thailand Journal of Dental Public Health 2009;14: 59-68.
75. Nedeljkovic I, De Munck J, Vanloy A, Declerck D, Lambrechts P, Peumans M, Teughels W, Van Meerbeek B, Van Landuyt KL. Secondary caries: prevalence, characteristics, and approach. Clinical oral investigations. 2020 Feb;24(2):683-91.
76. Santos-Junior AO, Pinto LD, Mateo-Castillo JF, Pinheiro CR. Success or failure of endodontic treatments: A retrospective study. Journal of conservative dentistry: JCD. 2019 Mar;22(2):129.
77. Motohashi M, Yamada H, Genkai F, Kato H, Imai T, Sato S, Sugaya A, Maeno M. Employing dmft score as a risk predictor for caries development in the permanent teeth in Japanese primary school girls. Journal of oral science. 2006;48(4):233-7.
78. Bureau of Dental Health. Yim-Sod-Sai Project, Ministry of Public Health. Bangkok: Bureau of Dental Health; 2021.
79. Jirapongsa W, Prasertsom, P. Evaluation of Oral Health promotion and Prevention in School Children Project under National Health Security "Yim (smile) Sodsai (Bright), Dek Thai (Thai Children) Fun Dee (Health Teeth)" 2005-2007. Thailand Journal of Dental Public Health 2008;13(5):85-96.
80. Senge PM, Forrester JW. Tests for building confidence in system dynamics models. System dynamics, TIMS studies in management sciences. 1980;14:209–28.
81. Shreckengost RC. HOW VALID ARE THEY? In: Self-Report Methods of Estimating Drug Use: Meeting Current Challenges to Validity. Department of Health and Human Services, Public Health Service, Alcohol …; 1985. p. 63.
82. Qudrat-Ullah H, Seong B. How to do structural validity of a system dynamics type simulation model: The case of an energy policy model. Energy Policy. 2010 May 1;38:2216–24.
83. Riewpaiboon A. Standard cost lists for health technology assessment. Health Intervention and Technology Assessment Program. 2011;182.

84. Tianviwat S, Chongsuvivatwong V, Birch S. Estimating unit costs for dental service delivery in institutional and community-based settings in southern Thailand. Asia Pacific Journal of Public Health. 2009 Jan;21(1):84-93.

APPENDICES

Operational definition

Caries prevention programs

It means the interventions intended to prevent disease occurrence (dental caries) in healthy conditions before the disease process begins. That includes supervised tooth brushing, fluoride varnish, combined supervised toothbrushing and fluoride varnish, dental sealant application, combined supervised toothbrushing and dental sealant, and oral health examination for a particular age group.

The purpose of primary prevention is to prevent the occurrence of diseases in healthy conditions before the disease process begins.

Lifelong effect

It means the effect of an intervention lasting or remaining throughout the person's life after its implementation in particular age groups. For example, if the intervention has a disease reduction or prevention effect after implementation on participants, lifelong effect means how long this intervention effect disease outcomes throughout the rest of participants' life.

Dental caries

It is a disease condition of the teeth in people. Teeth define with decay or cavities.

No caries

It is a healthy state of the teeth before the caries process begins in people. Sound natural teeth define as caries-free and without treatment due to caries.

Parameters for validity check

Data or parameters used in the model and source of the data were validated in the GMB session by experts. The following tables show the check of the parameters of two interventions: sealant and supervised toothbrushing, for the model's validity. The effective rates adjusted with coverage rates of the interventions (sealant and supervised toothbrushing) that affect the caries development fraction were set in the model and compared the values of how much percentage changes with the historical data for the validity of the model as follows tables.

Parameters for validity check of sealant

Status	Sealant					
	At 12 years old			At 15 years old		
	Historical data	Model	% Change	Historical data	Model	% Change
No caries	47.7%	48.83%	+1.13 (2.3%)	37.6%	40.55%	+2.95 (7.85%)
Caries	52.3%	51.17%	-1.13 (2.16%)	62.4%	59.45%	-2.95 (4.73%)

Parameters for validity check of Supervised Toothbrushing

Status	Supervised Toothbrushing					
	At 12 years old			At 15 years old		
	Historical data	Model	% Change	Historical data	Model	% Change
No caries	47.7%	42.58%	-5.12 (10.73%)	37.6%	32.98%	-4.62 (12.29%)
Caries	52.3%	57.42%	+5.12 (9.79%)	62.4%	67.02%	+4.62 (7.4%)

