AN INVESTIGATION INTO CHILD CARIES AND CREATION OF PREVENTATIVE CURRICULUM TO DECREASE DENTAL DECAY RATES IN CHILDREN

by

RISA BYERLY

A THESIS

Presented to the Department of Human Physiology
and the Robert D. Clark Honors College
in partial fulfillment of the requirements for the degree of
Bachelor of Science

May 2021

An Abstract of the Thesis of

Risa Byerly for the degree of Bachelor of Science
in the Department of Human Physiology to be taken June 2021

Title: An Investigation into Child Caries and Creation of Preventative Curriculum to Decrease Dental Decay Rates in Children

Approved: ___*Austin Hocker, Ph.D.*_____
Primary Thesis Advisor

Dental decay is the most common chronic pediatric disease. Despite the ability to prevent and even reverse decay, it remains four times more common than asthma. While dental decay is worrisome on its own, it is also associated with high rates of school absenteeism, lower quality of life, and other costly diseases such as Alzheimer's and diabetes. Additionally, dental decay disproportionately affects low income and minority children. In order to address this epidemic past interventions have utilized school-based models to decrease disparities in access to care. While many programs have been successful by providing services such as fluoride varnish and dental screenings, few have focused on education as a driver for preventative care. Therefore, this paper proposes a new model for a school-based dental intervention with the goals of increasing oral health care knowledge, decreasing the incidence of dental decay, and helping connect students to permanent dental providers. The intervention draws from the successes and shortcomings of past interventions as well as educational strategy research. Hopefully, upon the implementation of this intervention in schools, children will gain a deeper understanding of how and why to prevent dental decay and the overall incidence will decrease.

Acknowledgements

I would like to thank my primary advisor, Dr. Austin Hocker, for helping me throughout the entire process of writing my thesis. I am so glad that despite the pandemic and never being able to meet in person he was willing to help me embark on this project and make my idea for a school-based dental intervention a reality. Without our check-ins and the endless amount of helpful feedback my thesis would not be what it is today. I would also like to thank Dr. Lisa Bozzetti, my second reader, for her helpful advice, her insights, and her enthusiasm for joining my thesis committee. Finally, I would like to thank Dr. David Frank for his willingness to serve as my CHC representative.

Further gratitude is due to my friends that have helped me stay motivated not only throughout the process of writing my thesis but through the entirety of college. I truly would not have survived the late nights studying or the many exams, lab reports, and essays without them. Although our senior year has been nothing like we expected, I am glad I still got to spend it with such a wonderful group of people.

Lastly, I would like to thank my family for always supporting and believing in me. I would not be where I am today without them, and I am extremely grateful from the bottom of my heart for everything they have given me.

Table of Contents

List of Tables

Introduction

Despite their preventability, dental caries or cavities (tooth decay) remain the most common chronic disease among children and adolescents aged 6 to 19 years old. Among adolescents aged 14 to 17, it is four times more common than asthma. Additionally, 9 out of 10 adults have some degree of tooth decay (Dye et al. 2007). With such a high prevalence of dental decay in the United States, it is imperative that effective, accessible public health measures are created to combat this problem. I have been interested in dentistry my whole life, but I always knew I wanted to do more than just go to dental school and become a dentist. Therefore, the final product for my thesis will be a new model for an accessible, education based dental intervention. I hope that my contributions will eventually lead to concrete change in how this public health crisis is handled and help communities decrease the incidence of dental decay for happier, healthier kids.

Tooth decay is a broad term encompassing varying levels of oral health issues. Tooth decay begins when acid (produced as a byproduct of bacteria metabolizing sugar) breaks down tooth enamel. In the very early stages, tooth decay may not be visible and certainly does not include a cavity. Often, the first visible stage of decay is a white spot on the tooth. Later on, if tooth decay continues, a cavity will form and must be filled by a dentist. Tooth decay is reversible to a point; however, once a cavity has formed decay is not reversible. Thus, my intervention will aim to educate kids on how best to prevent decay so that it does not progress to the point of forming a cavity. Because dental decay is the most prevalent oral health issue currently, my intervention will focus on this specific aspect of oral health.

School-based dental interventions have existed in some form for many years. For example, as a child my school had a fluoride program where kids could receive a fluoride tablet each day free of charge. While fluoride is certainly an important aspect in maintaining healthy teeth and gums, there is much more to consider in the big picture. Elements that affect dental health other than fluoride consumption include frequency of sugar consumption, abundance of mutans streptococci bacteria, frequency of tooth brushing and flossing, and frequency of oral examinations by a dentist, among others (Threlfall et al. 2007). Thus, the school-based intervention I create will be multifaceted. I will include educational elements along with more concrete steps like fluoride availability and dental screening. Additionally, I will create a tiered structure to my intervention. The multiple levels will address larger community needs, as well as individual needs. I also recognize that this program is not likely to be successful without the help (or at least consent for kids' participation) of parents and guardians. Thus, a part of my intervention will include and educate adults prior to their children participating in the intervention.

In order to create my intervention, I will research past dental interventions that have aimed to reduce the incidence of dental decay in kids. I will then compile my findings in order to decide what elements were successful or not. Additionally, I will complete research on the physiological factors affecting the formation of dental decay and specific educational tools that can be utilized when creating an educational intervention. Finally, I will create a new school-based intervention utilizing my research and findings. My final product will be a school-based intervention informed by physiological information, educational strategy research, and results from past school-

based interventions. I hope that this intervention, if implemented, will cause concrete, beneficial changes for the students' oral health practices and inform students about the lifelong importance of maintaining good oral health. My intervention will also overcome the issue of disparities in access to dental services by requiring no payment and no transportation to a dental clinic. Although the issue of dental decay in children is widespread and multifaceted, I believe an intervention such as this one will have promising outcomes and health benefits for children.

Physiological Information

This section will include an overview about healthy teeth and gums as well as how caries form from a physiological perspective. In the final educational intervention, this information will help students understand why it is important to take care of their oral health by informing them of the physiological processes that occur in decayed or cavitated teeth. Additionally, it will help them recognize decay based on visible markers for the different stages that will be explained. While many people know at a surface level what a cavity is, in depth information is not common knowledge. Covering this topic in my intervention will help students gain a deeper understanding of common terms such as “cavity” and “decay” and hopefully encourage them to better maintain their oral health.

