Easy and Affordable Solutions to Preventing Oral Diseases

There Should be More Oral Healthcare Products Available on The Market

Tag Words: Xylitol, Sugar-Free Gum, Dental Caries, Oral, periodontal disease,

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Summary

The mouth is a gateway to the outside world and also, it is one of the most significant and biologically complex areas of the body. Dental caries are amongst the most chronic diseases in humans. Having easy and affordable ways to help prevent oral diseases is important. Finding a dental product with the right ingredients to keep the oral cavity clean is essential. Discussed are the components of the oral cavity, the natural ways in which the ecosystem of the mouth stays healthy, ingredients that assist in cleaning the mouth, and current products on the market that claim to keep your mouth healthy.

Video Link:

Oral Diseases and the Easy Way to Help Prevent Them

Wouldn’t it be great to have a healthy mouth without much hassle? Our mouths already have intrinsic ways to effectively keep us healthy and not only in our teeth, but our bodies as a whole. This paper will explain what preventative measures our body and mouths already have in order to help keep us healthy.

Appreciating the ecosystem of the oral cavity is extremely important in maintaining proper health in both the soft and hard tissues of the mouth. Everyday our bodies are exposed to a plethora of bacteria, knowing which microorganisms are essential to our wellbeing and which are detrimental is key. Understanding what bacterias harm our mouths, how they do this, and as a result how they affect overall health is pivotal. It is necessary to understand the ecology of the oral cavity and to identify the aspects accountable for the shift of the oral microbes from an equilibrium standpoint to a pathogenic relationship.

There are solutions to preventing damage to our mouths and health. By assessing ingredients that are helpful and also assessing current products on the market we can figure out easy and cost effective ways to help maintain our well being.

Current dental products ranging from sugar-free gums to dental chews for dogs will be studied and their effectiveness at preventing oral diseases will be noted.

The foods we eat, and their inherent effects

What we eat and drink directly affects the ecosystem of the oral cavity. Factors including how much we eat, how often, and what we eat in particular are all interrelated. It is particularly
important to remember to eat and drink in moderation when caring for the oral cavity. Even “healthy” foods and drinks can have negative effects on your mouth when eaten frequently.

Bacteria love when we eat; they metabolize the minerals in food and convert them to acid. This then brings about more bacteria and thus it lowers the pH in the mouth, destroying the enamel of the teeth. The more often you eat, the more you expose your mouth to decay. An easy way to help reduce the risk of dental caries would be to cut back on simple carbohydrates such as glucose, sucrose, and fructose (Table 1) (13) (11). The rate of consumption of these foods plays a key role in the formation of dental caries. When eating these foods often throughout the day the rate of dental decay increases. It is important to limit time between consumption of these foods to at least two hours. (11)

<table>
<thead>
<tr>
<th>Dietary factors associated with increased risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sugar-sweetened liquids, such as carbonated beverages, fruit drinks, energy drinks, and sweetened teas and coffees</td>
</tr>
<tr>
<td>• Sticky foods, such as raisins</td>
</tr>
<tr>
<td>• Slowly dissolving candies</td>
</tr>
<tr>
<td>• Sugary starchy snacks, such as cookies, cakes, etc</td>
</tr>
<tr>
<td>• Simple sugars, such as sucrose, honey, and molasses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dietary factors associated with decreased risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sugar-free chewing gum, mints, and candies</td>
</tr>
<tr>
<td>• Fresh fruits and vegetables</td>
</tr>
<tr>
<td>• High-quality protein foods, such as meats, eggs, cheese, fish, beans, and legumes</td>
</tr>
<tr>
<td>• Whole-grain, low-sugar breads and cereals</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eating patterns associated with increased risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Frequent and prolonged intake of foods rich in simple sugar</td>
</tr>
<tr>
<td>• Eating sticky, retentive foods alone</td>
</tr>
<tr>
<td>• Sipping sugar-sweetened beverages for prolonged periods</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eating patterns associated with decreased risk</th>
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<tbody>
<tr>
<td>• Space frequency of food and beverage intake at least 2 hours apart</td>
</tr>
<tr>
<td>• Select fresh, whole, unprocessed food to stimulate salivary output</td>
</tr>
<tr>
<td>• Chew sugarless gum for a brief period immediately after a meal or snack</td>
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</tbody>
</table>

Frequency of sugar-containing foods and drinks consumed throughout the day is an extremely important factor of dental erosion. (12) According to the Dental Health Foundation of Ireland twenty three percent of eight year olds and forty percent of fifteen year olds consume sweet snacks or drinks between normal meals three or more times a day. The DHF also concludes that half of all adults snack between meals and a staggering eighty six percent of adults consume at least three servings of food high in sugars per day. Below are tables of boys and girls between
the ages of ten to seventeen. In these tables the subjects reported if they consume sweets and soft drinks on a daily basis.

Figure 2, Sweets consumed daily, (12)

This table accounts children who reported eating sweets daily or more often, by age group and gender.

Figure 3, Soft Drinks consumed daily, (12)
This table accounts for children who reported drinking soft drinks daily or more often, by age group and gender.

“Sip all day and get decay”

The quote above is by Kimberly Harms DDS of the American Dental Association. It refers to the consumption of soft drinks. Harms claims it’s not the amount of sugars you consume but how long they remain in the mouth (23). Having a big lunch full of carbohydrates is one big exposure, but sipping on sugary drinks throughout the day is continuous exposure and much more harmful. The consumption of soft drinks is one of several leading causes to tooth decay amongst people of all ages. The carbonation, sugar, and acidity of these types of drinks weaken tooth enamel, thus creating a more suitable environment for harmful bacteria.

### Drink or substance pH and sugar rating

<table>
<thead>
<tr>
<th>Drink or Substance (12 oz. serving)</th>
<th>pH</th>
<th>Sugar (Tsp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>7.0 (neutral)</td>
<td>0</td>
</tr>
<tr>
<td>Milk</td>
<td>6.7</td>
<td>1</td>
</tr>
<tr>
<td>Barq’s Root Beer</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Minute Maid® Orange Juice</td>
<td>3.8</td>
<td>9</td>
</tr>
<tr>
<td>Propel® Fitness Water</td>
<td>3.4</td>
<td>1</td>
</tr>
<tr>
<td>Red Bull® Energy Drink</td>
<td>3.3</td>
<td>10</td>
</tr>
<tr>
<td>Sprite®</td>
<td>3.3</td>
<td>10</td>
</tr>
<tr>
<td>Mountain Dew</td>
<td>3.3</td>
<td>12</td>
</tr>
<tr>
<td>Diet Coke</td>
<td>3.1</td>
<td>0</td>
</tr>
<tr>
<td>Sierra Mist</td>
<td>3.1</td>
<td>10</td>
</tr>
<tr>
<td>Full Throttle Energy Drink</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Diet Pepsi</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Gatorade®</td>
<td>2.9</td>
<td>5</td>
</tr>
<tr>
<td>Sunkist® Orange Soda</td>
<td>2.9</td>
<td>13</td>
</tr>
<tr>
<td>Dr. Pepper</td>
<td>2.9</td>
<td>10</td>
</tr>
<tr>
<td>Vault™ Energy Soda</td>
<td>2.9</td>
<td>12</td>
</tr>
</tbody>
</table>
This table, from the Indiana Dental Association (17), illustrates relative amounts of sugar and acidity. Coca-Cola has a pH close to that of a battery and its sugar content is relative to ten teaspoons worth. That quantity of sugar is equivalent to roughly forty-eight grams of sugar. So, consuming one can of Coca-Cola a day would result in over fifteen kilograms of sugar a year. When sugar intake per person, per year, exceeds fifteen to twenty kilograms it is a direct influence on dental erosion. (16) Consuming soft drinks three or more times a day has also been shown to increase the risk of dental caries by 179%. (18)

The Academy of General Dentistry reported that the consumption of even diet sodas for years would yield the same effect on the mouth as someone who uses methamphetamine. (15)

Figure 4. Methamphetamine vs Coke, (15)
In their study, the man who used methamphetamine drank two to three cans of soda a day. He also used methamphetamine for three years prior to the picture above. (15) The patient on the right side of the picture was a single mother who drank two liters of cola a day for three to five years prior to the picture. She chose to drink diet soda fearing weight gain from normal cola. Although this woman thought diet soda would help her lose weight, the danger the soda presents to the mouth is not avoidable. The erosion to the hard dental tissues observed in the two patients above is very similar. The only difference between the two is the discoloration of the dentin lesion; due to the acid/sugar interaction in the mouth. (15)

**Energy drinks**

Both energy and sport drinks leave the enamel at just as much risk, if not more risk, as soft drinks. Sport drinks were found to have the same carcinogenicity as fruit juices and carbonated drinks, therefore there is a major potential for developing caries with the consumption of energy and sports drinks. (19) A recent study proved the detriment of sports and energy drinks. Poonam Jain, BDS, MPH, associate professor and director of community dentistry at the Southern Illinois University School of Dental Medicine headed this study.