Simulation results of SDM (all ages)

No caries population (0-6 years old, primary dentition model)

Time (Year)	Base-case	STB	FV	STB+FV
0	678243	678243	678243	678243
1	583289	594140.875	591427.875	597532.0625
2	501628.5313	520467.4063	515725.125	526425.75
3	431400.5313	455929.4375	449712.3125	463781.0938
4	371004.4688	399850.125	389900.5625	408591.1563
5	319063.8438	350668.5625	338043.7813	359968.7813
6	274394.9063	307536.3438	293083.9688	317132.5

Population with caries (deciduous teeth) (0-6 years old, primary dentition model)

Time (Year)	Base-case	STB	FV	STB+FV
0	0	0	0	0
1	94954.02344	84102.13281	86815.10938	80710.92188
2	167783.75	149954.0938	154444.0781	144311.125
3	222546.2969	200668.9531	206220.1719	193652.5313
4	262623.7188	238422.9375	247200.6875	231156.6875
5	290829.4688	266048.625	276703.3438	258876.1563
6	178625.5	165659.5469	172386.5781	162053.2344

Population with caries (permanent teeth) (0-6 years old, primary dentition model)

Time (Year)	Base-case	STB	FV	STB+FV
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	130873.258	119721.883	124516.5	116494.266

Population with restoration (0-6 years old, primary dentition model)

Time (Year)	Base-case	STB	FV	STB+FV
0	0	0	0	0
1	0	0	0	0
2	3798.160645	3364.085205	3472.604248	3228.436768
3	10372.77734	9241.141602	9525.353516	8884.658203
4	18901.20898	16935.21875	17431.24805	16310.91113
5	28725.71289	25862.46875	26691.75	24969.98633
6	39324.76563	35573.36328	36798.98047	34426.11328

Population with endodontic (0-6 years old, primary dentition model)

Time (Year)	Base-case	STB	FV	STB+FV
0	0	0	0	0
1	0	0	0	0
2	284.8620605	252.3063965	260.4453125	242.1327515
3	786.5041504	700.6548462	722.2149048	673.6133423
4	1449.424072	1298.457764	1336.542114	1250.529297
5	2228.598633	2005.935791	2070.125	1936.496094
6	3087.715332	2792.046143	2887.814209	2701.505615

Population with missing teeth (0-6 years old, primary dentition model)

Time (Year)	Base-case	STB	FV	STB+FV
0	0	0	0	0
1	0	0	0	0
2	4747.701172	4205.106445	4340.755371	4035.545898
3	13136.88867	11702.81152	12062.95898	11251.10254
4	24264.20508	21736.25977	22373.96875	20933.72852
5	37395.39063	33657.40625	34734.00391	32491.56445
6	51936.86328	46959.83984	48569.16797	45435.37109

No caries population (6-69 years old, permanent dentition model)

Time (Year)	Base-case	STB	FV	STB+FV	Sealant	STB+sealant	OH exam
6	436817	447968	443173	451196	436817	436817	436817
7	375663	391524	384231	397504	385273	388767	375663
8	323070	342192	333128	350201	339810	346003	323070
9	277840	299076	288822	308527	299713	307942	277840
10	238942	261392	250409	271812	264347	274069	238942
11	205491	228457	217104	239467	233154	243921	205491
12	176722	199671	188230	210970	205642	217090	176722
13	151981	174513	163195	185865	181376	193210	151981
14	130703	152524	141490	163747	159974	171957	130703
15	112405	133306	122672	144261	141097	153042	112405
16	96668.3	116509	106357	127094	124447	136207	96780.7
17	83134.7	101829	92211.1	111970	109762	121224	83328.2
18	71495.9	88998.8	79947.1	98645.2	96810.5	107890	71745.6
19	61486.4	77785	69314.1	86906.5	85386.9	96021.8	61772.9
20	52878.3	67984	60095.3	76564.6	75311.2	85459.4	53186.5
21	45475.4	59418.1	52102.6	67453.4	66424.5	76058.8	45793.6
22	39108.8	51931.4	45173	59426.4	58586.4	67692.4	39428.3
23	33633.6	45388	39165	52354.7	51673.2	60246.2	33947.7
24	28924.9	39669.1	33956	46124.5	45575.8	53619.1	29229
25	24875.4	34670.8	29439.9	40635.7	40197.8	47721	25166.2
26	21392.8	30302.3	25524.4	35800	35454.5	42471.7	21668.1
27	18397.8	26484.2	22129.6	31539.8	31270.9	37799.8	18656.2
28	15822.1	23147.2	19186.4	27786.6	27580.9	33641.8	16063
29	13607	20230.7	16634.6	24480	24326.4	29941.2	13830.2
30	11702.1	17681.6	14422.2	21566.9	21455.8	26647.7	11907.8
31	10063.8	15453.7	12504.1	19000.4	18924.1	23716.5	10252.6
32	8654.84	13506.5	10841	16739.4	16691	21107.6	8827.53
33	7443.17	11804.7	9399.16	14747.4	14721.5	18785.8	7600.5