In a healthy child, primary teeth form between 14 weeks in utero and 3 years of age. After birth, the primary teeth begin to erupt around 6 months. Once all primary teeth are present, they fall out so that the permanent teeth can emerge. The period in which some primary and some permanent teeth are present in the mouth is referred to as the mixed dentition period. Usually by age 13 children have a full set of permanent teeth (Nelson 2014). The visible portion of each tooth is referred to as the crown, and the portion of the tooth below the gums, or the gingiva, is called the root. There are three main layers that make up each tooth. The enamel is the visible, outermost layer. The next layer of a tooth is dentin, and finally pulp. Enamel is a hard, calcified tissue that contains no living cells. It is the hardest biological substance in the human body. Dentin, the bony substance beneath enamel, contains microscopic tubules which can cause sensitivity via the nerves if foods come into contact with them. Finally, pulp is the

soft inner layer that contains blood vessels, nerves, and connective tissue. Below the gums, a hard outer layer called cementum protects the tooth root and connects to the periodontal ligament which keeps the tooth in place (Sieroslawska 2020).

Aside from teeth and gums, the oral cavity contains varying levels of plaque on the teeth. Plaque is defined as the diverse microbial community found on the tooth surface, embedded in a matrix of polymers of bacterial and salivary origin (Marsh and Martin 1992). Bacteria residing in the plaque can cause serious damage to the enamel even before it is visible. Plaque forms first via interaction between colonizer bacteria and the acquired enamel pellicle, which is a protective protein film on the surface of teeth. Then, secondary bacteria attach to the colonizer bacteria via protein-protein interactions or carbohydrate-protein interactions. In this way, layers of bacteria build up and form what is commonly known as plaque (Marsh and Bradshaw 1995). If managed with proper oral care, plaque can be harmless. However, some bacteria in plaque known as cariogenic bacteria can cause cavities if circumstances allow. In particular, mutans streptococci and lactobacilli have a strong, positive correlation with dental caries on enamel surfaces (Marsh and Bradshaw 1995).

When carbohydrates such as sugars remain on a tooth, the bacteria within plaque metabolize it. As a byproduct of this metabolism the bacteria produce acid that can potentially break down and demineralize enamel on the tooth's crown or root (Selwitz et al. 2007). Usually, saliva in the mouth and oral care practices counterbalance the harmful accumulation of acid. Additionally, saliva has a beneficial antimicrobial purpose (Marsh and Bradshaw 1995). However, when acid is consistently produced due to excessive sugar consumption or improper cleaning the acid can build up and cause a

local drop in pH values. This pH drop prompts demineralization by the diffusion of calcium, phosphate, and carbonate out of the tooth. If this is allowed to continue, a cavity will form (Selwitz et al. 2007). The aforementioned cariogenic bacteria such as mutans streptococci and lactobacilli metabolize sugars quickly and thrive in the acidic environment created (Marsh and Bradshaw 1995), thus increasing the risk of cavitation.

Cavities can be referred to using the terms dental decay and dental caries. In general, a cavity is defined as permanent damage to the hard surface of the tooth that develops into tiny openings or holes (Cavities/Tooth Decay - Symptoms and Causes). The first visible sign of cavitation appears as a white spot on the tooth and marks an area of demineralization beneath dental plaque. This type of lesion can be reversed if cleansed properly, but if allowed to continue will cause cavitation (Selwitz et al. 2007). Thus, a focus on early intervention is imperative to reversing any decay that has formed previously. After white spots form, the next stage of decay is characterized by dark spots. Dark spots indicate complete erosion of the enamel and need to be treated with a filling (Tooth Enamel - an Overview). After enamel is degraded, the next layer to decay is dentin. Because dentin is connected to the nerve of the tooth, a cavity is likely to become painful once this layer has degraded. Dentin degradation can still be treated with a filling in a dental clinic. If left untreated, the pulp will become infected next. The pulp is the most central part of the tooth that contains blood vessels and the tooth's central nerve. To treat this level of infection, a root canal or tooth extraction is necessary. Finally, the last stage of decay is called abscess. This refers to the infection once it has moved to the surrounding tissues including bone and gums. Similar to pulp

infection, a root canal or tooth extraction is required. However, if this stage of decay is left untreated it can be fatal (Townsend 2017).

Cavities are formed over time and because of their slow progress have great potential to be reversible. A cavity's damage can be removed or reversed even once lesions have formed on the tooth, as long as enough decayed tissue can be removed (Selwitz et al. 2007). Additionally, if filling a cavity is not yet required, uptake of calcium, phosphate, and fluoride can reverse this damage. Fluoride catalyzes the diffusion of calcium and phosphate into the tooth; this remineralization can reverse the damage done by demineralization and often results in even stronger tooth structures (Selwitz et al. 2007). Normally, demineralization and remineralization occur frequently to maintain tooth homeostasis. It is when this balance is disrupted that a cavity can form.

The information outlined in this section will inform the creation of my final dental intervention. As part of the educational component students will learn the anatomy of a tooth and how demineralization and remineralization balance each other out to keep healthy teeth from decaying. They will then learn the stages of cavity formation and how cavities progress layer by layer. I have chosen to include information about healthy teeth as well as unhealthy teeth because I believe it is essential for students to understand both. While the cavity formation process is pertinent to understanding dental decay, it is equally important for students to recognize when they are doing a good job of taking care of their teeth.

Analysis of Past Interventions

The idea of school-based dental interventions is not new, in fact many interventions have taken place within the United States and across the world. For this thesis, it is critical to analyze these interventions and seek to replicate their successes and amend their shortcomings. These programs vary greatly in the style of approach, services offered, size, and duration. Therefore, the goal for this section of the thesis is to understand how and why past interventions were implemented and utilize their findings to create a new, improved dental intervention model.

Within the Los Angeles Unified School District (LAUSD), one dental intervention utilized a pyramid model and took a tiered approach with community wide oral health education as the base, universal prevention on school campuses as the middle tier, and access to restorative care as the top tier. The program was developed using input from parents, oral health providers, and school personnel. Allowing parents to provide insight into the intervention strategy resulted in increased likelihood of signing participation consent forms. To encourage parents and guardians to sign the consent forms for my intervention, they will have the option to meet with intervention staff to ask questions and learn about the program in person prior to their kids' participation. They may also customize their child's involvement to the level they are comfortable with by opting out of individual intervention components as they see fit.

On the day of the LAUSD event, student education kits were provided and dental screenings were performed. Each child received an oral health report as well as a list of low-cost dental providers who accept publicly and uninsured patients. Students needing immediate dental care for issues such as severe pain or decay were helped by

the district's Oral Health Nurse to ensure they received follow-up care. The program was free of cost to all students. Analysis of the program revealed that of the 62% of participants who had untreated caries initially, 44% had improved exams at follow up. However, because active consent was required for participation, researchers speculate that the results may be positively skewed. Understanding how to improve the screening process and overcoming barriers to accessing a dental home are critical issues that still need to be resolved in regard to this intervention (Dudovitz et al. 2017).