The sports drinks tested were:
- Gatorade Rain
- Powerade Option
- Propel Grape

The energy drinks tested were:
- Monster Assault
- Red Bull
- 5-hour Energy

Jain immersed enamels taken from humans into each of the drinks for fifteen minutes after which the researchers transferred the enamel to artificial saliva for two hours. Jain and her team repeated this four times a day for five days. Enamel loss was evident after the five-day tests. (20) About 1.5% of enamel was lost from sports drinks while 3% was lost from the energy drinks.

Energy, sports, and soft drinks have the capability of eroding the dental surfaces because of their inherent low levels of pH. At a pH of around 5.5 dissolution of the enamel will begin to occur. pH levels in most energy, sports, and soft drinks range from 2.3 to 3.4. The effects of the acidic beverages on the enamel surface are observed within five minutes and are most prevalent after thirty. (21)

**Sugars**

It is sometimes stated that the carcinogenicity of sugars is determined by its adhesiveness. The “stickier” a sugar is, the longer it will stick to the teeth and the lower the pH will be. However, this is not necessarily true. The carcinogenic potential and oral retention of the sugar is not defined by its stickiness (22).
Sugars are undoubtedly the most common dietary factor studied in relation to dental caries (22). They are an extremely important part of dental diseases. Sugars come in mono and disaccharides. The term “free sugars” refers to all mono and disaccharides added to food by a manufacturer, cook or consumer. It also includes naturally present sugars in fruit juices, honey and syrups. Fermentable carbohydrates refer to free sugars, glucose polymers, fermentable oligosaccharides and highly refined starches (22).

Preventative steps in nutrition

Listed below are some easy to follow guidelines for nutrition to help prevent tooth decay provided by Colgate (24). By adhering to this list you can prevent bacteria from metabolizing fermentable carbohydrates into acids.

1. Limit in-between meal snacking. The fewer snacks you eat between meals the less acid there will be in the mouth. When snacking, try to pick foods that won’t be fermentable.
   a. The best choices: Cheese, chicken or other meats or nuts. These foods neutralize acids by providing calcium and phosphorus to put minerals back in teeth.
   b. Moderate choices: Firm fruits like apples, pears and vegetables. Although firm fruits contain natural sugars they also contain plenty of water to help dilute the sugars once they enter the mouth. These foods also help stimulate saliva flow, which is the body’s primary mechanism in dental disease defense.
   c. Bad choices: Candy, cookies, cakes, crackers, breads, muffins, potato chips, French fries, pretzels, bananas, raisins and other dried fruits.
2. Limit the consumption of soft drinks or any other drinks containing sugar. These drinks include Sports, energy, soft drinks, lemonade, fruit juices, coffee, and other drinks added with sugar. Avoid sipping on the drinks throughout the day. The more you sip on your drink, the more exposure your mouth has to sugar and thus the more acidic your mouth will get.
   a. Better choices: water, unsweetened tea, and fluoridated water. Tea naturally has fluoride, and water helps dilute and wash out sugars left over in the mouth.
3. Avoid sucking on hard candies or mints that contain sugars. Candies and mints have more than enough sugar to lower the pH of the mouth to below 5.5 and create an acidic environment.
   a. Better choices: sugar-free gums, sugar-free candies. Candies with xylitol instead of sucrose reduce the amount of cavities in the mouth.
4. Limit acidic foods (like citrus fruits). Acidic foods, naturally, make the oral cavity more acidic. The more the mouth is exposed to these foods, the more likely the risk of dental diseases.
5. Brush your teeth after eating and after drinking sugary drinks. Brush at least two times a day. Brushing with fluoride removes most of the acids in the mouth, brushing without fluoride is not effective.
6. Chew sugar-free gums. Most of these gums contain xylitol as a replacement to sucrose. The chewing action of gum allows for the removal food stuck in-between teeth; it also helps increase saliva flow in the mouth to help neutralize the acids.
Oral Ecosystem

The oral cavity is normally at a constant temperature of 34 to 36°C and constant pH between 6 to 7. For these reasons it is one of the most densely populated areas of the human body, in terms of microbes (1).

The oral cavity is comprised of hard tissue (teeth) and soft tissue (mucosa). The teeth are one of the few tissues in the body without the ability to regrow. Once the host acquires permanent teeth they are not capable of being replaced biologically. Thus, the teeth need to be cared for multiple times a day. Harmful bacteria can colonize the surface of teeth from almost any angle so flossing in-between proximal teeth is extremely important. Conversely, the mucosa is constantly removing layers of tissue (epithelial cells) to be replaced by new tissue, similar to how a snake sheds its skin. This process allows the mucosa to remove bacteria from adhering permanently to its surface. The tongue, a small lump of tissue, has mechanical functions to remove the colonization of bacteria from its surface.

The supragingival surface, the tooth surface above the gum line, is constantly bathed by saliva while the subgingival, tooth surface below the gum line, is bathed by gingival crevicular fluid. Saliva helps maintain tooth integrity by providing ions such as calcium, phosphate, magnesium, and fluoride for the remineralization of tooth enamel. (1) Saliva will be explained in more detail in later sections. The gingival crevicular fluid is an exuded liquid, normally in low concentrations, that is located in the subgingival region. Fluid concentrations spike when inflammatory conditions exist within the mouth such as periodontal disease.(2)

Factors influencing Oral cavity

pH, temperature, acidity, nutrients, and host defense mechanisms lead to the growth of different microbes in the oral cavity. Each dynamic plays its role in keeping the bacteria in a state of equilibrium, not allowing any one bacterium to over colonize any specific part of the mouth. An imbalance in the ecosystem of the cavity will lead to oral diseases. In the following sections the factors that influence the oral cavity will be explained in detail. The ecosystem of the mouth is all interrelated, as is all ecosystems. They depend on diet, host, and oral hygiene.

pH

The pH, or hydrogen ion concentration, of an environment affects microorganisms and microbial enzymes directly and also influences the dissolution of many molecules that indirectly influence microorganisms. (1,4) Generally, microbes cannot tolerate extreme pH values so the relative normal pH of the mouth is a perfect home for many microbes. pH is kept within the values of 6.7-7.3 because of the two mechanisms of saliva. The first being its ability to wash off
carbohydrates. These carbohydrates, left alone, would otherwise be metabolized into acids by bacteria, which help cause cavities and periodontal diseases. The second mechanism is its buffer ability. This buffer eliminates acids brought into the mouth by food and drinks. Bicarbonate is the main buffering system of saliva. (1) Acids that are formed by the microbial metabolism of carbohydrates may result in dental plaque and cavities because of the slow diffusion of saliva through dental plaque. (1)

Following sugar intake, the pH of the oral cavity may decrease below 5.0 which is the value where bacteria metabolizes carbohydrates and other sugars into acid. When pH levels decrease, acidic bacteria concentrations such as S mutans and lactobacillus increase. An increase in these particular bacteria result in continuing drops of pH value. pH in the subgingival area is bathed by gingival crevicular fluid, not saliva. pH in this area is normally between 7.5-8.5, while crevicular fluid remains fairly constant between 7.5 and 7.9 (1). A basic pH in the subgingival area may result in a greater selective force towards colonization of periodontopathogens. (1) pH is an extremely important factor in the ecosystem of the mouth.