34	6401.12	10317.3	8149.07	12992.4	12984.3	16719.4	6544.03
35	5504.97	9017.34	7065.24	11446.3	11452.2	14880.2	5634.41
36	4734.27	7881.16	6125.57	10084.2	10100.8	13243.4	4851.23
37	4071.47	6888.13	5310.87	8884.2	8908.93	11786.6	4176.91
38	3501.47	6020.23	4604.52	7826.98	7857.68	10490.1	3596.32
39	3011.26	5261.68	3992.12	6895.57	6930.47	9336.19	3096.43
40	2589.68	4598.71	3461.17	6075	6112.68	8309.21	2666.03
41	2227.13	4019.27	3000.83	5352.07	5391.38	7395.2	2295.45
42	1915.33	3512.84	2601.72	4715.18	4755.2	6581.73	1976.38
43	1647.18	3070.22	2255.69	4154.07	4194.08	5857.74	1701.66
44	1416.58	2683.38	1955.69	3659.74	3699.18	5213.38	1465.13
45	1218.26	2345.27	1695.58	3224.23	3262.68	4639.91	1261.48
46	1047.7	2049.77	1470.07	2840.54	2877.68	4129.52	1086.13
47	901.023	1791.5	1274.55	2502.52	2538.12	3675.27	935.161
48	774.88	1565.77	1105.03	2204.72	2238.62	3270.99	805.174
49	666.397	1368.48	958.064	1942.36	1974.46	2911.19	693.255
50	573.101	1196.05	830.641	1711.22	1741.48	2590.95	596.892
51	492.867	1045.35	720.166	1507.58	1535.98	2305.95	513.924
52	423.866	913.635	624.384	1328.18	1354.74	2052.3	442.489
53	364.525	798.517	541.341	1170.13	1194.88	1826.54	380.983
54	313.491	697.904	469.343	1030.88	1053.88	1625.62	328.026
55	269.602	609.968	406.92	908.207	929.523	1446.8	282.431
56	231.858	533.112	352.8	800.13	819.839	1287.66	243.173
57	199.398	465.94	305.877	704.915	723.098	1146.01	209.372
58	171.482	407.232	265.196	621.03	637.773	1019.95	180.269
59	147.475	355.92	229.925	547.127	562.516	907.758	155.212
60	126.828	311.074	199.345	482.019	496.139	807.904	133.792
61	109.072	271.879	172.832	424.659	437.594	719.035	115.329
62	93.8021	237.622	149.845	374.124	385.958	639.941	99.4137
63	80.6698	207.682	129.916	329.604	340.415	569.547	85.6946
64	69.3761	181.514	112.637	290.381	300.246	506.897	73.8687
65	59.6634	158.643	97.6562	255.825	264.817	451.139	63.6748

66	51.3105	138.654	84.668	225.382	233.569	401.513	54.8877
67	44.1271	121.184	73.4071	198.562	206.008	357.347	47.3132
68	37.9493	105.915	63.644	174.933	181.699	318.039	40.784
69	32.6364	92.5693	55.1793	154.116	160.258	283.054	35.1558

Population with caries (6-69 years old, permanent dentition model)