A possible improvement on the pyramid model tested by the LAUSD intervention is the application of an ecological model. Ecological models posit that factors at multiple levels influence disparities in access and quality of services and aim to address issues through multi-level solutions (Gargano et al. 2019). At the center of the ecological model are the desired outcomes for the program. In this case healthcare access, health and well-being, and skills-based health education are the goals of the ecological model. The multiple levels of the ecological model aim to address these main concerns. First, individual and interpersonal factors are considered in the creation of ecological interventions. These include areas such as family and school influences on eating and oral care and stressors such as poverty. Next, community-level determinants of health are considered. For example, social and physical environmental factors that may affect aspects of oral health include social stigma surrounding poor oral health and dental and health care services provided in school. Lastly, societal influences are accounted for and considered in the provisions for an ecological model. These include oral health disparities as well as lack of integrated health care and public health systems (Gargano et al. 2019). Consideration of these factors in the creation of a dental

intervention allows many more children to benefit from the intervention, as their individual oral health may be suffering due to one or many of these factors. Also, this model decreases the risks of making a child's situation worse by ignoring or invalidating their individual struggles. By addressing many levels of influence in a child's life the oral health intervention is able to address the root of the issue and work toward concrete changes in society as a whole. Thus, for my final intervention I will determine a way to address interpersonal, environmental, and societal factors in order to help create more positive changes.

The importance of multi-level interventions can be deduced from a review and meta-analysis done by Joury et al. These researchers found that at the time of the review there was no evidence to support or refute the clinical benefits or harms of dental screening (Joury et al. 2017). Thus, the success of the ecological model is likely due to the multi-level approach. A different study in Massachusetts determined that although dental screening at school provides accurate results into their students' dental needs and oral health, full service school-based programs should be pursued in order to address these needs (Culler et al. 2017). Based on these analyses from past interventions it can be concluded that the strongest results come from interventions that address multiple levels of influence on oral health, include parent and teacher input, and involve concrete oral health care steps beyond initial screenings. Therefore, in my final intervention I will include these elements in order to obtain the best results from my intervention.

Another type of intervention that has been examined involves community-based models in which members of the community help initiate and organize a dental intervention. One such example is the Preventative Services Program (PSP) in Missouri,

which is a community-based oral health program that engages volunteers as well as dentists or hygienists to provide preventive services and education for underserved children. The program includes guidelines for how to implement the intervention, but it is the responsibility of a school nurse, parent, head start coordinator, or other adult to take on the role of event coordinator and plan the PSP in their area (Information About PSP). The program itself calls for four components: evaluation of the state of oral health/disease in the community's children through annual oral screenings, the provision of toothbrushes, toothpaste, floss (age appropriate) and educational materials/presentations, the application of fluoride varnish 2 times per year, and establishment of a referral network for immediate/urgent needs identified during the oral screenings. In 2006, 273 volunteer dentists and dental hygienists and 415 community volunteers provided oral screenings, oral health education, fluoride varnish applications, and referral for unmet dental care for 8,529 children. In 2011, nearly 65,000 children were provided these services (Hoffman et al. 2014). Programs such as this one show that it is possible for local citizens to meet their own needs and care for their communities. In the conclusion of this article, the authors suggest that a national review of successful community models be published in order to help other areas looking to implement similar programs. Perhaps one of the most successful but also potentially harmful elements of the PSP is that it can be initiated by an individual community member for the benefit of their own community. This can be beneficial because it holds the coordinator of the PSP accountable since they know their work will benefit those around them directly. On the other hand, if a community does not have anyone willing to coordinate the program (due to lack of knowledge, transportation, or

time constraints) they may not benefit from the PSP equally. Thus, my intervention will take place in schools in order to provide access to care for all children. Additionally, to engage community members such as parents and guardians there will be an information session as an opportunity to ask questions about the school-based program as well as to encourage parents to promote healthy oral habits at home.

Another intervention is called the I-Smile Dental Home Initiative. Although, as its name suggests, the primary program outcome is finding kids permanent dental homes, the I-Smile Dental Home Initiative also provides screenings, applies fluoride, and participates in community events to promote the importance of oral health. The initiative is geared towards both pregnant women and children, and specifically responds to a Medicaid mandate that children 12 years and younger have a dental home and receive dental screenings and preventive care by 2008 (Bailit and D'Adamo 2012). The initiative is run through I-Smile coordinators who work for county health departments or private, non-profit organizations to administer I-Smile in Iowa's 99 counties. In all there are 23 coordinators and their jobs are to work with children and families, dentists and dental office staff, medical providers, school nurses, teachers and administrators, businesses, civic organizations, and social service organizations to implement the I-Smile programs. Among other things, they help schedule appointments, find transportation, provide interpreters, and identify payment sources for dental care. In other words, the coordinators serve as liaisons to help children access dental care despite any barriers that may exist (I-Smile Dental Home Initiative). In terms of successes, there was a 36% increase in children receiving services from 2005 to 2009 meaning that over 10,000 more children received care. The percentage of children

below age one receiving dental examinations increased 61% (80 more children), and the number screened by hygienists increased from 974 to 3,012. Overall, the number of Medicaid enrolled children with untreated decay decreased from 28.0% to 20.6% between 2005-2009 (Bailit and D'Adamo 2012). While the reason is not known for sure, it is likely that the decrease is due in part to I-Smile. Based on these results, it seems that finding a dental home is made easier with the help of a coordinator who is familiar with their area's available practices and policies. Additionally, by targeting pregnant women the I-Smile program is able to preemptively address the issue of finding a dental home for children.

An emerging concept, in contrast to finding a physical dental home, is the idea of a virtual dental home. This concept was introduced by Paul Glassman in California during a four-year demonstration program. The goal of the virtual dental home is to provide basic care to low income and disabled patients without the need to make a visit to the dental office. In this model, dental hygienists provide screening, preventative services, temporary restorations, and case management services in Head Start Centers, schools, residential facilities for people with disabilities, and long-term care facilities for dependent adults. Meanwhile, dentists are linked electronically via portable video cameras to the hygienists and patients, and they can review materials, make diagnoses, and develop treatment plans virtually. In some cases, dentists will come to the remote site to provide services. This model greatly reduces the need for patients to travel to dental offices unnecessarily and frees up time in dentists' schedules so they can treat severe cases in a more timely manner (Bailit and D'Adamo 2012). While this model has great potential to reduce disparities in access to dental care, the advisory committee for

the virtual dental home demonstration project determined that "alterations are needed in the educational environment that trains providers, state systems that regulate scopes of practice and the delivery of services, and financing mechanisms" in order to sustain the program and optimize oral health for underserved people (Glassman et al. 2012). Since then, the project has continued to develop and in 2019 a virtual dental home pilot project was begun in Maui, Hawaii. Additionally, while this concept was not created with the intention of increasing patient access to care during a global pandemic, this model allows high risk patients to be seen in a more accessible, safe manner than traveling to and being seen in a dental office. Thus, a success of this model is that it eliminates the barrier to care due to lack of transportation; in this model, the care team travels to the patients instead. This benefit is one of the main reasons for holding my intervention within a school during normal class hours. Additionally, this model suggests the potential for including a virtual dentist overseeing the screening and fluoride varnishing in my intervention.

