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Chemistry of Toothpaste

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Dental caries and periodontal diseases are two of the most common chronic human diseases and continue to challenge the field of dentistry[1]. Dental medicine is focused on diagnosing, treating, and preventing diseases and conditions in the oral cavity, or mouth. The structure of a tooth contains a strong outer layer of an inorganic mineral called hydroxyapatite and a solid supporting structure known as dentine[2]. In the oral cavity, the diversity of microorganisms is greater than in any other location in the human body, with more than 750 species. The numerous species of bacteria present in the oral cavity environment are linked to the cause of dental caries, periodontitis, endodontic infection, and the formation of dental plaque[3]. To control some of the diseases listed, it is important to control the formation of dental plaque. Dental plaque consists of bacteria in an organic matrix that resides on the tooth, and that functions to destroy the tooth enamel causing dental diseases like caries[4]. Plaque can be controlled by mechanical removal, antimicrobial toothpaste, and antimicrobial mouthwashes[5]. By practicing good oral hygiene, the formation of plaque can be slowed down and dental diseases can be prevented, especially dental caries, or cavities, which develop as a result of breaking down of the tooth structure. The American Dental Association, ADA, establishes guidelines for recommendations surrounding home oral care. The ADA advises that patients brush their teeth twice a day with fluoride toothpaste, clean between teeth daily, eat a healthy diet low in sugars, and visit a dentist regularly for prevention and treatment of oral diseases[6]. In oral hygiene, the purpose of using toothpaste is to reduce oral bacterial flora and deliver fluoride to the teeth. Fluoride has been found to strengthen the tooth to help prevent and protect teeth against bacterial attack[4]. Understanding the importance of toothpaste in maintaining good oral hygiene, the specific ingredients and function of toothpaste is the focus of this paper.

A dentifrice, more commonly known as toothpaste, is a product encouraged to be used twice a day to maintain good tooth enamel structure. A toothpaste is defined as a semi-solid material that is designed for removing naturally occurring deposits from teeth and is to be used simultaneously with a toothbrush and good technique[5]. Toothpaste is proven to help remove plaque and spread therapeutic ingredients in the oral cavity, by interacting with the hydroxyapatite layer on the tooth structure[7,8]. In addition, it can remove stains caused by the food and drinks that are consumed and prevents bad breath from the oral cavity. In the current consumer market, there are many different products to choose from concerning the patient's preferences and desires with their teeth. Also, it is critical to follow the recommendations of a dentist for a certain formula, ingredient, or brand to use based upon examination of the teeth. From the beginning of time, a good bright smile is synonymous with good health. This has led to growing demands in the field of dentistry to research and develop products to enhance the aesthetic appearance of teeth[9].

History

Furthermore, the progression of toothpaste formulation has evolved immensely from the earliest recorded tooth cleaning preparation in 4000 BCE. In a similar fashion to modern-day goals with oral hygiene products, dentifrices in this time were used for aesthetic purposes aimed at removing odors from the mouth, strengthening teeth, allaying pain, and as a prophylactic for epidemic diseases[1]. In 1500 BCE, Ebers Papyrus was an Egyptian medical manual that was compiled with works dating back to 4000 BCE containing recipes for tooth cleaning preparations[1]. In the Tang dynasty in China, there was mention of a toothpowder dating back to 618-907 AD with components of salt, musk, and ammonia[10]. Hippocrates was the first to suggest dentifrices in his text "*De Morbis Mulierum*" which was prepared by burning the head of one

hare and three mice and taking out the intestines but not removing the liver or kidney. The Romans included components of burnt stag's horn, carbonized heads of mice, goat's feet, eggs shells, snail shells, and pumice powder all mixed with myrrh that would be washed and rubbed on the teeth. In ancient Egypt, the first toothpaste was produced by physicians that consisted of a highly abrasive mixture of pumice powder and white vinegar. The ancient history of toothpaste was fascinating as people tried new products and concoctions to relieve pain and clean their teeth[1].