Temperature

The temperature of the oral cavity remains fairly constant around 34 to 36°C, which allows for a diverse community of bacteria. With the consumption of different foods and drinks, these bacteria must be able to adapt to both extreme heat and cold. Little research has been done on the effect of the sudden changes in temperature and its consequence on bacteria. (1)

Acidity

A wide range of oxidation-reduction reactions characterizes the oral cavity; this allows the growth of aerobic, facultative anaerobic, and anaerobic bacteria. (1) Redox potentials (E_h) are the result of the proportions of oxidized and reduced components. (1) Anaerobic bacteria need a negative E_h for growth while aerobic bacteria need an oxidizing (positive E_h) environment. In general, facultative anaerobic bacteria tend to grow on the top part of the tongue, as it tends to have a reductive environment. The gingival and proximal teeth have the lowest E_h with respect to the oral cavity. (1) For this reason they have the highest obligatory anaerobic bacteria in the mouth. The E_h values vary between +158 to +542 mV in saliva but may reach −300 mV in gingival crevices (4). During plaque formation oxygen has a difficult time diffusing through the plaque, thus reducing the E_h. Anaerobic bacteria consuming oxygen primarily cause the negative E_h. As this process intensifies more anaerobic bacteria adhere to the gingival surfaces and cause damage to the mouth.

Nutrients

Chemostat and mice studies suggest that the populations of bacteria are largely determined by substrate availability. (1,5) According to Liebig’s law, growth of bacteria is determined by the least amount of resources available, rather than the more abundant. (6) For this reason, each
species of bacteria must out compete others to metabolize the resources available. In the supragingival region of the mouth, bacteria have indigenous (saliva) as well as exogenous (food and drink) nutrients readily available. Saliva contains carbohydrates, water, glycoproteins, amino acids, calcium, sodium, gases, bicarbonate, and phosphates. The composition of saliva provides nutrients for many microorganisms, especially in the absence of external nutrients. Exogenous nutrients contain carbohydrates, proteins, amino acids, starches, sugars and other components. Primarily, carbohydrates and proteins are most metabolized by the oral microbes in the mouth and have the greatest influence on their relative quantities in the oral cavity. The subgingival area of the mouth is not bathed in saliva or exogenous nutrients. Instead bacteria in this region rely on the crevicular fluid for nutrients. This fluid is an excellent source of Vitamin K and hemin that is required by P. gingivalis, a main component in adult periodontal diseases. (1) P. gingivalis is a gram-negative rod, which are more difficult to eliminate from the mouth.

It is well documented that continuous ingestion of sucrose containing foods and drinks will increase the amount of S mutans and Lactobacillus in the mouth. When sucrose is fermented, it causes the mouth to become more acidic, favoring acidogenic and acidophilic bacteria. (1,4)

**Saliva**

Saliva is the mouths main defense against cavities. (1) It continuously cleanses the supragingival part of the mouth. With the aid of muscular movements of the lips and tongue, saliva is able to wash out most bacteria that try to aggregate to the surface of the hard and soft tissues of the mouth. Saliva’s minerals help strengthen the surfaces of teeth.

**Saliva Composition**

Saliva is composed of primary and secondary components. Primarily, Immunoglobulin A (SIgA) acts as saliva’s specific defense mechanism. SIgA is an antibody created by B cells (produces antibodies). It has the ability to identify and neutralize bacteria, viruses and enzyme toxins (4) Immunoglobulin’s structure is like a Y, the tops of the Y have specific binding structures which allows it to attach and destroy viruses, bacteria’s, and toxins. This mechanism prevents bacteria like S mutans from aggregating on the enamel.

Mucins are high molecular weighted glycoproteins produced by epithelial tissues. Mucins are the principal organic material that creates a slimy, viscoelastic material called mucus. This material envelops the entire mucosal parts of the body. (1,7) Within the mouth, mucins make a protective coating, hydrating and lubricating, the hard and soft tissues of the mouth and protecting them from exogenous abuse. (7) Potential harmful microorganisms are thus eliminated by the continual renewal of the mucous layer combined with the washing action of saliva. (1)

Saliva also possesses defense factors with direct antimicrobial activity in vitro. (1) Salivary proteins such as, lysozyme, lactoferrin, and peroxidase act together with other minerals of saliva to kill bacteria. (1,8) Lysozyme in particular is anti-microbial and eradicates bacteria by degrading their cell wall. Gram-positive bacteria are more susceptible than gram-negative
because of gram-negatives lipopolysaccharide cell wall. P gingivalis is a gram-negative bacterium that contributes heavily to the formation of dental plaque.

Saliva has a buffer ability as well. It prevents pathogenic microorganisms from being able to colonize by denying them the preferred conditions. The buffers keep the acidity of the mouth between typical pH ranges of 6.7-7.3 (1,4). When salivary flow is elevated, bicarbonate ions increases which boost pH in the orifice allowing the buffering capability to be much more affective.

**Bacteria and Adherence**

There are over 300 species of bacteria in the mouth not including protozoa, yeasts, and mycoplasmas. However, only a few bacteria cause oral diseases, specifically S mutans, Lactobacillus, P gingivalis, and some other anaerobes. S mutans are gram-positive coccus shaped bacteria. They are a significant contributor to dental plaque and overall health of the mouth. S mutans are carcinogenic bacteria that break down sugar for energy and thus produce an acidic environment. This acidic environment demineralizes the surfaces of teeth. They are one of few specialized microorganisms equipped with special adaptations allowing them to better adhere to the surface of teeth. (9)

To get established in the oral cavity, microbes must first adhere to the surface of teeth or mucosal area. When bacteria are able to adhere to these surfaces saliva flow is decreased and thus pH levels in the orifice decrease as well. Microbial adhesins consist of polysaccharides, lipoteichoic acids, glucosyltransferases, and carbohydrate-binding proteins (1). Bacteria adhesins are surface-cell component or appendages that attach to other surfaces (1). The adherence may be a result of physiochemical interactions between the bacteria and oral tissue. It is hypothesized that bacteria initially adhere to the surfaces of oral tissue by nonspecific ways, later they acquire more stereocohemical interactions. (1,9) Bacteria also adhere to oral surfaces by attaching themselves to other bacteria, called coaggregation, which is how plaque forms. “Most coaggregates that have been studied in detail involve two strains from different genera; this is referred to as intergeneric coaggregation. Intragenic coaggregation is seen almost exclusively within oral viridans streptococci”. (1) Coaggregation is particularly important for the formation of dental plaque because bacteria that are not equipped to attach directly to the surface can “piggyback” off other bacteria. In studies, microscopic viewing of plaque revealed two types of structures, gram-positive filaments covered by gram-positive cocci bacteria, and gram-negative filaments covered by gram-negative rod shaped bacterium. The synthesis of polymers by mutans streptococci in the presence of sucrose is probably one of the factors implicated in caries formation.

**Plaque**

Plaque is a diverse community of microorganisms that adhere to the tooth surfaces and form a biofilm. Dental plaque is a yellowish biofilm.

Biofilms form when bacteria are able to adhere to a surface usually in a watery environment and secrete a slimy, glue-like substance that allows for other bacteria to coagulate and stick to many
different kinds of surfaces (25). Biofilms can be created by a single microbe but normally consist of a complex community of bacteria. It can also include algae, protozoa, debris, and corrosion products (25).

How Biofilms Form

Colgate for professionals helps to illustrate how these bacterial communities form.
- Free-swimming bacterial cells land on a surface, arrange themselves in clusters, and attach.
- The cells begin producing a gooey matrix.
- The cells signal one another to multiply and form a microcolony.
- The microcolony promotes the coexistence of diverse bacterial species and metabolic states.
- Some cells return to their freeliving form and escape, perhaps to form new biofilms. (25)

The bacterial composition of plaque is normally in homeostasis. When Ph is low bacteria are able to attach to the enamel, and coagulate. When this occurs, harmful bacteria can create biofilms on tooth surfaces and develop a dense community of other disease-causing bacteria that can lead to cavities and gum disease.