Time (Year)	Base-case	STB	FV	STB+FV	Sealant	STB+sealant	OH exam
6	130873	119722	124517	116494	130873	130873	130873
7	182046	167221	174068	161542	172436	168941	182046
8	220011	203288	211276	196103	204164	198296	220011
9	247266	229947	238399	221975	227747	220382	247266
10	265887	248905	257328	240682	244615	236430	265887
11	277594	261592	269640	253511	255978	247485	277594
12	283812	269209	276648	261546	262856	254438	283812
13	285712	272760	279443	265702	266110	258042	285712
14	284260	273082	278929	266746	266459	258935	284260
15	280244	270870	275849	265319	264507	257655	280244
16	274309	266700	270816	261957	260757	254653	274196
17	266974	261046	264331	257104	255628	250307	266791
18	258663	254298	256800	251129	249466	244935	258441
19	249711	246776	248555	244336	242556	238798	249472
20	240387	238736	239859	236973	235132	232114	240148
21	230902	230388	230924	229242	227384	225062	230674
22	221418	221898	221915	221307	219465	217788	221209
23	212063	213396	212963	213299	211498	210411	211877
24	202930	204986	204167	205322	203580	203026	202769
25	194087	196747	195601	197457	195787	195709	193953
26	185584	188736	187320	189766	188177	188518	185475

27	177452	180996	179360	182296	180793	181500	177368
28	169711	173559	171748	175080	173666	174689	169650
29	162369	166442	164496	168143	166818	168110	162328
30	155426	159656	157612	161499	160261	161778	155404
31	148878	153205	151094	155157	154004	155706	148872
32	142714	147088	144937	149118	148047	149897	142723
33	136921	141299	139130	143380	142388	144355	136942
34	131484	135829	133663	137940	137021	139076	131515
35	126385	130668	128521	132789	131939	134056	126425
36	121606	125803	123689	127917	127132	129289	121652
37	117128	121221	119150	123313	122589	124766	117180
38	112934	116906	114888	118966	118298	120479	112990
39	109004	112845	110886	114864	114247	116417	109063
40	105321	109023	107128	110992	110423	112570	105382
41	101868	105425	103598	107339	106814	108927	101929
42	98627.1	102038	100280	103891	103406	105478	98689.2
43	95583.9	98846.3	97160.3	100637	100188	102212	95645.8
44	92723.4	95838.4	94224.2	97563.9	97148.5	99119	92784.5
45	90031.6	93001.2	91458.5	94660.3	94275.2	96188.2	90091.5
46	87495.5	90322.7	88850.5	91915.1	91557.5	93410.1	87554
47	85103.2	87791.9	86388.7	89317.6	88985	90775	85160
48	82843.3	85397.9	84062	86857.8	86547.9	88274.2	82898.1
49	80705.4	83131	81860.2	84526.2	84236.8	85898.8	80758.2
50	78679.9	80981.8	79773.8	82313.9	82043.1	83640.9	78730.6
51	76758	78941.7	77793.9	80212.5	79958.5	81492.6	76806.5
52	74931.4	77002.6	75912.4	78214.2	77975.4	79446.7	74977.8
53	73192.8	75157.2	74121.9	76311.7	76086.6	77496.4	73237
54	71535.2	73398.4	72415.3	74498.2	74285.5	75635.4	71577.2
55	69952.4	71719.9	70786.4	72767.3	72565.9	73857.6	69992.3
56	68438.5	70115.9	69229.2	71113.3	70922.1	72157.5	68476.4
57	66988.4	68580.9	67738.4	69530.7	69348.7	70529.9	67024.3
58	65597.2	67110	66309.2	68014.5	67840.9	68969.9	65631.2

59	64260.6	65698.4	64936.9	66560.2	66394.1	67473.1	64292.8
60	62974.5	64342.1	63617.6	65163.3	65004.2	66035.3	63004.8
61	61735.4	63037.2	62347.3	63820	63667.2	64652.7	61763.9
62	60539.9	61780.1	61122.7	62526.7	62379.7	63321.6	60566.8
63	59384.9	60567.5	59940.7	61280	61138.3	62038.8	59410.3
64	58267.8	59396.5	58798.3	60076.9	59940	60801.2	58291.8
65	57186	58264.4	57692.9	58914.6	58782.1	59606	57208.8
66	56137.3	57168.7	56622.2	57790.4	57662	58450.5	56158.9
67	55119.6	56107	55584	56702	56577.3	57332.4	55140
68	54131	55077.3	54576.2	55647.2	55526	56249.5	54150.4
69	53169.7	54077.6	53597.1	54623.9	54506	55199.6	53188.1

Population with restoration (6-69 years old, permanent dentition model)