Importantly, the high incidence of childhood caries and overall dental decay is not exclusive to the United States. One study in Indonesia surveyed 1,906 12-year-old children and through their responses found a significant correlation between school-based dental programs and oral health related quality of life. Specifically, children who scored poorly on the school-based dental programs were significantly associated with a lower quality of life (Amalia et al. 2015). Thus, aside from dental decay causing loss of school time and being linked with other serious diseases, it is also important to address decay in children in order to improve their day-to-day life. Additionally, this study suggests the potential for well designed and executed school-based interventions to

make a significant impact on oral health and overall daily life. Other studies examine the issue in terms of access to care at the state level. Variables such as state population demographics, the number of dentists and hygienists per state population, availability of community clinics, fluoridated water, and sealant programs all affect children's oral health or access to care (Bailit and D'Adamo 2012). Yet, whatever the reasons behind barriers to access are, it is clear that successes can be achieved through interventions.

Importantly, the most successful intervention models include multiple levels of care. Many offer concrete services such as screenings and fluoride varnishing in addition to care coordination for greater needs. The model tested by the LAUSD reveals the importance of teachers, administrators, and caregivers being able to provide input into the program as a way to boost enrollment. The PSP also exemplifies the benefits of community participation and accountability. Next, the I-Smile program reveals the potential for finding a dental home and providing key services to pregnant women and children via area-specific coordinators. Employing many coordinators familiar with smaller areas in the state allows more accurate, customizable care and reveals the importance of area-specific dental home recommendations. Lastly, the virtual dental home model presents yet another way to decrease barriers to access for children and other groups. In this model the roles are reversed and the hygienists travel to their patients before requiring a trip to see the dentist in person. This eliminates the need for all patients to visit the dental office and frees up time in the dentist's schedule to care for the most time sensitive cases. In creating my intervention, I will utilize these findings to create a new, improved intervention and hopefully cause even greater decreases in rates of dental decay among children.

My Research, Findings, and Product

My intervention aims to combine all of the most successful aspects of the past interventions addressed in the previous analysis. In order to have the largest impact, I will utilize an ecological model to address oral health from many levels including education about dental caries and prevention, access to oral exams and cleanings in school, and connections to dental homes for future dental needs. The core of my proposed intervention includes an in-depth educational program to inform students about correct brushing, flossing, and fluoride practices, healthy versus unhealthy dental anatomy, and other related topics. Additionally, a mobile clinic will be set up in schools to offer immediate care including dental exams and fluoride varnishes. Hopefully the execution of this model in schools across the country will result in a decrease in the occurrence of decay in children participating. In the following paragraphs, I will outline specific details of the program as well as my reasoning for choosing each element.

In order to maximize oral health benefits and minimize the amount of time taken from the school day, my intervention will occur twice throughout the school year: once in the Fall and a follow up in the Spring. On each day of the program, the entire intervention should take approximately 2-4 hours to complete depending on the number of participants. Additionally, it should be scheduled into regular school hours to prevent any child from missing the opportunity due to lack of transportation or other obligations. Participating students will spend half of the program time in the oral health educational lesson and the other half in the mobile clinic receiving exams, cleanings, fluoride varnishes, and directions for follow up care. This way, group sizes will be smaller for each activity and the overall program time will be halved. If multiple

classrooms within the school are participating in the intervention, the intervention staff will go classroom by classroom in order to keep group sizes as small as possible.

The clinic will ideally be set up in a large room such as the school's cafeteria. In it, many dental exam stations will be constructed in order to assess multiple children at once. While children are waiting for their exams, program staff will hand out toothbrushes, floss, and fluoride toothpaste for them to take home. When an exam station is free children will switch out with their peers until everyone has been seen. The initial dental exams will include a thorough screening for any signs of decay, a cleaning, a fluoride varnish application, and, if necessary, connection with a dentist to address further oral care needs. Similar to the Virtual Dental Home model by Dr. Glassman, the hygienists screening children at school will be able to consult with a dentist virtually.

Meanwhile, the other half of the classroom will participate in an educational lesson with an emphasis on active learning in small groups. The dental education lesson begins with the class separating into three smaller groups. Ideally, these groups will be around five kids but depending on the size of the classroom may be larger. Small group learning can be beneficial at any age; however, its efficacy is often underestimated in young children. According to Barbara Wasik, "fewer should be considered as more" when deciding on group sizes (Wasik 2008). Additionally, Wasik asserts that small group learning allows teachers to devote more attention to individual students, which has important cognitive, social, and emotional implications for children (Wasik 2008). Small groups will help achieve the goal for this oral health curriculum to be as inclusive, adaptable, and relatable as possible for each child.

Each group of kids will rotate through three stations set up in the classroom. The goal of each station is to teach about critical aspects of oral health, to promote healthy behaviors, and to include active learning elements to engage the children. Active learning is a teaching strategy that aims to engage students in many forms of participation throughout a lesson, rather than traditional lecture style lessons in which students merely observe and do not engage. Active learning can take many forms, but some common techniques used by teachers include letting students share ideas in small groups, having them write the answer to questions asked during a lecture, or helping them fill in worksheets as the lecture progresses. In a study done by Freeman et al., 225 studies regarding active learning versus traditional lecturing were meta analyzed. The results showed that classrooms that incorporated active learning had an increase in exam performance of just under half a standard deviation, and that lecturing increased failure rates by 55% (Freeman et al. 2014). Thus, student success was significantly increased when active learning was incorporated into lessons. While this study utilized data from undergraduate courses, the results can be applied to classrooms of all ages.

Station one will address how to brush, floss, and use fluoride correctly. These skills will help the students complete the objectives outlined in Table 1, which utilizes the backwards design framework. In the tooth brushing activity, students will learn how to properly brush their teeth using the Circular brushing method, with demonstrations on a jaw model. They can also practice on the model themselves using a real toothbrush. This technique was used successfully in an intervention that resulted in improved knowledge and self-reported oral health behavior of participants (Halawany et al. 2018). Breaking down how to brush teeth correctly will include holding the bristles

at a 45 degree angle to the tooth surface, using a circular motion, brushing in the correct sequence, and brushing each surface for at least five seconds. One study done by Poche et al. utilized these criteria for brushing and found that the children in the study completed 95.8% of the steps correctly after the training, and on a follow up visit still maintained 86.6% of the correct skills (Poche et al. 1986). This intervention was done in preschool children with still-developing motor skills, suggesting that early elementary children will be even more likely to succeed in learning proper brushing technique.