Bacteria are highly selective and their adhesion occurs in both specific and non-specific ways. Non-specific ways include ionic, hydrophobic, van der Waals, and hydrogen bonding between the microbes and host surfaces. Non-specific methods of adhesion do not fully explain the colonization of plaque. (10) In specific methods or stereochemical methods interactions are highly selective, and when superimposed on non-specific ways it allows for specific colonization. Both non-specific and specific methods are interrelated and are the probable way bacteria form plaque. Some salivary proteins have been found in dental plaque and may increase the formation of the colonies. Saliva components that selective adsorb to bacteria likely modifies their adhesive methods. (10) Once plaque begins formation increases by growth, multiplication and sequestration, and ion bonding of additional microorganisms on the surface of teeth. Scannapieco (10) provides relevant points, below, regarding the adhesion of bacteria to the teeth.

<table>
<thead>
<tr>
<th>Features of Bacterial Adhesion and Colonization of Teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacterial adhesion is selective</td>
</tr>
<tr>
<td>Bacterial adhesion to surfaces occurs by nonspecific and specific mechanisms</td>
</tr>
<tr>
<td>Salivary Components modulate bacterial adhesion by forming pellicles on oral surfaces</td>
</tr>
<tr>
<td>Following initial adhesion, bacteria grow, multiply, and bind additional bacteria, saliva may contribute to this process by providing a source for bacterial nutrition</td>
</tr>
<tr>
<td>Bacterial clearance is the most common outcome and is facilitated by the binding of salivary components that foster agglutination of bacterial cells or block bacterial adhesions</td>
</tr>
</tbody>
</table>
**Dental Caries**

A dental caries is a bacterial infection that demineralizes the enamel, dentin, and cementum of the teeth. When pH levels are low in the mouth, saliva is not able to provide its buffering capabilities effectively thus; the once hard tissues break down producing dental caries. The more calcium and phosphate that develop in the mouth, the lower the pH will become, further reducing saliva’s defense capabilities. Tooth decay, is caused by bacteria that produce acid by converting carbohydrates into energy (26).

The earliest visible manifestation of dental caries is with the appearance of a small white spot on a smooth surface or a pit or fissure. (28) At this point the demineralization of the tooth is reversible if treated quickly. If oral conditions remain the same, the tooth will continue to be eroded and lose its natural contour forming a cavity. Once a cavity has been formed restorative measures need to be taken to reduce the continuation of the cavity. If that cavity is repaired, as long as the tooth is taken care of, the cavity will not return in that spot. It would be effectively “killed”. However, if left untreated it will eventually result in pulpitis (toothache) and ultimately tooth loss (28).

**Periodontal disease**

One of the most widespread inflammatory conditions on earth, It is associated with bacterial community structures unique from those of health. When inflammation/infection of the gums is left untreated periodontitis occurs. The infection spreads from the gums to the ligaments and bones that support the teeth. This will result in eventually loosening the teeth to the point that they fall out. (27) The inflammation causes a pocket to develop between gums and teeth that fill up with tartar and plaque.

**Oral Diseases are Preventable**

One fourth of children aged two to five years old have tooth decay and half of those aged twelve to fifteen (34). Half of all children and two thirds of young teens aged twelve to nineteen from lower income families have had decay (34).

Children and teens of some racial and ethnic groups and those from low income homes have more untreated tooth decay than those children from less poverty conditions. Forty percent of Mexican American children six to eight years old have untreated dental diseases, compared with twenty five percent of non-Hispanic Caucasian children (34).

Between four and twelve percent of U.S. adults have advanced gum disease as reported by the CDC. Half of these cases are the result of cigarette smoking; the prevalence of gum disease is three times higher among smokers compared to non-smokers.

A quarter of U.S. adults over sixty-five years old have lost all of their teeth (34).

More than 7,800 people, mostly older Americans, die from oral and pharyngeal cancers every year (34).
**Prevention**

The way to prevent oral diseases as a whole is to prevent fermentation of carbohydrates, reduce harmful bacteria, and increase the resistance and cleanliness of teeth.

Using antimicrobial rinses and toothpaste directly reduces dental diseases. Behavioral changes in nutrition and frequency of exogenous intake also play a major role in the health of the oral cavity. By being conscious of how often we eat and drink we are able to reduce the availability of fermentable carbohydrates.

Increasing the resistance of teeth is normally achieved by the use of sealants and fluorides. Sealants are applied to the gaps between teeth. By adding sealants bacteria’s access to these hard to reach areas is limited. Fluorides are used topically and systematically to reduce and prevent dental caries. (28)

**Sealants**

Dental sealants are plastic coatings that are applied to grooves of the back teeth to protect them from decay. The back teeth are the premolars and molars. Sealants protect these vulnerable areas that aren’t always cleaned by brushing and flossing. Permanent molars are most likely to benefit from the sealants. Dental sealants are preferably applied soon after the teeth have emerged to prevent the chance of decay.

The process of applying sealants does not involve any heavy machinery. After the teeth are cleaned a special gel is placed on the teeth momentarily (86). After the tooth is washed off and dried a sealant is painted onto the tooth. Sealants can only be seen up close most are clear, white or slightly tinted usually not noticeable unless examined closely. The sealants can be felt in the mouth but they are very thin and only fill the pits and grooves of the molar teeth (86). Sealants can protect teeth from decay for anywhere up to 10 years per application (86).

Only about one-third of children aged six to nineteen have sealants (34). The map below provided by the CDC (34), shows sealant insertion amongst third-grade students across the country as of 2011.
Fluoride

Fluoride is composed of a natural mineral, fluorine, which is the 17\textsuperscript{th} most abundant element found on earth’s crust in a free state of nature (29). It has been categorized as an essential nutrient by the United States National Academy of Sciences (31). Fluorine only exists in combination with other elements to produce fluoride compounds.

In the case of teeth, fluoride is found in two forms: topical and systemic. Topical fluorides strengthen teeth and increases resistance against bacteria.

Topically induced fluoride is incorporated into the surface of the teeth making them more decay resistant (29). It provides localized protection of the tooth surfaces. Fluoride works during the demineralization and remineralization processes that naturally occur in the oral cavity (30). After exposure, fluoride is found in plaque, saliva and the tooth surfaces where it is able to increase resistivity to acid dissolution (29). It also serves as a reservoir for remineralization of initial caries lesions (29).

Systemic fluorides are those that are ingested (32). When ingested regularly during tooth development, the fluoride is deposited throughout the entire orifice and provides longer lasting protection than those applied topically (29). Systemic fluorides can also give topical protection because they are present in saliva (29). The saliva continually bathes the tooth surfaces providing a reservoir of fluoride that can be incorporated in the prevention of tooth decay (29).

Bhatnagar (29) provides three specific mechanisms in which fluoride prevents tooth decay:
1) It reduces the solubility of enamel in acid by converting hydroxyapatite into less soluble fluorohydroxyapatite/fluroapatite.

2) It exerts an influence directly on dental plaque by reducing the ability of plaque organisms to produce acid.

3) It promotes the remineralization or repair of tooth enamel in areas that have been demineralized by acids.

When fluoride is used regularly, the fluoride ions on the enamel surface not only allow the teeth to be more resistant to decay, but the enamel is also able to repair itself during early stages of dental decay (29).

Topical fluoride used in tooth paste has been shown to reduce caries in children by twenty to forty percent (22). Over 800 studies have shown the effectiveness of fluoride on reduction dental caries (22).

**Fluorosis**

An excess intake of systemic fluoride can lead to dental fluorosis (22). This happens particularly where fluoride levels in public water are high. Fluorosis can only occur in children aged eight years and younger before the teeth have erupted through the gums (33).

The CDC has made community water fluoridation one of the ten great public health achievements of the 20\(^{th}\) century (34). Fluoride’s incorporation into public water systems has reduced tooth decay by twenty five percent in children and adults across the lifespan (34).