Time (Year)	Base-case	STB	FV	STB+FV	Sealant	STB+sealant	OH exam
6	59685	59685	59685	59685	59685	59685	59685
7	62771.3	62325.2	62517	62196.1	62771.3	62771.3	62771.3
8	67793.3	66770.4	67229.1	66418.7	67408.9	67269.1	67793.3
9	74153.2	72498.1	73259.9	71871.8	73148.8	72779.3	74153.2
10	81374.3	79086.1	80158.5	78163.4	79625.3	78974.5	81374.3
11	89080.3	86195.2	87565.9	84976.8	86543.3	85588.6	89080.3
12	96977.2	93555.8	95199.1	92058.1	93666.9	92406.8	96977.2
13	104838	100956	102838	99205.8	100809	99257.7	104838
14	112493	108232	110313	106262	107824	106006	112493
15	119813	115259	117499	113107	114601	112547	119813
16	126710	121945	124303	119648	121056	118802	126710
17	133121	128223	130661	125819	127128	124711	133116
18	139007	134048	136530	131573	132776	130234	138996
19	144350	139395	141887	136882	137975	135343	144329

20	149141	144247	146722	141728	142710	140022	149113
21	153388	148604	151034	146104	146978	144266	153350
22	157102	152470	154834	150014	150782	148075	157057
23	160303	155857	158136	153466	154133	151456	160251
24	163015	158782	160962	156473	157044	154420	162957
25	165263	161265	163334	159053	159533	156982	165201
26	167077	163329	165278	161225	161622	159159	167012
27	168486	164999	166821	163012	163330	160970	168419
28	169518	166299	167990	164435	164682	162435	169450
29	170204	167254	168812	165519	165700	163575	170136
30	170572	167891	169315	166286	166408	164410	170504
31	170648	168233	169524	166760	166828	164963	170582
32	170460	168305	169465	166962	166982	165252	170396
33	170032	168129	169161	166917	166892	165299	169971
34	169388	167729	168637	166643	166580	165123	169330
35	168549	167124	167912	166161	166064	164741	168494
36	167537	166334	167008	165491	165363	164173	167486
37	166370	165378	165944	164650	164495	163434	166322
38	165065	164273	164736	163655	163477	162541	165022
39	163640	163036	163401	162522	162324	161509	163601
40	162110	161680	161954	161266	161050	160351	162074
41	160486	160221	160409	159900	159669	159081	160454
42	158784	158670	158778	158437	158194	157711	158755
43	157012	157039	157073	156889	156635	156253	156987
44	155183	155339	155305	155267	155004	154716	155162
45	153306	153581	153483	153580	153309	153111	153287
46	151388	151772	151616	151837	151561	151447	151373
47	149438	149921	149712	150048	149767	149731	149425
48	147462	148036	147777	148219	147935	147972	147452
49	145467	146122	145820	146357	146071	146176	145460
50	143459	144187	143845	144469	144182	144349	143454
51	141441	142236	141857	142561	142273	142499	141439

52	139420	140273	139862	140637	140350	140628	139419
53	137398	138303	137864	138703	138416	138744	137399
54	135379	136330	135866	136762	136477	136849	135382
55	133367	134358	133871	134818	134535	134947	133372
56	131364	132390	131883	132876	132594	133044	131370
57	129372	130429	129904	130937	130658	131140	129380
58	127395	128477	127937	129004	128728	129241	127403
59	125432	126536	125984	127081	126808	127347	125442
60	123487	124609	124046	125168	124898	125461	123498
61	121561	122696	122125	123269	123002	123586	121572
62	119654	120801	120223	121384	121121	121723	119666
63	117768	118923	118339	119515	119256	119874	117781
64	115904	117065	116477	117664	117408	118040	115917
65	114062	115226	114636	115831	115579	116222	114075
66	112243	113409	112816	114018	113769	114423	112257
67	110448	111613	111020	112224	111980	112642	110462
68	108676	109839	109247	110452	110212	110880	108691
69	106929	108088	107497	108702	108465	109138	106944

Population with endodontic (6-69 years old, permanent dentition model)

Time (Year)	Base-case	STB	FV	STB+FV	Sealant	STB+sealant	OH exam
6	6782	6782	6782	6782	6782	6782	6782
7	7133.93	7100.47	7114.86	7090.79	7133.93	7133.93	7133.93
8	7637.26	7559.53	7594.37	7532.87	7608.43	7597.95	7637.26
9	8251.47	8124.04	8182.64	8075.98	8175.27	8147.25	8251.47
10	8943.76	8765.14	8848.74	8693.45	8809.46	8759.51	8943.76
11	9687.75	9459.26	9567.63	9363.34	9490.45	9416.24	9687.75
12	10462.4	10187.3	10319.1	10067.7	10201.4	10102.2	10462.4