Goal	Objective	Program Day One	Program Day Two
By the end of the course, students will be able to: 1.Understand how and why to practice good oral health habits 2. Make concrete changes in their lives to reduce the incidence of caries	Students will be able to: 1. Brush teeth correctly 2. Floss correctly 3. Use fluoride correctly 4. Recognize foods that are good and bad for their teeth 5. Describe how a cavity forms and how it can be repaired using fluoride 6. Describe why it is important to have good oral health and the consequence of poor oral health 7. Access professional dental care if necessary	Split the classroom into three "stations," each one will teach a portion of the material in small groups and kids can rotate through them. Group one will address how to brush, floss, and use fluoride correctly. In the tooth brushing station, kids will learn how to properly brush their teeth using a jaw model and toothbrush and can practice themselves. Group two will learn the basic physiology behind cavities and how they form. Group two will utilize many anatomical posters to visualize what happens in the mouth when a cavity forms and fill in a coloring worksheet. Group three will learn how different foods affect cavity formation and the importance of maintaining good oral health. Group three will write down common foods they like to eat, and	Split the classroom into three "stations," each station will focus on the same concepts as day one but emphasize recalling the information. Optional materials for use outside of the intervention: - Calendar to track/ mark when participants brush and floss - Small rewards for meeting certain goals (i.e., pencil

		these will be incorporated into the lesson. The main takeaway for this activity will be that decreasing frequency of consumption of sugar can help decrease cavity formation and keep their teeth healthy.	with teeth on it, xylitol gum)

Table 1: Backwards Design Lesson Plan

This table outlines the intervention activities utilizing the backwards design educational framework.

Flossing is equally as important as brushing and some sources even recommend flossing over brushing if there is only an option for one. However, when combined, these two oral health activities have a significantly greater effect than when used alone. A study done by Terézhalmy et al. tested the plaque removal outcome of five groups, one that only brushed manually and four that brushed manually in combination with a certain floss type. They found that all floss types used (unwaxed, woven, shred-resistant, and one powered flosser) resulted in a significant increase in plaque removal. Mean plaque reductions (baseline minus post-brushing) in floss contact areas were 0.181 with the toothbrush alone; 0.228, 0.217, and 0.210 for the toothbrush in combination with the three traditional flosses, unwaxed, woven, and shred-resistant, respectively; and 0.252 for the toothbrush plus powered flosser (Terézhalmy et al. 2008). These results emphasize the importance of daily flossing in combination with tooth brushing. Thus, this station will also include an emphasis on increased flossing. Similar to the toothbrushing activity, students will be given floss and jaw models to practice flossing. The jaw model will represent the anatomy most likely for these children to have; six-year molars will be present and twelve-year molars will not be. Additionally, these models will emulate a child's mouth by including missing teeth,

crooked teeth, and other variations common at a young age. By practicing flossing between all teeth on the model, students will be able to visualize how to floss their own teeth.

For the last lesson in station one, students will learn the importance of fluoride use and how to best obtain it. Fluoride is important in maintaining the homeostasis between demineralization and remineralization of tooth surfaces. If this balance is lost, cavities can form. Thus, fluoride utilization is a key component of this dental intervention. A review done by Kanduti et al. concluded that even though fluoride can be toxic in extremely high concentrations, it's topical use is safe (Kanduti et al. 2016). Any parents feeling unsure about the use of fluoride are encouraged to refer to the informational packet provided to them, and to read in full the sources cited within the packet. There are many sources of topical fluoride including community water, processed foods, beverages, toothpastes, mouth rinses, gels, foams, and varnishes (Carey 2014). The European Academy of Paediatric Dentistry (EAPD) recommends a preventive topical use of fluoride supplements because of their cariostatic effect (Kanduti et al. 2016). Due to the ease of accessibility, this lesson will focus on toothpaste and mouthwash as primary methods for daily fluoride attainment. Students will receive fluoride varnish as an additional component to this intervention, but for the purpose of the educational initiative daily fluoride use will still be emphasized. To practice swishing mouthwash all throughout the mouth, students will be given a disposable rinse cup of water and practice swishing “mouthwash” as a group.

As a final activity in station one, the group will be split in half and each small group will be tasked with creating and performing a skit to demonstrate proper

brushing, flossing, and fluoride techniques. The kids are encouraged to be as creative as possible and can choose any scenario or setting for their oral health care demonstration. After each skit, the other kids will point out what the performing group did well and any improvements to their technique they could make. This activity will allow kids to recall information and collaborate in a fun, low-stakes activity. Overall, the materials in station one include toothbrushes, jaw models, floss, and mini cups for rinsing with water.

Station two will focus on the physiology behind cavity formation. Often, oral physiology is skipped over in health and science curriculums so this lesson aims to fill the gap in knowledge that may exist. Dental decay is caused when acid, a byproduct of bacterial fermentation of sucrose and other carbohydrates, dissolves tooth minerals (Loesche 1996). This dissolution begins in dental plaque where most bacteria reside (Selwitz, Ismail, and Pitts 2007). When the acid byproduct builds up, the local pH decreases and leads to demineralization of the tooth. Over time, if this demineralization occurs frequently, a cavity will begin to form. Calcium, phosphate, and fluoride uptake can reverse demineralization in its early stages. Fluoride is a catalyst for uptake of calcium and phosphate, both of which remineralize structures in the tooth. Thus, to prevent cavitation, an individual should increase uptake of these substances. In healthy individuals, the processes of demineralization and remineralization occur frequently in order to maintain a homeostatic balance (Selwitz, Ismail, and Pitts 2007). This is the basic information that will be taught to kids during this activity. The active learning component will include an illustrated worksheet which the children will color and fill in as they learn. Additionally, physiological posters will be put up to show detailed images

of the oral cavity. Because this information can be considered more advanced than students are used to, the structure of this lesson aims to make the material more approachable and understandable to young children by breaking down the cavitation process into many smaller steps and including images to reinforce the new knowledge.

Group three will learn how different foods affect cavity formation and the importance of maintaining good oral health in regard to other diseases associated with dental decay. The main takeaway for this activity will be that decreasing frequency of consumption of sugar can help decrease cavity formation and keep their teeth healthier. Group three students will write down common foods or foods they like to eat, and these will be incorporated into the lesson. On a magnetic board, there will be a chart with three columns: one labeled “high acid”, one labeled “medium acid”, and the third labeled “low acid”. This lesson is independent of the physiology lesson on how cavities form, so the idea that greater amounts of sugar lead to cavitation due to the high levels of acid produced will be introduced. Then, students will collaborate and make predictions about where the foods they chose as well as other common foods (provided as magnets) would fall in the chart. Once the predictions are made, foods that were placed both correctly and incorrectly will be explained and moved if necessary. In order to make this lesson as inclusive as possible, the word choice and overall message will be highly intentional. In an ideal world all children would have access to a range of foods including those that fall in the low acid category, however this is not the case. Thus, the goal of this lesson is to remain sensitive to all situations and avoid adding in any unnecessary stress for children. While it would be tempting to teach that certain foods should only be eaten occasionally, this may have adverse effects. Therefore, the

specific language of high or low acid will be used instead. Additionally, this lesson will stress that proper oral care is the most important factor, so high acid foods are okay to eat if followed by brushing teeth and flossing. Overall, it is critical for students to understand which foods are likely to cause dental decay but also to recognize that ultimately proper oral care can counterbalance some food choices.