Water fluoridation benefits all people of a community regardless of their economic or social status (35). Community fluoridated water, at regulated amounts, is beneficial to both children and adults in preventing oral diseases. Fluoridated water is being introduced into developing countries. Affordable fluoridated toothpaste has been an especially beneficial strategy in aiding developing countries.

**Dental Products that should be available**

Our goal is modify, or create a dental product that will help keep mouths clean when brushing and flossing aren’t readily available. Currently there is a wide array of dental products that are available to the public. There are dental mints, candies, gums, Listerine strips, and more. However, we believe that a gum is the most effective way to improve the health of the oral cavity. The chewing action of gum stimulates saliva, which is the mouth’s main defense system against harmful bacteria. In order to keep a healthy mouth, saliva needs to active.

The ingredients that should go into the gum are of vital importance. Currently there are sugar-free gums on the market that are helpful in cleaning the mouth but they have many additives that are there to help provide longer shelf life. These ingredients can be substituted with healthy, slightly more expensive, ingredients.

**Dental Products Currently On The Market**
Sugar-free chewing gum is one of the best additions to prevent oral disease. Chewing gum helps clear out food stuck to teeth. The chewing action itself stimulates saliva. There are also mints and other candies available but they are less effective in preventing tooth decay.

When looking for a good chewing gum, look for the ADA seal. This seal provides an assurance that the gum has been evaluated for safety and effectiveness, by scientific experts (36).

All about Gum

Gum, which is perhaps the world’s oldest confection, began as an edible treat from trees. The ancient Greeks chewed a mastic sap from the mastiche tree. The Mayans enjoyed chewing on tsiclle, the sap of the sapodilla tree. Native Americans living in what is now New England chewed on the sap of spruce trees. Spruce-sap was brought into the US market in the mid 1800s by entrepreneur John Curtis, who sold small sticks of the gum (37). Interestingly, the first patent for a chewing gum was issued to a dentist, Dr. W.F. Semple, Mount Vernon, Ohio in 1869 (41).

Chewing gum is very popular, with the average American chewing 300 sticks (1.5lb) of gum a year according to CEN (37). Over 374 billion pieces of gum are sold worldwide every year, representing 187 billion hours spent chewing gum based on each piece being chewed for 30 minutes (41). Chewing gum can thus be assumed to play a major role in the overall health of the mouth.

Most people are used to gums as being a candy, but in this case the gums are made in order to protect the teeth. The ADA evaluates gums submitted to them and backs the science behind them if the gum passes their guidelines.

What’s Gum made of?

Gums normally consist of:

a) Gum base
b) Artificial sweeteners (such as aspartame, sorbitol or mannitol)
c) Softeners (glycerin or other vegetable oil products)
d) Flavorings and colorings (36)

The process for making gum

a) Gum base ingredients are melted together
b) Other ingredients are added until the warm mix thickens like dough
c) Softeners (glycerin or other vegetable oil products)
d) Flavoring and colorings (36)

Gum Base
Gum base gives chewing gum its physical characteristics, like its chewing ability, or its elasticity, plasticity, and hardness. It is made of special polymers, waxes and softeners, which give it its texture and also functions to hold and deliver the other ingredients in gum, such as its sweet flavor and other beneficial ingredients, to the mouth (61).

Gum bases come in many different forms depending on the ingredients it needs to carry and its form, for instance if it is a bubble gum or just a chewing gum (61). Because of this there are over 200 different kinds of gum bases (61). The gum base for sugar or sugar-free, acidic or non-acid flavors, and the shape of chewing gum if it is a: dragees, sticks, tabs, chunks, balls, filled gum… each one has a different gum base.

Types of chewing gum

Cut & wrap

These gum bases are elastic. Because of its big size, the chewing gum is soft, made so by adding liquids like glucose or liquid sweeteners into the formula.

Sticks/Tabs

This gum base is very plastic, allowing the shape to form and stay while it’s being produced. It’s a laminated chewing gum with a high gum base percentage and an adjusted glucose concentration so that the gum isn’t soft, but hard, although with some elasticity.

Pellets/Pillows

This is similar to stick gums with the same production process only a different shape.

Hollow Balls

This is considered a revolutionary product since the gum base is in between that of a cut and wrap and a stick. The gum base has an elasticity less than cut and wrap but has enough plasticity enough to maintain its shape and prevent leaks if it’s filled. It’s also much drier with a low concentration of glucose or liquid sweetener, thus giving it the right hardness with minimal elasticity.

Liquid-filled gum

This is another gum base with a combination of elasticity and plasticity in a ratio that allows for good formation and a good seal. If certain ingredients of gum base are insufficient or excessive the gum base will be deformed.

Gum-filled candy

These are all bubble gum bases.

Compressed chewing gum

This gum base is made of a powder that is compressed and is used in functional and pharmaceutical industries (62).
Why gum?

Recently there has been much research on chewing gum’s effectiveness against dental caries. It is well known that chewing gum increases salivary flow, which allows the buffer capacity of saliva to wash out the mouth and help stabilize pH levels. In a clinical study involving 73 students who chewed 4 pieces of sugar-free gum per day for 8 weeks, a significant increase in saliva was reported (41). The flow rate continued to rise even after the end of the eight-week trial. In another study 24 healthy men and women (12 men, 12 women) aged 20 to 21 years old were given sugar-free gum to chew after two meals a day instead of brushing. The results included a reduction of 14.18% of interdental debris (42). This effect proves that the mechanical aspect of sugar-free gum is beneficial to the oral cavity for new debris left over from food.

Gum research primarily falls into two categories, each of which is characterized by the nature of the mechanism used to clean the teeth. The first mechanism is an anti-caries agent, such as fluoride (40). When testing these agents, it must be demonstrated that the therapeutic agent is the key factor in preventing caries (40). The second mechanism is a mechanical action of saliva stimulated by chewing the gum itself as the primary defense against caries (40). In these studies a focus is drawn on the chewing action itself, and not on the presence or lack of any particular agent in the gum.

ADA acceptance

Products are evaluated upon the request of the company, or upon the initiative of the ADA council. Any company may submit their product to the ADA for consideration for acceptance. In order to receive the ADA Seal of Acceptance products must meet the program’s acceptance criteria with respect to safety, efficacy, composition, labeling, package inserts, advertising and other promotional material (38).

Products are that ineffective or dangerous to the health of the user will be unaccepted. The council may also submit reports on unaccepted products to the editor for publication in The Journal of the American Dental Association.

ADA Gum Acceptance Guidelines

The Company must provide their basic information and a summary of their submission. In relation to the product, much information must be given. The ADA provides the full acceptance program guidelines but for the purpose of this paper it has been shortened.

1) Claims of efficacy
a. Effectiveness claims for the product in labeling and in advertising shall be limited to helping to reduce/prevent tooth decay or to factors that have an effect on reducing/preventing tooth decay.

b. All claims of efficacy, including all health benefit claims and all claims which imply a health benefit, must be documented.

2) Product description
   a. Chemical composition and amounts.
   b. Principles of design.

3) Safety data
   a. Evidence must be provided that the components of the product are safe for use in the oral cavity. Compliance with applicable FDA standards should be provided (where appropriate).
   b. Adequate evidence must be provided that the unsupervised use of the product by the average patient will not be harmful to hard and soft tissues, or restorations.

For sugar free gums without active anticaries agents clinical trials are not necessary. Instead the companies must provide in vivo salivary flow rate tests, in vivo rate of return of plaque pH following a cariogenic snack, and in situ remineralization. Based on the composition of the gum, the council may require additional tests (39).

Gums that contain agents for protection against cavities must have objective data from clinical and laboratory studies demonstrating safety and effectiveness, if the company wishes to make an anticaries claim the council will require at least two clinical caries studies that proves the gum makes a statistically significant caries reduction. The ADA does not specify the study design, and it is up to the company to ensure that it is scientifically sound (39).

