Caries Process and Prevention Strategies: The Host

Video Transcript

Hello and welcome to dentalcare.com's cariology course that focuses this time on the host. This is part three of a 10 part series entitled Caries Process and Prevention Strategies. It's been established that a host must be present for caries to develop. In this course, three host factors, the tooth, saliva, and the oral cavity's immune response are introduced, and the roles in the caries process are explained. One of the things we'd like to do first is to go over a clinical significant snapshots. This is the kind of question you're likely to have with respect to the host itself in your practice. The question here, in managing patients at risk of dental caries, is how should I approach managing host factors in the caries process? The two tissues of the host affected by dental caries are the enamel and the dentin. In young persons enamel is the main tissue that's affected, as no dentin is exposed directly to the oral cavity.

Later in life, when gingival recession has exposed the roots of the teeth, dentin becomes exposed to the oral cavity. So as the first line of defense, it's important to protect the enamel and try to prevent gingival recession. First, saliva bathes all tissues exposed to the oral cavity. In healthy individuals, there is an adequate flow or quantity of this fluid. It helps flush away cariogenic foods and the fluid is saturated with respect to calcium, which reduces demineralization and encourages remineralization. The effects of medication are the most common problem that leads to a lack of saliva. Many prescription and over-the-counter medicines, and some recreational drugs reduce the flow of saliva and cause xerostomia or dry mouth. In cases of dry mouth, caries and erosion are highly prevalent. It's important that the dental professional checks for adequate quantity and quality of saliva and consults with the patient's physician if necessary.

Second, the hard tissue should be protected by a plentiful exposure to fluoride. Brushing twice a day with a fluoride toothpaste is clinically proven to reduce dental caries by more than 50%. Fluoride can also be applied in the office or at home by the use of rinses, gels, and similar products. The roots can be protected from risk of root caries by preventing gingival recession first and foremost, and by practicing safe and general oral hygiene methods. If roots are exposed, they can also be treated with fluoride compounds and the patients should be advised the increased risk of dental caries and the need for thorough oral hygiene of the exposed root surfaces.

Our expectations for you, the dental professional, upon completion of this study, are that you will be able to discuss tooth structure, to be able to describe how the mineral composition and structure of an animal relates to caries. To be familiar with the concept of enamel maturation. To be able to explain what saliva is and how it's produced. To identify the major salivary glands. To explain the nerve control of saliva secretion. To be able to list the physical, chemical, and antibacterial properties of saliva. And to describe the host immune response in the dental caries process.

Caries cannot develop without the presence of a host, which comprises tooth structure, the saliva that surrounds a tooth, and the immune responses of saliva and plasma in the oral cavity. In the caries process, particular attention is paid to the enamel, the hard, outer most layer, because it's the primary contact with cariogenic bacteria and where demineralization first begins. It's also the only tissue of the tooth that does not have the ability to grow or repair itself after maturation. Saliva is also important to consider in the caries process because it has protective properties that can reduce caries risk. It neutralizes pH in the vicinity of the tooth. It assists in remineralization and acts as an antibacterial agent, and it plays a role in the immune response to cariogenic oral bacteria.

The tooth itself has four major tissues, the enamel, the dentin, the dental pulp, and cementum. Enamel is the most mineralized tissue in the body forming a very hard, thin, translucent layer of calcified tissues that covers the entire anatomic crown of the tooth. It can vary in thickness and hardness on each tooth, from tooth to tooth, and from person to person. It can also vary in color, typically from yellowish to grayish white, depending on variations in thickness, the quality of its mineral structure, and surface stains present. Enamel has no blood or nerve supply within it. It is enamel's hardness that enables teeth to withstand blunt, having masticatory forces.

Enamel is so hard because it is composed primarily of inorganic materials. Roughly 95 to 98% of it is calcium and phosphate ions that make up strong hydroxyapatite crystals. Yet, these are not pure crystals, they're carbonated, and they contain trace minerals such as strontium, magnesium, lead and fluoride. These factors make biological hydroxyapatite more sizeable than pure hydroxyapatite. Approximately one to 2% of enamel is made up of organic materials, particularly enamel specific proteins called enamelins, which have a high affinity for binding hydroxyapatite crystals. Water makes up the remainder of enamel, accounting for about 4% of its composition.