After this activity, there will be a discussion about some future consequences of poor oral health. Dental decay is highly associated with other serious diseases such as cardiovascular disease, diabetes, respiratory diseases, stroke, kidney disease, peripheral vascular disease, and dementia (Dental Health Services Victoria 2011). For example, periodontitis (infection or lesions resulting in the destruction of tissues and supporting bone that form the attachment around the tooth) and diabetes are thought to involve an inflammatory response due to hyperglycemia as a common pathogenesis (Southerland, Taylor, and Offenbacher 2005). Aside from diseases, dental pain and cavities are also associated with school absenteeism and lower academic achievement (Blumenshine et al. 2008). The goal of this discussion will be to highlight that dental decay is not an isolated occurrence, and it will hopefully encourage students to continue good oral care for the rest of their lives.

On the second visit, the structure of the intervention will be the same. Half of the class will stay in the classroom while the other half visits the mobile clinic, and they will switch halfway through. In the clinic, a similar screening, cleaning, and fluoride varnish will take place. In addition, the option of dental sealant application on the first molars (also called six-year molars) will be available for eligible children. Importantly, sealants reduce decay in permanent molars by 81% approximately 2 years after

placement. They also continue to be effective up to 4.5 years, which highlights the benefit of students in the intervention receiving sealants (Griffin et al. 2014). Again, dental volunteers providing services will communicate with the presiding dentist virtually. Students participating will be given new toothbrushes, floss, and fluoride toothpaste to replace the first set given.

The goal of the educational component on the second day of the intervention is to reinforce the knowledge learned on day one. Rather than re-teaching every element included in the first intervention day, students will be encouraged to recall information and ask clarifying questions. In group one, students will share their experiences utilizing the techniques for brushing, flossing, and fluoride use. They will have similar materials available and be able to practice brushing and flossing on the jaw model.

In station two, physiology posters will again be set up for students to observe. For the activity, students will be asked to recall to the best of their ability how cavities form. They will first be asked to work individually, then share ideas with a partner. Finally, the answers will be reviewed as a group and gaps in knowledge will be filled in by the intervention staff member. In this station, students will also have time to ask questions about aspects of oral physiology or anything they are curious about.

In station three, students will again utilize the magnetic board to place foods in the categories “high acid”, “medium acid”, and “low acid”. For this activity students will choose some of their own favorite foods to categorize in addition to some trickier foods chosen by the intervention staff. They will first work together in a small group to sort out the food options, and once they have a final answer the adult overseeing the activity will step in to check their work and give hints. Lastly in this station, students

will be asked to reflect on their experience participating in the intervention. Then, they will create oral health goals for themselves to complete in the coming weeks, months, and years.

At the end of the intervention, once students have completed the three lessons in small groups as well as visited the mobile clinic, all students will receive a special calendar to keep track of their brushing and flossing progress. Each day will have morning and evening check boxes to fill in when students brush or floss. Depending on the teacher's willingness, rewards can be given out to students for keeping up with daily brushing and flossing. Rewards can include items such as pencils with teeth printed on them, xylitol gum, or fun flossers such as Wild Flossers. Hopefully the prospect of receiving small prizes such as these will encourage students to continue with proper brushing and flossing as learned in the intervention.

The last component of this intervention involves communication with teachers, parents, and guardians. The goals of including adults in the intervention are to increase consent for their children's participation and increase likelihood of adults utilizing the references to establish dental homes for their children. A few weeks before the intervention, whenever the school is available, a meeting will be held to address questions and concerns. This meeting may also be held at the school's back to school night in order to eliminate the need for parents to find the time and transportation means to visit the school an additional night. Program staff will present the details of the program so that parents know exactly what will be happening, and attendants at the meeting will receive a comprehensive information packet about the program. Also at this meeting, information about dentists in the area that accept publicly or uninsured

patients will be distributed. A care coordinator will present this information and explain the resources available including transportation to and from the appointment and help with finances. In the LAUSD dental intervention, adults in the community were involved in the creation and planning of the event in order to increase participation, so hopefully this meeting to address questions or concerns will have the same effect. Lastly, parents or guardians in attendance will have the opportunity to sign consent forms for their children in advance of the program happening. If the attendees do not wish to give consent at the time of the meeting, they will be sent home with a form that can be returned any time before the intervention takes place in their school. Additionally, a representative from the school will take on the role of sending out periodic reminders until the program date to encourage more forms to be returned.

Conclusion

Future interventions must address the high prevalence of dental decay in children. This is the most common chronic disease that children face, and it disproportionately affects low income and minority children. Despite caries being completely preventable and reversible in most stages, they continue to plague children across the world. Other than oral cavity pain, caries cause school absenteeism and lower the overall quality of life for children (Amalia et al. 2015). Additionally, carries are linked to increased risk for other chronic diseases later in life. Thus, it is imperative that efforts are made to combat the epidemic of childhood caries. My intervention takes advantage of successes from previously studied interventions in order to decrease disparities in access to dental care. First, the intervention program takes place in schools, during regular school hours. This helps eliminate barriers to access such as finding transportation or time for the appointment. Additionally, my intervention will be free of cost to all participants. As the high cost of dental services is a large deciding factor in whether or not children will have access to dental care, the goal of the program is to eliminate this barrier as completely as possible. While further systemic changes such as new policies and increased healthcare funding must be made to completely eliminate the financial barrier, my intervention will serve as a first step in beginning this process. Finally, in order to maximize the effects of the dental visit, my program will focus heavily on dental education. Students will learn how to properly care for their teeth and gums as well as how to recognize decayed versus healthy teeth. The knowledge the students obtain will help them maintain healthy teeth even after the intervention and will hopefully help form healthy lifelong habits.

Importantly, limitations for this intervention exist. First, while it is the hope that dental education inspires students to care for their teeth permanently, this will not occur universally. This pattern, called the science-policy-education-behavior paradigm, occurs in other fields as well. For example, despite the abundance of scientific knowledge regarding climate change and many efforts to teach these findings, little changes occur in policies made or people's daily behavior. Thus, while the dental education included in this intervention is meant to inspire positive changes well beyond the intervention, this will not be the case with all students. Some students may make no changes to their dental habits at all, and some may make short-term changes only.