**ADA approved gums**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>COMPANY</th>
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<tbody>
<tr>
<td>Dentyne Ice Sugarless Gum</td>
<td>Mondelez International</td>
</tr>
<tr>
<td>ICE BREAKERS ICE CUBES Sugar Free Chewing Gum</td>
<td>The Hershey Company</td>
</tr>
<tr>
<td>Stride Sugarless Gum</td>
<td>Mondelez International</td>
</tr>
<tr>
<td>Trident Sugarfree Gum</td>
<td>Mondelez International</td>
</tr>
<tr>
<td>Wrigley’s Extra Sugarfree Gum</td>
<td>Wm. Wrigley Jr. Company</td>
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<tr>
<td>Wrigley’s Orbit for Kids Sugarfree Gum</td>
<td>Wm. Wrigley Jr. Company</td>
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<tr>
<td>Wrigley’s Orbit Sugarfree Gum</td>
<td>Wm. Wrigley Jr. Company</td>
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**Ingredients in ADA approved gums**

Dentyne Ice Sugarless Gum: Sorbitol, gum base, maltitol, mannitol, glycerin, artificial & natural flavoring, less than 2% of: acacia, acesulfame potassium, aspartame, BHT (to maintain freshness), candelilla wax, soy lecithin, sucralose, titanium dioxide, (for Spicy Cinnamon: Red 40 Lake, Blue 2 Lake)
ICE BREAKERS ICE CUBES Sugar Free Chewing Gum: Peppermint: Xylitol, gum base, maltitol syrup, mannitol, contains 2% or less of: natural and artificial flavor, soy lecithin, maltodextrin, artificial color (Blue 1 Lake, Blue 1), aspartame*, gum acacia, gelatin, acesulfame potassium, BHT (to maintain freshness), neotame, sucralose----- Spearmint: Xylitol, gum base, maltitol syrup, mannitol, contains 2% or less of: natural and artificial flavor, gum acacia, maltodextrin, soy lecithin, artificial color (Blue 1 Lake, Yellow 5 Lake, Blue 1, Yellow 5), aspartame*, gelatin, acesulfame potassium, neotame, BHT (to maintain freshness), sucralose----- Strawberry Smoothie: Xylitol, gum base, maltitol syrup, mannitol, contains 2% or less of: natural and artificial flavor, artificial color (Red 40 Lake, Red 40), soy lecithin, citric acid, malic acid, gum acacia, aspartame*, acesulfame potassium, gelatin, neotame, BHT (to maintain freshness), sucralose ----- *PHENYLKETONURICS: CONTAINS PHENYLALANINE

Stride Sugarless Gum: Sorbitol, gum base, mannitol, xylitol, glycerin, natural & artificial flavors, aspartame, acesulfame potassium, soy lecithin, BHT (to maintain freshness), and any of the following may be present depending on flavor: Blue 1 Lake, Blue 2 Lake, Yellow 5 Lake

Trident Sugarfree Gum: Sorbitol, gum base, xylitol, glycerin, mannitol, less than 2% of: acesulfame potassium, aspartame, BHT (to maintain freshness), natural & artificial flavoring, soy lecithin, sucralose and any of the following may be present depending on flavor: Blue 1 Lake, Red 40, Red 40 Lake, Yellow 5, Yellow 5 Lake, Yellow 6, Yellow 6 Lake

Wrigley’s Extra Sugarfree Gum: Sorbitol, gum base, glycerol, mannitol, natural and artificial flavors, hydrogenated starch hydrolysate, less than 2% of: aspartame, acesulfame K, soy lecithin, BHT (to maintain freshness), colors

Wrigley's Orbit for Kids Sugarfree Gum: Sorbitol, gum base, glycerol, natural and artificial flavors, less than 2% of: hydrogenated starch hydrolysate, aspartame, mannitol, acesulfame K, soy lecithin, xylitol, BHT (to maintain freshness)

Wrigley's Orbit Sugarfree Gum: Sorbitol, gum base, xylitol, natural and artificial flavors, glycerol, less than 2% of: mannitol, citric acid, soy lecithin, malic acid, aspartame, fumaric acid, acesulfame K, BHT (to maintain freshness), colors

Ingredients overview
Sorbitol
Sorbitol is a polyhydric alcohol with half the sweetness of sucrose (52).
It is the most commonly used sweetener in sugarless gums because it’s cheaper than xylitol and easy to make (53).

People make it synthetically from glucose, but it occurs naturally in the body too (54). It helps prevent dental caries because it isn’t metabolized by the bacteria causing dental caries by promoting acidity, however it does not help decrease the concentration of streptococcus mutans (55).

**Maltitol**

Maltitol is part of the polyol sugar alcohol family. It is made by hydrogenation of maltose, which comes from starch. It has a sweet taste similar to sucrose, and is 90% as sweet as sugar (63). But unlike sugar, it doesn’t cause tooth decay. Also, because it’s so sweet it doesn’t need to be used in combination with other sweeteners, making it a good substitute for sugar in sugar-free products.

Maltitol’s main benefit in oral health is its ability to prevent tooth decay (63). Oral bacteria can’t break down maltitol so no acids are produced, and thus no cavities or the erosion of tooth enamel occurs, making maltitol a non-cariogenic substance.

In a study comparing maltitol and xylitol to plain gum base or no gum, maltitol and xylitol were able to reduce plaque acidogenicity and decrease four species of oral bacteria (namely S. mutans, S. sobrinus, A. viscosus, and Lactobacillus). The study was double blind and had children 13 to 15 years old as test subjects with a 10g consumption of polyol per day. This study showed maltitol was just as effective as xylitol in helping with oral hygiene (64).

**Mannitol**

Mannitol is a small 6-carbon chained chemical that is water-soluble controlling hydration (65). Because of its natural properties it is often used as an osmotic diuretic that works mainly on the kidney. It balances water hydration within the gum.

**Glycerin**

Glycerin is a trihydroxy sugar alcohol that is also an intermediate product in the metabolism of carbohydrates and lipids. It mainly functions as a water-attracting molecule, making it a good moisturizer. It has many uses such as a solvent, emollient, pharmaceutical agent, and sweetener (66). But, its most common use in medicine is as a moisturizer mostly used for dry skin and minor skin irritation. As an emollient it softens and moisturizes (67). It also, belongs to the polyol family, which is why it has a sweet taste (68).
Acacia

Acacia comes from the acacia tree, released in a gummy form. It’s a water-soluble dietary fiber, and in medicine is taken to reduce cholesterol levels and helps in weight loss because it makes people feel full (69). When in chewing gum, the Acacia functions as an antimicrobial and acts against Streptococcus fecalis (70). It does this by inhibiting the enzyme dextranucrese in streptococcus mutans thus preventing sucrose metabolism, which is responsible for dental caries (71).

Acesulfame potassium

Acesulfame potassium is an artificial sweetener used in foods and beverages. It’s 200 times sweeter than sugar and is calorie free since the body doesn’t metabolize it and quickly excretes it. Not only is it sweet but also it stays sweet for a long time, increasing a candies shelf life, and its good in food processing because it is not lost when foods are being baked or heat processed (72). It is also commonly found along with other sweeteners (73).

Aspartane

Aspartane is 200 times sweeter than sugar and is broken down in the body into two amino acids asparatic acid and phenylalanine, and a little bit of menthol. However, in food processing unlike acesulfame potassium, aspartame is lost in high heat temperatures (74). There are concerns about cancer seen in animal lab studies, however the FDA has approved it as a safe food additive since there are minimal health effects in humans (75).

BHT

BHT stands for butylated hydroxytoluene. It is a synthetic antioxidant used in food as a preservative (76). There were concerns of it causing cancer, since it is metabolized in the body through complex, pathways and animal studies had shown tumors grow, however very low dose proved BHT is safe to use (77).

Candelilla wax

Candelilla wax is a hard and brittle wax that’s commonly found in cosmetic products (78). It’s insoluble in water, but soluble in organic solvents. It’s an ingredient used in gum base (79).

Soy lecithin

Soy lecithin is a phospholipids that is extracted from soybean oil. It has emulsifying properties and is useful to cells since it is a good source of choline, which is part of cell membranes (80).
Sucralose

Sucralose is a sugar that comes from sugar, but has no calories and is 600 times sweeter than sucrose (81). Its perceived taste is similar to sugar, but it’s not broken down in the body like sucrose it simply passes through the body. It also isn’t used in the metabolism of bacteria, making it a good sugar substitute without the dental caries (82).