The inorganic, organic, and water components of enamel are highly organized. Millions of carbonated hydroxyapatite crystals are arranged in long thin structures called rods, that are four to eight microns in diameter. It's estimated that the number of rods in a tooth ranges from 5 million in the lower lateral incisor, to about 12 million in the upper first molar. In general, rods extend at right angles from the dental enamel junction, the junction between enamel and the layer below it called dentin, to the tooth surface. Surrounding each rod is a rod sheath made up of a protein matrix of enamelins. The area in between the rods is called interrod enamel or interrod cement. While it has the same crystal composition, crystal orientation is different, distinguishing rods from interrod enamel.

Minute spaces where crystals do not form between rods, or minute spaces exist where crystals do not form between rods typically called pores. They contributed to an animal's permeability, which allows fluid movement and diffusion to occur. But they also cause variations in density and hardness in the tooth, which creates spots that are more prone to demineralization, the loss of calcium and phosphate ions when the oral pH becomes too acidic and drops below about 5.5. In the demineralization process that crystal structure shrinks in size while the pores enlarge. Enamel is formed by epithelial cells called ameloblasts. Just before a tooth erupts from the gums, the ameloblasts are broken down, removing enamel's ability to regenerate or repair itself. This means that when enamel is damaged by injury or decay, it cannot be restored beyond the normal course of remineralization.

When a tooth erupts, it is also not fully mineralized. To completely mineralize the tooth, calcium phosphorus and fluoride ions are taken up from the saliva to add a layer of about 10 to 100 microns of enamel over time. There are conditions that can affect the formation of enamel and thus increase the risk of caries. These include the genetic disorder amelogenesis imperfecta, in which enamel is never completely mineralized and flakes off easily, exposing softer dentin to cariogenic bacteria. Other conditions are linked with increased enamel demineralization, such as gastroesophageal reflux disease or GERD, and celiac disease.

Dentin is a hard, light yellow, porous layer of tissue directly underneath the enamel and cementum. Dentin constitutes the largest portion of the tooth and consists of approximately 70% inorganic matter and 30% organic matter and water. Its organic matter is calcium and phosphate ions that form hydroxyapatite crystals as an enamel, but the crystals are 30 times smaller making dentin somewhat softer than enamel. Another way in which dentin is different than enamel is that it is a living tissue with the ability for constant growth and repair. Tiny dentinal tubules that run between this cementum and enamel junction, the interface of crown enamel and the tooth roots, cementum, and the pulp layer beneath it assist in this regeneration process. Cell processes in the pulp layer reach into the tubules, creating new dentin and mineralizing it. Nerves also pass through these dentinal tubules allowing dentin to transmit pain, unlike enamel.

The dental pulp is a soft tissue of the tooth. The chamber containing the dental pulp that underlies and is connected to the dental layer is called the pulp chamber. It contains the coronal pulp within the crown and is continuous with the radicular pulp within the, within the root. Pulp also contains odontoblasts, cells whose biological function is a creation of dentin. It also contains neurons, vascular tissues, fibroblasts, and macrophages. It was long thought that pulp contained lymphatic vessels, but a 2010 Immunohistochemical Staining Study found that under normal conditions, dental pulp does not contain true lymphatic vessels. One area of note is the apical foramen at the end of the radicular pulp. Blood vessels, nerves, and connected tissue pass through this area to reach the interior of the tooth.

Cementum is a thin, light yellow layer of bone like tissue that covers the roots of the teeth. Its main function is to anchor the teeth to the bony walls of the two sockets in the periodontal, by attaching to the periodontal ligament. The cementum is composed of approximately 55% organic material and 45% inorganic material, mainly calcium salts. It joins the enamel at the cervix of the tooth at the cementoenamel junction. In most teeth, the cementum overlaps the enamel for a short distance. In some, enamel meets the cementum in a sharp line. And in a few teeth, there's a gap between the enamel and the cementum, exposing a narrow area of root dentin. Such areas may be very sensitive to thermal, chemical, or mechanical stimuli. Cementum is formed continuously to make up for the loss of tissue due to wear and to allow for the attachment of new fibers of the periodontal ligament to the surface of the root.

Saliva is a mixture of mucus and serous fluid, the term given to body fluids that are pale yellow, transparent, and benign in nature. This mixture is formed by the salivary glands whose structure and function are explained in more detail below. Here's a short and insightful video with Dr. John Featherstone on the topic of saliva.