13	11251.1	10933.8	11087.2	10791.9	10928.8	10804.9	11251.1
14	12040.7	11686.5	11859	11524.3	11661.6	11514.2	12040.7
15	12821.2	12435.6	12624.6	12255.4	12391	12221.9	12821.2
16	13585	13173.6	13376.4	12977.8	13110.1	12921.6	13585
17	14326.5	13894.6	14108.6	13685.8	13813.7	13608	14326.1
18	15041.4	14594.4	14816.9	14375	14497.7	14277.3	15040.5
19	15727.2	15269.7	15498.4	15042.1	15159.2	14926.4	15725.6
20	16381.9	15918.5	16151.1	15684.9	15795.9	15553.2	16379.7
21	17004.8	16539.1	16773.8	16301.7	16406.5	16156.3	17001.8
22	17595.5	17131.1	17365.9	16891.6	16990.2	16734.5	17591.9
23	18154.2	17694	17927.5	17454.2	17546.7	17287.5	18149.9
24	18681.4	18228	18458.8	17989.4	18075.9	17815	18676.7
25	19178.1	18733.6	18960.5	18497.4	18578.2	18317.2	19172.9
26	19645.3	19211.4	19433.6	18978.8	19054	18794.4	19639.7
27	20084.2	19662.4	19878.9	19434.2	19504.3	19247.2	20078.3
28	20496.1	20087.4	20297.7	19864.5	19929.6	19676.2	20490
29	20882.2	20487.5	20691.2	20270.5	20331	20082.2	20876
30	21244	20863.9	21060.5	20653.3	20709.5	20466	21237.7
31	21582.8	21217.7	21407	21013.9	21066	20828.6	21576.5
32	21900	21550	21731.9	21353.3	21401.6	21170.7	21893.6
33	22196.7	21862	22036.3	21672.5	21717.4	21493.4	22190.4
34	22474.3	22154.7	22321.4	21972.6	22014.2	21797.5	22468.1
35	22733.9	22429.3	22588.5	22254.6	22293.2	22083.9	22727.9
36	22976.7	22686.7	22838.5	22519.5	22555.3	22353.6	22970.8
37	23203.6	22928	23072.6	22768.1	22801.3	22607.3	23197.9
38	23415.8	23154.1	23291.6	23001.4	23032.3	22846	23410.3
39	23614.1	23365.9	23496.5	23220.3	23249	23070.4	23608.8
40	23799.4	23564.2	23688.2	23425.6	23452.2	23281.2	23794.3
41	23972.6	23749.9	23867.4	23618	23642.8	23479.2	23967.7
42	24134.3	23923.7	24035	23798.3	23821.4	23665.1	24129.7
43	24285.4	24086.3	24191.7	23967.2	23988.7	23839.6	24281
44	24426.5	24238.3	24338	24125.3	24145.3	24003.2	24422.2

45	24558.1	24380.4	24474.6	24273.2	24291.9	24156.5	24554
46	24680.8	24513.1	24602.2	24411.6	24429	24300.1	24677
47	24795.2	24637	24721.1	24540.9	24557.1	24434.5	24791.6
48	24901.8	24752.5	24831.9	24661.6	24676.7	24560.3	24898.3
49	25000.9	24860.2	24935.1	24774.2	24788.2	24677.7	24997.6
50	25093	24960.4	25031.1	24879.1	24892.2	24787.4	25089.9
51	25178.5	25053.6	25120.2	24976.8	24989	24889.6	25175.6
52	25257.7	25140.1	25202.9	25067.6	25078.9	24984.7	25254.9
53	25330.9	25220.3	25279.4	25151.8	25162.4	25073.1	25328.3
54	25398.5	25294.4	25350.1	25229.8	25239.7	25155.2	25396.1
55	25460.7	25362.9	25415.3	25301.9	25311.1	25231.2	25458.4
56	25517.8	25425.9	25475.1	25368.4	25376.9	25301.3	25515.6
57	25570	25483.6	25530	25429.6	25437.4	25366	25568
58	25617.6	25536.5	25580	25485.6	25492.9	25425.4	25615.6
59	25660.7	25584.6	25625.4	25536.7	25543.4	25479.8	25658.8
60	25699.5	25628.2	25666.5	25583.2	25589.3	25529.3	25697.8
61	25734.2	25667.4	25703.3	25625.1	25630.8	25574.2	25732.6
62	25765	25702.5	25736.2	25662.9	25668	25614.7	25763.5
63	25792	25733.7	25765.1	25696.5	25701.2	25651	25790.6
64	25815.4	25761	25790.4	25726.1	25730.4	25683.2	25814.1
65	25835.3	25784.6	25812	25752	25755.8	25711.5	25834.1
66	25851.9	25804.7	25830.2	25774.2	25777.6	25736.1	25850.7
67	25865.2	25821.4	25845.1	25793	25795.9	25757	25864.1
68	25875.4	25834.8	25856.8	25808.3	25810.9	25774.5	25874.3
69	25882.5	25845	25865.4	25820.4	25822.6	25788.6	25881.5