Titanium dioxide

Titanium dioxide is a mineral that is used in both cosmetic products and food. Its use is as a pigment (83) Titanium dioxide is normally used in tiny amounts, near the end of the ingredient list, and gives the product its color.

Citric Acid

Citric acid is a weak acid found in fruit. It is a natural preservative and is added to food to give a sour taste. Because of its acidity it can promote tooth decay (84).

Xylitol

Xylitol overview

Xylitol is an alcohol found in plants, fruits and vegetables. It’s used as a sugar substitute in “sugar-free” chewing gums, mints, and other candies, and it’s a good sugar substitute for people with diabetes. Xylitol is an ingredient added in chewing gums because of its sweet taste and it has beneficial qualities in oral health care since it was found to prevent tooth decay and dry mouth. It’s the chewing gums company solution to a sweet gum without the tooth decay that regular sugar causes in the mouth. This is because unlike sugar, xylitol is not converted into an acid that causes tooth decay, and xylitol actually reduces the number of decay-causing bacteria in saliva (56).

Effects of short-term xylitol gum chewing on the oral microbiome

Xylitol is a sweetener that has beneficial effects on oral health (57). Clinical trials showed a daily dose of 5grams of xylitol or more seems to be effective in reducing caries (57). This was also seen when xylitol used in conjunction with pastilles, syrup, and wipes, and the xylitol was still able to reduce caries occurrence (57). Xylitol in gums and even in consumption specifically reduced the number of mutans streptococci.

The way scientist think xylitol works on mutans streptococci is that xyliotl inhibits its growth, decreases the amount of plaque on teeth, elevates the pH in the mouth, and decreases the adhesive polysaccharides produced by mutans streptococci in addition to inhibiting specific stress proteins (57). However, the main mechanism xylitol reduces mutant streptococci by inhibiting the inducible fructose transport system in mutant streptococci thus inhibiting its
growth. In addition to this, xylitol consumption changes the conditions in the mouth reducing mutant streptococci chances of survival. Xylitol does this by increasing the pH, so acidic loving streptococci can’t live as well in a more basic environment. Xylitol didn’t just reduce mutants streptococci in the mouth, but also in saliva. Its action was shown to be better than sorbitol gum, which did not decrease the amount of mutant streptococci in saliva. However, while xylitol reduces mutants streptococcus it is not a microbicide and in order for xylitol to be effective it has to be given in a high enough dose.

In one particular double-blind study, the short-term effect of xylitol on the mouth was tested. The test had 122 children aged 11-12 volunteer for the study. All were healthy and had a high amount of mutant streptococci in their saliva or plaque, and were randomly put into either the xylitol test gum group or the sorbitol control group. No mouthwash or chewing gum other than the ones tested were used by the children for 5 weeks. They were instructed to take two pieces of gum three times a day, specifically after breakfast and lunch so that 6 grams of xylitol was had per day, or 6 grams of sorbitol was had per day by the control group. The results showed that “apart from a decrease in mutant streptococci, short term use of xylitol chewing gum had no significant effect on the microbiota of children” (57). This is good because while the child’s microbial flora remains in balance the caries causing mutant streptococci is reduced.

Effects of sugar-free chewing gum sweetened with xylitol or maltitol on the development of gingivitis and plaque: a randomized clinical trial.

Xylitol is such an effective ingredient against caries that another study comparing its effectiveness to maltitol and gum base under brushing and no brushing conditions, showed it significantly reduced gingivitis and plaque. The study was double-blind and lasted 3 weeks with the participants taking chewing gum five times a day for 10 minutes (58). Bleeding on marginal probing and plaque scores were used as a measure of success with a lower score being better than a higher score. The result was that with regular brushing chewing gum had no effect on bleeding and plaque scores, however in the no brushing group, chewing xylitol or maltitol gum reduced gingivitis scores compare to chewing gum base, which was not effective in reducing gingivitis since its result was similar to having no gum and not brushing. Therefore in a no brushing situation chewing xylitol or maltitol gum has a beneficial effect on oral health by decreasing the effect of gingivitis. Not only is xylitol good for oral health in a no brushing situation, it can actually prevent caries occurrence in children since it creates an inhospitable environment for the primary caries causing agent the mutant streptococci. In a study of mothers chewing on gums and the incidence of caries in 4-year old children, it was shown that xylitol gum reduced caries incidence in children after their baby teeth erupted, compared to children whose mothers didn’t have gum (59). Another study where xylitol was used in topical syrup for infants 9-15 months old showed xylitol administered 2 to 3 times a day for a daily dose of 8 grams actually reduced the number of decayed teeth in children (60). Therefore, using xylitol can actually prevent early childhood caries.

Other sugar-free gum brands that should be ADA approved and more widely recognized

Xylo dent
Epic Dental
Xlear
Pur Gum

Xylodent gum ingredients: xylitol, gum base, natural flavors, gum Arabic, glycerin, sodium bicarbonate, soy lecithin, titanium dioxide, carnuba wax

Epic dental gum ingredients: xylitol, gum base, natural flavors, lecithin, gum arabic, titanium dioxide, carnauba wax

Xlear Spry gum ingredients: xylitol, gum base, natural flavor (cinnamon oil), vegetable glycerin, gum Arabic, soy lecithin, beeswax

Pur gum ingredients: xylitol, gum base, natural flavors, gum Arabic, carnauba wax, tocopherols

These gums are of particular importance as they limit their ingredients to what is necessary. All of the gums contain xylitol. This additive has a great influence on S mutans and other harmful bacteria that metabolize Carbs and sugars into acids. The xylitol acts to inhibit the growth of those bacteria. Gum Arabic is another helpful additive to the gum. When in chewing gum, the gum Arabic, or Acacia, functions as an antimicrobial and acts against Streptococcus fecalis (70). It does this by inhibiting the enzyme dextranmucrase in streptococcus mutans thus preventing sucrose metabolism, which is responsible for dental caries (71). Cinnamon oil is an under the radar type of ingredient. In studies, cinnamon oil along with cedarwood oil, lemongrass oil, clove oil, and eucalyptus oil also exhibited antibacterial properties against S mutans (85). Including these oils in more gums can be a viable substance to aid in the inhibition of harmful bacteria. These products are aimed directly at the causative factors that destroy the mouth.

What do these Gums do?

All the gums listed above have replaced sucrose with some form of a polyol or “sugar alcohol”. The normal, chief ingredient is xylitol. Plenty of research is available on xylitol effectiveness at reducing the amount of S mutans in the mouth that in turn lowers acidity and dental diseases by not allowing the bacteria to ferment carbohydrates.

What ingredients should sugar-free gums also include?

Cloves

Cloves are the flower buds of tropical trees. This herbal product is used to help treat fever, mosquito bites and help clean the mouth. Clove essential oil should be included in sugar-free gum. It may be as effective as benzocaine in helping to alleviate dental pains, (87) when applied
to the gums, topically (88). If we can manage to include this product in sugar-free gum, the chewing action will act as the medium for the clove to interact with the gums.

**Red Thyme Oil**

Red thyme is an herb and when used as oil it eliminates many harmful bacteria (89). The oil contains thymol, a compound that destroys the bacteria (90). A study done by the Center of Studies of Animal and Veterinary Sciences saw that thyme oil could reduce many food born microbes that can cause human disease (90). If incorporated into a gum, the oil can be used as a flavoring agent.

**Tea tree oil**

Tea tree oil is an extract from tea trees native to Australia (91). A five-week study found that tea tree oil outcompeted both garlic and chlorhexidine (92). The oil was able to destroy both S mutans and other harmful oral microbes. Garlic and chlorhexidine were primarily effective against S mutans. This product would also be helpful at reducing bacteria and maintaining overall health of the mouth.

**Coconut Oil**

This oil has also been found to be helpful at eliminating bacteria and one study found that the oil contains peptide chains that single out a variety of harmful bacteria (93).