Saliva is the most important fluid that we have in relation to oral diseases. And saliva is not simply a fluid that keeps the mouth moist, it is full of many components, including calcium phosphate, some fluoride, proteins, antibacterials, lipids, and buffering agents. So saliva in terms of dental decay, first action, is it buffers or neutralizes the acids as the bacteria are producing them or after that. Secondly, it provides calcium and phosphate to slow down the dissolving of the mineral and also to provide calcium and phosphate for remineralization. And fluoride cannot work unless that calcium and phosphate is present. Secondly, it has a large number of antibacterial substances, which slow down the action of the bacteria. And without that, decay would be rampant in all of us, as it's seen when we have situations where the saliva flow is interrupted, or stopped, or slowed down. And in that case, you can put as much fluoride as you like in, and it still will not be enough to balance the pathological effects from the bacteria.

And now the anatomy of salivary glands. These are made up of an acinus, a very shaped cluster of excretory cells and ductile systems. Saliva is formed in the acini, with a serous or watery secretion formed by serous cells and the mucus are viscous secretion formed by the mucus cells. There are three major bilateral salivary glands, the parotid, the sublingual, and the submandibular. The parotid is the largest pair of glands occupying the parotid facial space, an area of posterior to the mandibular ramus, and anterior and inferior to the ear. It secrete saliva through the stents and ducts into the oral cavity to facilitate mastication and chewing and swallowing. The submandibular are a pair of glands located beneath the lower jaws. Even though they are smaller than the parotid, they produce 70% of saliva, secreted via the Wharton's ducts. These two glands produce true saliva, the combination of serous fluid and mucus.

They also have acini connected to the intercalated ducts, essentially transitional tissue, which then connect striated ducts that have the capacity to modify the mineral content of saliva. On the other hand, the third major set of glands, the sublingual glands, which are located beneath the tongue, secretes mainly mucus and does not have striated ducts, releasing its mucus directly from the acini via excretoty ducts. In the oral cavity, there are also over 600 minor salivary glands. These are found in all parts of the oral mucosa, except for the gingival tissue and anterior hard palate. Each gland is usually a number of acini connected in a tiny labial, and then they have their own excretory duct, or they may share one with another minor gland. Their secretion is mainly mucus and they work to keep the whole, the whole oral cavity coated with this fluid.

The salivary glands are innervated by the parasympathetic and sympathetic branches of the autonomic nervous system. Parasympathetic stimulation favors the serous or watery secretions and occurs via cranial nerves, with the glossopharyngeal nerve innervating the parotid, and the facial nerve innervating the submandibular and sublingual glands. These release acetylcholine and substance P, neurotransmitters that bind to receptors on acinar and ductal cells of the salivary glands. Direct sympathetic stimulation favors the viscous or mucoid secretions and takes place via preganglionic nerves in the thoracic segment of the spinal cord which synapses with postganglionic neurons. These release the neurotransmitter norepinephrine that binds to receptors on the salivary gland acinar and ductal cells. There's also indirect sympathetic stimulation of the salivary glands via innervation of the blood vessels that supply the glands. With both types of stimulation, the binding of neurotransmitters to salivary gland receptors leads to increases and intracellular calcium and alterations in membrane permeability, and a corresponding increase of saliva, as organic material, organic molecules, electrolytes, water, and mucus are created into the acinar lumen.

It has been established that saliva plays a crucial role in reducing caries risk. This is due in large part to saliva's physical, chemical, and antibacterial properties. Due to its water content and flow rate, saliva physically cleanses the oral cavity of food and debris. Unstimulated flow rates are approximately 0.3 to 0.4, milliliters per minute, while stimulated flows are approximately one and a half to two milliliters per minute, although there are wide variations between individuals. Most humans produce between a half to one liter of saliva per day, with 90% secreted from the major glands. Saliva also dilutes and removes organic acids from dental plaque.

Saliva contains a number of electrolytes and organic molecules that minimize decreases in local pH, creating an environment that favors remineralization. For example, sodium bicarbonate and phosphates, along with other salivary components act as buffers or neutralizing agents in saliva. In addition, one salivary protein called sialin tends to raise salivary pH to neutral levels.

Saliva is also super saturated with hydroxyapatite, fluorapatite, and calcium and phosphate ions compared to the carbonated-hydroxyapatite in enamel. This super saturation is maintained by the proline-rich proteins and statherins in saliva, and it increases the likelihood of remineralization via the incorporation of calcium and phosphate into the enamel.

Saliva contains several proteins with different types of antibacterial properties. The mucins are sulfated glycoproteins that trap, aggregate, and clear bacteria. The enzymes called amylases breakdown food particles that stick to teeth, reducing the bacterial buildup that can lead to decay. Lysozyme is a cationinc protein that lyses or damages the cell walls of bacteria, rendering them inactive. Lactoferrin is an iron-binding glycoprotein that deprives bacteria of energy generating iron so that they cannot survive. Peroxidase enzyme is a protein that forms free radical compounds in bacterial cells, which cause them to self-destruct. Immunoglobulins are antigen-binding proteins that block the adherence of bacteria to the tooth surface and or promote the clearance of bacteria from the tooth structure.