Population with missing teeth (6-69 years old, permanent dentition model)

Time (Year)	Base-case	STB	FV	STB+FV	Sealant	STB+sealant	OH exam
6	44086	44086	44086	44086	44086	44086	44086
7	50629.6	50072.1	50311.9	49910.7	50629.6	50629.6	50629.6
8	59731.9	58433.2	59015.3	57987.8	59251.4	59076.7	59731.9
9	70732.5	68597.6	69579.1	67792.9	69459.6	68991.5	70732.5
10	83095.8	80094.9	81499	78891.7	80846.9	80010.6	83095.8
11	96390.1	92540.2	94365.4	90925.8	93077.7	91832.1	96390.1
12	110270	105620	107847	103601	105877	104206	110270
13	124460	119080	121680	116679	119019	116928	124460
14	138746	132718	135652	129964	132325	129830	138746
15	152959	146372	149598	143301	145648	142777	152959
16	166971	159916	163391	156567	158873	155660	166971
17	180687	173251	176932	169665	171911	168393	180681
18	194035	186303	190148	182520	184692	180908	194021
19	206969	199018	202988	195076	197166	193155	206943
20	219454	211357	215416	207293	209293	205094	219416
21	231473	223294	227409	219142	221050	216700	231424
22	243019	234813	238955	230604	232419	227953	242957
23	254089	245908	250051	241669	243393	238843	254018
24	264693	256578	260699	252334	253967	249363	264612
25	274839	266827	270907	262600	264146	259515	274750
26	284543	276664	280687	272473	273936	269300	284448
27	293823	286101	290053	281961	283345	278726	293721
28	302695	295151	299021	291076	292384	287801	302590
29	311181	303829	307609	299830	301068	296535	311072
30	319299	312151	315834	308237	309408	304941	319189
31	327071	320134	323714	316312	317422	313030	326959
32	334514	327794	331269	324070	325122	320815	334403

33	341650	335148	338516	331526	332524	328310	341539
34	348496	342213	345472	338695	339643	335528	348386
35	355070	349005	352155	345592	346495	342481	354962
36	361390	355538	358582	352232	353091	349184	361283
37	367470	361828	364766	358627	359448	355649	367365
38	373326	367889	370723	364793	365578	361887	373225
39	378973	373735	376468	370741	371493	367911	378874
40	384423	379377	382012	376485	377205	373732	384327
41	389689	384828	387369	382034	382726	379360	389596
42	394783	390099	392548	387401	388067	384807	394693
43	399714	395201	397562	392596	393237	390081	399627
44	404493	400144	402420	397628	398246	395191	404409
45	409129	404935	407132	402506	403104	400147	409049
46	413631	409585	411705	407239	407818	404956	413553
47	418006	414102	416147	411835	412396	409627	417931
48	422261	418491	420467	416300	416845	414166	422189
49	426403	422761	424670	420643	421172	418579	426334
50	430438	426918	428763	424870	425384	422874	430372
51	434372	430967	432751	428985	429486	427056	434308
52	438210	434914	436641	432996	433484	431131	438149
53	441957	438764	440437	436907	437383	435103	441898
54	445616	442522	444143	440722	441187	438978	445559
55	449193	446192	447764	444447	444901	442760	449138
56	452691	449778	451303	448085	448530	446453	452638
57	456113	453284	454764	451641	452076	450061	456062
58	459462	456713	458151	455118	455543	453587	459413
59	462742	460068	461467	458518	458935	457036	462694
60	465955	463353	464714	461846	462255	460409	465909
61	469104	466570	467894	465105	465505	463711	469059
62	472191	469722	471012	468296	468689	466944	472148
63	475218	472811	474068	471422	471808	470110	475176
64	478187	475839	477065	474486	474864	473212	478146