With the addition of these oils into a gum, we can create a more natural and effective product. Further research is needed to see if the oils can be implemented into the gum base.

**Xylitol Overview**

In one study, over a twenty-four month period, 750 children aged 8 to 9 years old chewed xylitol gum on school days or chewed no gum at all. The children were broken up into three groups. One group chewing xylitol gums, one a xylitol-sorbitol mix, and the last chewing no gum. Children chewing xylitol gum showed statistically significant reduction in S mutans after the twenty-four month period. The xylitol-sorbitol mix also showed significant reduction in the bacteria but wasn’t as effective as the xylitol only group. After an additional fifteen months had past, some children were examined again for levels of S mutans. After a total elapsed time of thirty-nine months, children still had reduced bacterial growth of S mutans. These results indicate a biochemical relationship between xylitol and S mutans (45). In the turku sugar studies (46,47) xylitol was compared with sucrose in reducing caries. There was a significant difference between the two, favoring xylitol; in both situations salivary flow was the same. In the Belize studies (47,48) xylitol was challenged further with higher levels of carcinogens and still was effective at reducing dental caries. In this study xylitol was compared along side sorbitol, which it out performed. Shyu and Hsu (49,47) also showed that when xylitol in rats had an 86% reduction in dental caries. Xylitol has also been shown to inhibit cytokine expression by a
lipopolysaccharide from P. gingivalis (50,51). Thus, the regular usage of xylitol could possibly help prevent not only cavities, but also periodontal disease and gingival inflammation.

Sugar alcohols simply are when all the oxygen molecules in simple sugar are arranged as a hydroxyl. Polyols contain three or more hydroxyls (47).

**Fundamental properties of polyols associated with remineralization**

A) No reducing group: the lack of a reducing carbonyl group allows xylitol and other alditols to be less reactive and avoid being made carcinogenic (47).

B) Reducing power: sugar alcohol molecules contain “extra” hydrogen atoms, which allows the acidogenicity of dietary xylitol, in the presence of dental plaque, to be relatively insignificant (47).

C) Complexation: the structure of the polyols allows the molecules to form complex compounds with various metal cations and oxyacids (47). With regards to tooth remineralization, the complexes formed between sugar alcohols and Ca(II) are important (47).

D) Free radical scavenging: Polyols, like xylitol, can act as free radical scavengers in biological and experimental systems (47). These scavengers act as antioxidants.

**Dental chews for dogs**

Greenies

Milk-bones

Greenies are a pet treat company specializing in dental chews for both cats and dogs. Backed by the VOHC, Veterinary Oral Health Council, Greenies has created a dog chew that claims to reduce plaque, halitosis, gingivitis, and calculus. A clinical trial done by Quest (42) took sixty dogs between the ages of 2 to 8, all healthy, and split them into two groups for a 28-day trial. Half of the dogs were given dry diets with no dental chew while the other half were given dry diets with the greenies dental chew. Initial recordings of calculus, halitosis, gingivitis, and plaque were recorded. After the 28 day treatment the dogs fed with the dental chew showed significant reductions in all four categories. The mean for gingivitis of dogs who were given the treat was 80% less than those who weren’t. With respect to halitosis, dogs given the treat had a 45% reduction compared to the control group. Test dogs had 32% less plaque than those who did not receive the treatment and the test dogs also had 60% less calculus than the control dogs.

Greenies dental chews use mechanical action to clean the teeth. This method is based on the characteristics and kibble size that provide cleansing of the teeth. Combining increased fiber content with a size and pattern promotes the maximum chewing time and contact with the teeth which is critical to obtaining a dental benefit.

Greenies has also released clinical trials regarding the dental chew’s solubility. According to an independent study done at the University of Illinois, when the dog treats were left in a pepsin solution of pH 2.0 for six hours most of the dog chew had lost its structural stability. The study showed that within 6.8 to 18 hours over 95% of the dog chew was dissolved (44).
Milkbone has also created a dental dog chew very similar to that of greenies claiming to help reduce tartar, and plaque.

The simple chewing action of these treats is sufficient enough and approved by the VOHC to reduce plaque and tartar significantly in dogs. Adding a substance called polyphosphate to the surface of the treats can also help increase the effectiveness of the dog chews (94). Unlike with humans, xylitol is extremely toxic to the canine family (95). Xylitol has caused hypoglycemia, liver failure, seizures, and death, even in low dosage (95). It only takes around 50mg for the effects to begin according to researcher Justine A. Lee (95). In conclusion, although expensive these dental chews are an effective means to improving canine dental health. It is vital however to brush their teeth regularly.

Conclusion

The oral ecosystem is affected by many factors like pH, temperature, acidity, and the nature of the foods we eat. A change in any one of these conditions will bring the mouth out of balance and allow disease to flourish. A preventive mechanism our body has is saliva, which keeps the bacteria and other organisms living in our mouth under control. Being that each individual’s mouth contains a plethora of different microbiota, it is difficult to develop an effective medical therapy. In addition, scientific studies have not shown, at present, a way to effectively reduce harmful bacteria. The problem is finding a solution that can limit harmful bacteria without affecting the normal ecosystem of the mouth.

That being said, it has been shown that chewing sugar-free gum 20 minutes after a meal, for 30 minutes can help reduce dental disease. The ADA has backed several sugar-free gums, all of which replace sugar with a sugar substitute like xylitol or sorbitol. About one gram of xylitol should be in one stick of gum for it to be significantly effective. Six to seven grams of xylitol containing gum was shown to be efficient in prevalence of dental caries. Both xylitol and sorbitol effectively reduce the amount of harmful bacteria but xylitol is the best of the polyols since it targets streptococcus mutans, a main bacteria contributing to dental caries. In addition to xylitol, acacia has been shown to act as an antimicrobial when incorporated into gum. Other than antimicrobial properties, sugar-free gum is particularly effective in preventing dental caries precisely because it’s sugar-free. Bacteria are unable to digest sweeteners like xylitol and sorbitol.

Starving bacteria from sugary food helps prevent dental caries, making sugar-free gum an easy cheap way to promote good dental health. The reason sugary food is bad for our teeth is because when bacteria break down sugar, they release an acidic product into our mouth, which causes our teeth to rot. An acidic mouth is bad for our teeth and a high sugar diet promotes that type of environment.

The main role of sugar-free gum in the oral cavity can prevent the colonization of pathogenic microorganisms and dental caries. Bacteria and our mouths have developed a communal interrelationship that keeps the oral cavity in equilibrium. It must be kept in mind that the gum is not the only mechanism for eliminating bacteria but also must act as a selective force in the destruction of indigenous bacteria. Ingredients in the gum may select for different pathogenic bacteria creating an environment with low pathogenicity and cariogenicity. The great complexity of the oral microbiota makes it difficult to pinpoint which antigens can effectively remove harmful bacteria, however removing a bacteria’s food source like sugar and opting for a gum with xylitol, which tastes sweet to us but is bad for bacteria’s survivability, is a good step on the path for good oral health.
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Letter to the Editor

Sent to Tom Moran at tmoran@starledger.com

April 2, 2014

Dear Editor,

Please consider publishing this letter. We believe this information is of vital importance to the general public as a whole. If you have any questions or concerns, please call me or email us. I can be reached at <Redacted>, Thank you!

**Easy and Affordable Solutions to Preventing Oral Diseases**

Americans chew on average over 300 sticks of sugar containing gum a year. This much sugar is erosive to teeth and gums. Instead, consider chewing sugar-free gum containing Xylitol, a sugar substitute. Chewing 20 minutes after every meal for 30 minutes can help reduce cavities by up to 40%. When looking for these gums try to find one containing around 1g of Xylitol per stick. By chewing sugar-free gum you are helping to stimulate saliva in your mouth, which is the mouth’s primary defense system against dental disease. Most people are used to gums being tasty and stress relieving, but now people can enjoy chewing gum knowing it is actively fighting off all that harmful stuff. So keep on chewing gum, but make it sugar-free gum with Xylitol.

Sincerely,

Ben Kahan and Dr. Julie Fagan Ph. D. Rutgers University 2014