Saliva plays a pivotal role in the health of the mouth and contributes to host defense mechanisms through physio-chemical barriers, non-specific innate immunity factors, and specific adaptive immunity factors. Of key importance are the specific factors, which include the immunoglobulins that increase in number when there is exposure to cariogenic bacteria. Here's another short video this time on the topic of diseases that affect salivary flow and caries by Dr. George Stookey.

And while one could list a group of diseases that, that affect dental caries or one could simply categorize the diseases into a single category that involves simply those that either through direct, involvement or through treatment affect salivary function and salivary flow. Anything that reduces salivary flow will surely increase dental caries. Caries attack rates in the absence of saliva can be 10 to 20 times as great as a, as a normal individual. An example of a condition like that could be for example, or cancer of say the parotid gland or, uh, in the head and neck, uh, area where radiation treatments are used to, uh, to treat the disease. Radiation treatments will destroy, uh, the salivary glands and their ability to function. And so inevitably have reduced salivary flow and enormous caries attack rates, uh, in one month equivalent to what would normally be seen in, in perhaps two years in an individual.

Other diseases could be those that, um, that affect renal function and, uh, diabetes, uh, anything that causes the perception of dry mouth or the medications that, that, uh, are used to treat any disease. Um, they may also reduce salivary flow and it's recognized that the majority of medications that are prescribed for, for, for medical reasons, um, have the, the ability to reduce or the, the side effect of reducing salivary flow. So patients on medications are, are almost certainly at risk for increased caries.

And now a discussion of secretory immunoglobulin A, also known as IgA. This is the dominant immunoglobulin in the healthy mouth. SigA is produced by gland-associated immunocytes that are scattered in acini and in clusters adjacent to salivary ducts. SigA is composed of two molecules of heavy and light chains, a secretory component that protects the immunoglobulins from being degraded by proteolytic enzymes and a J chain. This is a unique joining chain, not found in any other immunoglobulin that connects the two IgA molecules into a dimeric structure.

SigA can agglutinate oral bacteria, such as S mutans, modulate enzyme activity, and inhibit the adherence of bacteria to the buccal epithelium and to enamel. It does well at interfering with the initial colonization of caries associated microflora on the tooth surface, but being a salivary protein, it does not always have access to bacteria that are deeper in periodontal pockets. SigA is also a poor activator of the compliment system, the biochemical cascade that helps antibodies physically clear pathogens. It is also a poor opsonizer that does not reliably make bacterial cells susceptible to phagocytosis.

Immunoglobulin G, this type is almost entirely derived from gingival crevicular fluid, now more commonly called gingival fluid. This is a blood exudate, a protein rich fluid that has escape from blood vessels that emerges from the crevice between the gingival and the tooth. It contains immunoglobulin such as IgG, which can be produced by plasma in periodontal pockets. An increase in gingival fluid and IgG to a variety of oral microbial agents, including S mutans, has been seen in response to periodontal irritation and inflammation. Yet IgG to oral microbial agents are also present in the healthy mouth, suggesting that it prevents early stages of plaque development from worsening. Compared to SigA, IgG is strong in compliment-activating and opsonizing that can lead to antibody-mediated phagocytosis. In the absence of inflammation, the naturally low levels of compliment would reduce IgG, and may play a role in modulating oral microflora.

So in conclusion, a primary factor in the development of caries is the presence of a host. A number of host-related sub factors can influence the caries process. These include tooth structure, the physical, chemical, and anti-bacterial properties of the saliva that surround the tooth, and the immunity conferred by the immunoglobulins in the host environment, the mouth. Understanding tooth anatomy and the composition of all tooth tissues, the protective role of saliva, and the two main different types of immune responses by secretory immunoglobulin A and immunoglobulin G will help dental professionals reduce caries risk in their patients.

Okay, let's conclude this section by discussing how this information can help you in your practice. First, fully understanding the host will help to clearly identify evidence-based and scientifically supported interventions to reduce subsurface mineral loss and making decisions regarding your patients at home care and reduction of caries risks. Second, information regarding the host, when communicated at the level of the patient, can be a powerful tool in driving compliance and overall adherence to your at-home oral care recommendations. Describing how caries developed and making the connection to your specific recommendations, instills a strong sense of trust and confidence in patients and can be far more powerful than simply instructing patients to brush more often. Thank you very much.