Despite all of the combined efforts of the program, it is an unrealistic goal to believe that a single intervention could have a 100% success rate. However, even if only a portion of students understand the gravity of this issue and work to change their daily habits this will still be a positive outcome for the program. Also, because my intervention includes support for finding permanent dental homes, hopefully students who do not introduce daily oral health practices will still be able to benefit from the program.

Another limitation to consider in the creation of this intervention is the reality that funding will play a large role in whether or not the intervention can run. In an ideal situation, money would not be an issue and all children would have equal access to dental care. However, this is not nearly the case in today's world. Thus, program staff running the intervention will need to collaborate with the school district and local governments to find funding for the intervention. A possibility to limit the financial burden would be to utilize volunteer dental students, hygienists, and dentists to help run

the program. This is especially feasible because the intervention is meant to last only one day and thus does not require too much time commitment from volunteers. Hopefully, once cities and school districts recognize the severity of the issue this will serve as motivation to make the intervention a reality. And, even further in the future if the intervention is successful, ideally the federal government would shift policies to make programs like these possible in all areas of the country. Considering the extremely high cost of restorative dental treatments, it is much more cost efficient to fund prevention of childhood caries. According to the University of Illinois at Chicago School of Dentistry, crowns can cost $600 to $1000, while implants can cost $2,000 or more. Gum disease treatments are even more expensive and can range from $500 to $10,000 in total depending on the severity of the disease. Additionally, a growing body of research has linked poor oral health with increased risk for other chronic diseases such as Alzheimer's and diabetes, both of which are expensive to treat and manage (The Many Costs (Financial and Well-Being) of Poor Oral Health).

The issue of childhood caries is multifaceted and widespread. Thus, many varied approaches may be necessary to solve the problem. The intervention I created is just one option that may work for specific groups, school districts, or locations. However, due to the nature of the issues regarding child caries, more than one solution will likely be necessary. Additionally, in order to create long lasting change this intervention or others like it will need to be implemented repeatedly for each incoming class of students. It is my hope that this program will contribute to bettering the oral health care practices of children as well as influence them to continue taking care of their teeth and gums for the rest of their lives. As a society, we must work together to address this

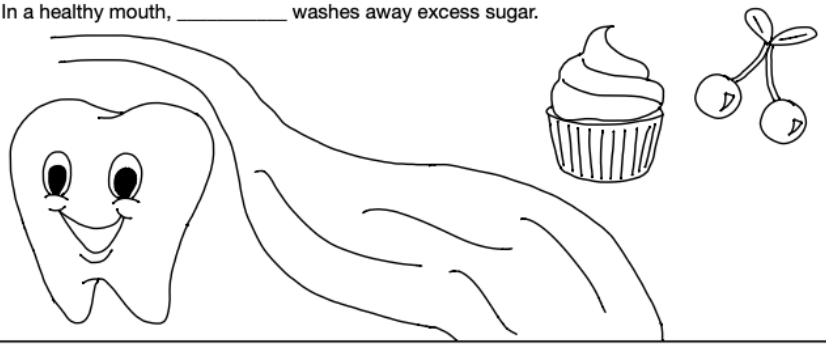
issue. Whether utilizing more interventions such as this one or creating new healthcare policies to make dental care more affordable and accessible, changes must be made now in order to increase the health and wellbeing of generations to come.

Additional Materials

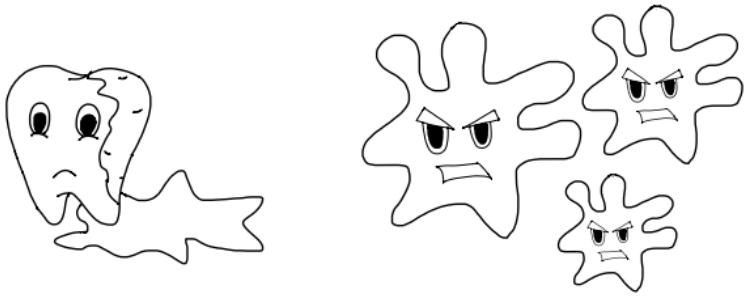
Cavity Formation Coloring Sheet

Name:
Date:

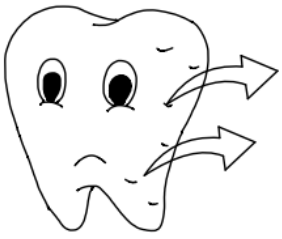
In a healthy mouth, _____ washes away excess sugar.



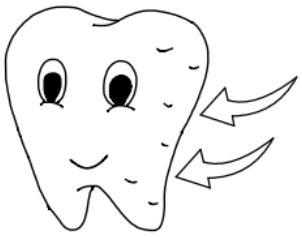
When sugar sits on the teeth and isn't washed away, bacteria creates _____.



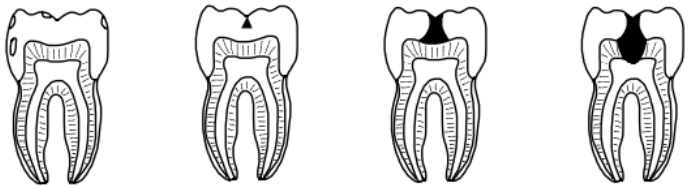
Repeating this process over and over can lead to a decrease in the pH. This causes _____ and _____ to leave the tooth, a process called demineralization.



_____ remineralizes the tooth, reversing the demineralization. _____ is a natural element that helps speed up and strengthen remineralization.



If demineralization occurs more frequently than remineralization, a cavity will start to form. Fill in the stages of a cavity below:



White spots | Enamel decay | Dentin Decay | Involvement of the pulp

---

The best ways to prevent cavities are: _____, _____, and _____!

Bibliography

Amalia, Rosa et al. 2017. "Impact of School-Based Dental Program Performance on the Oral Health-Related Quality of Life in Children." *Journal of Investigative and Clinical Dentistry* 8(1): e12179.

Bailit, Howard, and John D'Adamo. 2012. "State Case Studies: Improving Access to Dental Care for the Underserved." *Journal of Public Health Dentistry* 72(3): 221–34.

Blumenshine, Stephanie L., William F. Vann, Ziya Gizlice, and Jessica Y. Lee. 2008. "Children's School Performance: Impact of General and Oral Health." *Journal of Public Health Dentistry* 68(2): 82–87.

Carey, Clifton M. 2014. "Focus on Fluorides: Update on the Use of Fluoride for the Prevention of Dental Caries." *Journal of Evidence Based Dental Practice* 14: 95–102.

Culler, Corinna S. et al. 2017. "A School-Based Dental Program Evaluation: Comparison to the Massachusetts Statewide Survey." *The Journal of School Health* 87(10): 784–89.