65	481100	478809	480005	477490	477861	476252	481061
66	483960	481722	482889	480436	480801	479232	483921
67	486766	484581	485721	483325	483684	482155	486729
68	489522	487386	488500	486160	486513	485021	489486
69	492229	490140	491229	488942	489289	487834	492194

Experts in GMB sessions

ครั้งที่ 1 วันที่ 25 มกราคม 2565 GMB 1 25 Jan 22

1. รองศาสตราจารย์ ดร.ทพญ.สุกัญญา เธียรวิวัฒน์ Aj Sukanya
2. รองศาสตราจารย์ ดร.ทพ.ทรงชัย ฐิตโสมกุล Aj Songchai
3. ผู้ช่วยศาสตราจารย์ ดร.พงศ์พัฒน์ สนทะมิโน Aj Pongpat
4. ทพญ.จิราพร ขีดดี Dr. Jiraporn Keeddee MOPH school children
5. ทพญ.ภัทราภรณ์ หัสดิเสวี Dr. Pattaraporn Hassadisewee MOPH school children
6. ทพญ.กษมลรัตน์ ดิษฐาน Dr. Kasamonrat Disatarn Community Hospital, WCC and school children
7. ทพญ.พิชญาดา สายสินธุ์ชัย Dr. Pitchayada Saisinchai Provincial Health Authority, School children
8. ทพญ.สุภัค วงษ์วรสันต์ Dr. Suphak Wongworasun Sirindhorn College of Public Health, Chonburi Children all age gr and elderly
9. ทพญ.ชลธิชา เปี่ยมศิริ Dr. Cholticha Piamsiri Faculty of Dentistry, Naresuan University, Phitsanulok

ครั้งที่ 2 วันที่ 11 กรกฎาคม 2565 GMB 2

1. รองศาสตราจารย์ ดร.ทพญ.สุกัญญา เธียรวิวัฒน์ Aj Sukanya
2. รองศาสตราจารย์ ดร.ทพ.ทรงชัย ฐิตโสมกุล Aj Songchai
3. ผู้ช่วยศาสตราจารย์ ดร.พงศ์พัฒน์ สนทะมิโน Aj Pongpat
4. ทพญ.วรมน อัครสุต Dr Voramon Agrasuta MOPH, DPH specialists
5. อ.ดร.ทพญ.นิภาพร เอื้อวัณณะโชติมา Dr. Nipaporn Urwannachotima Chulalongkorn University, DPH specialists
6. ทพญ.ชนิฎาภรณ์ สอนสังข์ Dr. Chanidaporn Sornsung, Provincial Health Authority, All age gr
7. ทพญ.สุณี วงศ์คงคาเทพ Dr Sunee Wongkongkhatep, MOPH Experts, all age gr, Health system
8. ทพญ.จันทนา อึ้งชูศักดิ์ Dr Chantana EngChooosak, MOPH Experts, all age gr, Health promotion

ครั้งที่ 3 วันที่ 12 กันยายน 2565

1. รองศาสตราจารย์ ดร.ทพญ.สุกัญญา เธียรวิวัฒน์ Aj Sukanya DPH Experts
2. รองศาสตราจารย์ ดร.ทพ.ทรงชัย ฐิตโสมกุล Aj Songchai DPH experts
3. ผู้ช่วยศาสตราจารย์ ดร.พงศ์พัฒน์ สนทะมิโน Aj Pongpat SDM specialists
4. ผู้ช่วยศาสตราจารย์ ดรกุลจิรา อุดมอักษร Aj Kuljira Udomaksorn, SDM specialists

VITAE

Name Miss Tin Htet Oo

Student ID 6210830008

Educational Attainment

Degree	Name of Institution	Year of Graduation
Bachelor of Dental Surgery	University of Dental Medicine, Yangon	2015

Scholarship Awards during Enrolment

Prince of Songkla University, Thailand, The 2019 PSU-Faculty of Dentistry International Student Graduate Scholarships (PSU-Dent ISG Scholarships).

List of Publication and Proceeding

1. Journal Paper

Oo TH, Tianviwat S, Thitasomakul S. Oral health system in Myanmar: A review. Journal of International Society of Preventive & Community Dentistry. 2021 May;11(3):231.