Likewise, heading into the early 1600s it was published in Italy that the smell in the mouth was arising from the stomach that would then deposit on the teeth. It was instructed to use a rough cloth to remove this decay[1]. With the invention of the toothbrush in 1770, the field of toothpaste products exploded and became desirable to consumers. Toothpaste was being sold before the Civil War and was available in a jar format. In 1841, the idea for a collapsible tube came into play after inspiration from tubes created for artist paints from John Raud. Around 1840, a profession related to oral health began to emerge, with the establishment of schools, a journal, and a society of professionals[10]. In 1850, charcoal toothpaste claimed to be "sharp as diamond dust" and whiten teeth no matter the condition. Then in 1859, William Henry Hall promoted a red liquid dentifrice, Sozodont, the name meaning "save" and "teeth" in Greek[10]. Hall marked the beginning of advertisement strategies for toothpaste, pushing big claims about the function of his product. Dr. Israel Lyon was another early pioneer in the dentifrice field, presenting his product that was a powder because the ADA condemned liquid dentifrices in 1866[10]. Dr. Lyon produced a very successful product that topped sales into the 20th century.

Additionally, in 1890 a new area of preventative dentistry emerged from the research of W.D. Miller declaring the cause of dental caries. Miller described that dental caries were caused

by weak organic acids, produced by oral bacteria acting on fermentable carbohydrates in contact with the enamel[1]. This discovery caused an increase in production and research to find the right agent to prevent this problem of decay. In addition, there was also a concern about the hardness of the product. The degree of abrasiveness of the powder was a concern so that the utilized paste was not to be harder than the tooth enamel[10]. At this point in the toothpaste formulation race, everything that was available is recognizable in today's market. In America, families stopped making homemade toothpaste and started purchasing products on the market[10]. In the 1900s, the formulations of toothpaste switched to more paste and gel construction rather than liquid and powder. The establishment of the ADA in 1932 included a Council of Dental Therapeutics that evaluated the function and claims of all the products on the market. At this point in history, dentifrices were not recommended by dentists because they were not useful in preventing tooth decay. From 1946 to 1960, this was the time of additives in toothpaste formulations. In 1955, Crest introduced its fluoride formulation, claiming to prevent the progression of tooth decay and increase remineralization of the tooth structure. Fluoride products like Crest did not take over the market until 1960, when the ADA recognizes fluoride additives as effective in fighting tooth decay[10]. With the introduction of fluoride, dentifrices were now recommended by dentists to be used on a routine basis to prevent tooth decay[11]. But with the introduction of new products, many advertisements claimed to provide more than their function could deliver.

The leading clash between the dental profession and the toothpaste industry was over advertising. One of the earliest ads for toothpaste appeared in the *New York Times* in 1860[10]. During this time, toothpaste was seen as insignificant compared to the toothbrush, so it was up to advertising to advocate for dentifrices. From newspaper articles to magazines to commercials, the misrepresentations and false claims were outrageous. The deceptive advertisements drew the

public's attention and desire to want an impactful toothpaste to improve their oral health. In *Image 1* below, there are two examples of advertisements that were from products on the market in 1864 and 1921 in America[10]. The advertisement on the left, claims to cure bad breath but also cure the complexion, and leave the skin "soft and white." In addition, an advertisement from Pebeco claims to remove all stains from a smoker's mouth and save the teeth from all the acidic substances that enter the oral cavity. Neither product could deliver what the advertisement claimed.

[Advertisement.]

A BAD BREATH THE GREATEST CURSE THE HUMAN FAMILY IS HEIR TO.—How many lovers it has separated —how many friends forever parted! The subject is so delicate your nearest friend will not mention it, and you are ignorant of the fact yourself. To effect a radical cure use the "Balm of a Thousand Flowers" as a dentifrice, night and morning. It also beautifies the complexion, removing all tan, pimples and freckles, leaving the skin soft and white. For sale by all druggists.

PEBECO TOOTH PASTE

Even the heavy smoker may have a clean, fresh mouth

Pebeco Tooth Paste restores to the smoker's mouth the clean, fresh taste which makes the first smoke after breakfast so enjoyable.

Pebeco gives instant refreshment to the membranes of the mouth, both in the morning and at night. And it keeps the teeth cleaner.

We do not claim that Pebeco will prevent a smoker's teeth from becoming stained. Teeth should be "scaled" by your dentist at regular intervals.

But Pebeco will keep your mouth fresh. It will keep the teeth clean, and it will check the condition known as "Acid-Mouth," which destroys teeth. The cost of one good cigar will keep a man supplied with Pebeco Tooth Paste for weeks.