"Cavities/Tooth Decay - Symptoms and Causes." *Mayo Clinic*. https://www.mayoclinic.org/ diseases-conditions/cavities/symptoms-causes/syc-20352892 (March 7, 2021).

Dental Health Services Victoria. 2011. "Links Between Oral Health and General Health: The Case for Action" www.dhsv.org.au

Dudovitz, Rebecca N. et al. 2018. "A School-Based Public Health Model to Reduce Oral Health Disparities." *Journal of Public Health Dentistry* 78(1): 9–16.

Dye, B. A., et al. 2007. "Trends in oral health status: United States, 1988-1994 and 1999-2004." *Vital and Health Statistics. Series 11, Data from the National Health Survey*, *248*, 1–92.

Flores, Glen and Hua Lin. 2013. "Trends in Racial/Ethnic Disparities in Medical and Oral Health, Access to Care, and Use of Services in US Children: Has Anything Changed over the Years?" *International Journal for Equity in Health* 12: 10.

Freeman, Scott. et al. 2014. "Active Learning Increases Student Performance in Science, Engineering, and Mathematics." *PNAS*, *111*(23), 8410–8415.

Gargano, Lynn, Margaret K. Mason, and Mary E. Northridge. 2019. "Advancing Oral Health Equity Through School-Based Oral Health Programs: An Ecological Model and Review." *Frontiers in Public Health* 7: 359.

Glassman, Paul, Maureen Harrington, Elizabeth Mertz, and Maysa Namakian. 2012. "The Virtual Dental Home: Implications for Policy and Strategy." *Journal of the California Dental Association* 40(7): 605–11.

Griffin, Susan O. et al. 2014. "Use of Dental Care and Effective Preventive Services in Preventing Tooth Decay among U.S. Children and Adolescents--Medical Expenditure Panel Survey, United States, 2003-2009 and National Health and Nutrition Examination Survey, United States, 2005-2010." *MMWR supplements* 63(2): 54–60.

Gussy, Mark G., Elizabeth G. Waters, Orla Walsh, and Nicola M Kilpatrick. 2006. "Early Childhood Caries: Current Evidence for Aetiology and Prevention." *Journal of Paediatrics and Child Health* 42(1–2): 37–43.

Joury, Easter et al. 2017. "Systematic Review and Meta-Analysis of Randomised Controlled Trials on the Effectiveness of School-Based Dental Screening versus No Screening on Improving Oral Health in Children." *Journal of Dentistry* 58: 1–10.

Halawany, Hassan Suliman et al. 2018. "Effectiveness of Oral Health Education Intervention among Female Primary School Children in Riyadh, Saudi Arabia." *The Saudi Dental Journal* 30(3): 190–96.

Hoffman, Ann M., Bonnie G. Branson, Nancy T. Keselyak, and Melanie Simmer-Beck. 2014. "Preventive Services Program: A Model Engaging Volunteers to Expand Community-Based Oral Health Services for Children." *Journal of dental hygiene: JDH* 88(2): 69–77.

"Information About PSP." *Preventive Services*. https://psp.health.mo.gov/ (February 26, 2021).

"I-Smile Dental Home Initiative - Education Just for You - Dental Providers." https://ismile.idph.iowa.gov/education/dental-providers (March 7, 2021).

Kanduti, Domen, Petra Sterbenk, and Barbara Artnik. 2016. "Fluoride: A Review Of Use And Effects On Health." *Materia Socio-Medica* 28(2): 133–37.

Loesche, W. J. 1996. Microbiology of Dental Decay and Periodontal Disease. In S. Baron (Ed.), *Medical Microbiology* (4th ed.). University of Texas Medical Branch at Galveston.

Marsh, P. D., & Bradshaw, D. J. (1995). Dental plaque as a biofilm. *Journal of Industrial Microbiology*, *15*(3), 169–175.

Martin, M. and Marsh, P. 1992. *Oral Microbiology.* Chapman & Hall.

Mattila, K. J. et al. 1989 "Association Between Dental Health and Acute Myocardial Infarction." *British Medical Journal*, *298*(6676), 779–781.

Nelson, S. J. 2014. *Wheeler's Dental Anatomy, Physiology and Occlusion—E-Book*. Elsevier Health Sciences.

Paulson, Donald R. 1999. "Active Learning and Cooperative Learning in the Organic Chemistry Lecture Class." *Journal of Chemical Education,* 76(8): 1136.

Poche, Cheryl, Heather McCubbrey, and Tom Munn. 1982. "The Development of Correct Toothbrushing Technique in Preschool Children." *Journal of Applied Behavior Analysis* 15(2): 315–20.

Reisine, S., & Douglass, J. 1998. "Psychosocial and behavioral issues in early childhood caries." *Community Dentistry and Oral Epidemiology*, *26*, 32–44.

Selwitz, R. H., Ismail, A. I., and Pitts, N. B. 2007. "Dental Caries." *The Lancet*, *369*(9555), 51–59.

Sieroslawska, Alexandra. 2020. "Anatomy of the Tooth." *Kenhub*. https://www.kenhub.com/ en/library/anatomy/anatomy-of-the-tooth (April 29, 2021).

Sutherland, J., Taylor, G., and Offenbacher, S. 2005. "Diabetes and Periodontal Infection: Making the Connection." *Clinical Diabetes,* 23(4): 171-178.

Terézhalmy, Géza T., Robert D. Bartizek, and Aaron R. Biesbrock. 2008. "Plaque-Removal Efficacy of Four Types of Dental Floss." *Journal of Periodontology* 79(2): 245–51.

"The Many Costs (Financial and Well-Being) of Poor Oral Health." 2019. *University of Illinois Chicago College of Dentistry*. https://dentistry.uic.edu/news-stories/the-many-costs-financial-and-well-being-of-poor-oral-health/ (April 25, 2021).

Threlfall, A. G., Milsom, K. M., Hunt, C. M., Tickle, M., & Blinkhorn, A. S. 2007. Exploring the content of the advice provided by general dental practitioners to help prevent caries in young children. *BRITISH DENTAL JOURNAL*, 4.

"Tooth Enamel - an Overview" ScienceDirect Topics. https://www.sciencedirect.com/ topics/medicine-and-dentistry/tooth-enamel (March 7, 2021).

Townsend, Eric. 2017. "Dentist Discusses the 5 Stages of Cavity Formation." *Ponte Vedra Complete Dentistry*. https://www.pvcompletedentistry.com/ blog/2017/10/dentist-discusses-5-stages-cavity-formation/ (February 21, 2021).

Wasik, Barbara. 2008. "When Fewer Is More: Small Groups in Early Childhood Classrooms." *Early Childhood Education Journal* 35: 515–21.

Wiggins, Grant, and McTighe, Jay. 2005. *Understanding by Design*. Association for Supervision and Curriculum Development.