LEHN & FINK, Inc.
635 Greenwich Street, New York
Canadian Agents: Harold F. Ritchie & Co., Limited, 10 McCaul St., Toronto

Also makers of Lysol Disinfectant, Lysol Shaving Cream, and Lysol Toilet Soap

Have You "Acid-Mouth" ?

It Is Thought To Be the Chief Cause of Tooth Decay

These Test Papers Will Tell You —Sent Free With 10-Day Trial Tube of Pebeco

There are probably many causes that contribute to decay of the teeth, but dental authorities seem to agree that in the vast majority of cases decay results from over acidity of the mouth. You can easily tell if you have "Acid-Mouth," and also see how Pebeco tends to counteract this tooth-destroying condition, by the simple and interesting experiment with the test papers, which we will gladly send to you upon request.

Moisten a blue Litmus Test Paper on your tongue. If it turns pink, you have "Acid Mouth." Brush your teeth with Pebeco and make another test. The paper will not change color, thus demonstrating how Pebeco helps to counteract "Acid-Mouth."

Just send a post-card for Free Test Papers and 10 Day Trial Tube of Pebeco.

False claims abounded in this 1921 ad with Pebeco stating it defeated acid-mouth as well as doing wonders for smokers.

Image 1: Two advertisements from 1864 and 1921 for toothpaste in America

Ultimately the advertisement schemes were successful and attracted many people to buy different products based on what the companies were claiming[10]. With the continuous testing and evaluation of products by the ADA and researchers, the function of dental therapeutics is documented and tested. The ADA provides a list of accepted products all containing fluoride that are been evaluated and received the ADA's Seal of Acceptance[11]. A convenient logo is placed on all products on this list, making it easy for the consumer to evaluate the options for dentifrices.

Components of Toothpaste Formulation

The following section of the paper will analyze certain components included in the composition of conventional toothpaste. This is not an exhaustive list, but the most important aspects are highlighted, and their function is further explained.

Abrasive

Following the history of the production of toothpaste, today's modern production of synthetic toothpaste consists of four major components. These include an abrasive, sudser, sweetener, and flavoring[12]. The first component, an abrasive, is a constituent that functions to remove debris and stains from teeth by polishing the enamel[7]. The Mohr's hardness scale is used to help rank minerals and their relative hardness, resulting in a scale from 1 to 10, with 10 being the hardest mineral. The tooth enamel contains a Mohr's hardness ranking at 6 to 7, whereas common abrasive components rank at 3 on the scale[5]. The tooth enamel is a harder mineral and will not be damaged by components that are softer, so the abrasive component has been selected with tooth enamel hardness in mind. In addition, the particle size on an abrasive component should be 20 μm or less to avoid damage to the tooth surface and gums. Abrasives are commonly harder than dentine but softer than enamel and are weakly acidic to weakly alkaline[5]. In addition,

abrasion is defined as "the removal of hard tissues mechanically with the introduction of foreign bodies repeatedly to the oral cavity, which comes in contact with the tooth surfaces[13]". It is also important to note that abrasives should not be damaging to the tissues in the oral cavity as well as dental restoration work. If there is damage, this could lead to gingival recession, cervical abrasion, and dental hypersensitivity[9].

To reduce the problems that abrasives could cause in the oral cavity by being in toothpaste, dentists and researchers have implemented four different groups of common abrasives. Most common abrasives are white powders that are insoluble in water, including but not limited to calcium hydrogen phosphate, calcium carbonate, silica hydrate, and aluminum hydroxide[7]. Other researchers define abrasives into four major categories such are carbonates, silica, phosphates, and alumina[13]. In America during the 1940s, common abrasives were talc, calcium carbonate, magnesium carbonate, tricalcium phosphate, and pumice. These were all good products to be considered as possible abrasives for toothpaste formulation, however, products like talc were not abrasive enough whereas tricalcium phosphate and pumice were harder than the tooth enamel[10]. The carbonate group of abrasives is a common abrasive included in toothpaste, and mainly includes sodium bicarbonate and calcium carbonate that contains an alkaline pH in the oral cavity. Sodium bicarbonate is a water-soluble white crystalline solid, with a low hardness rating, making it safer to use consistently in the oral cavity. Commonly referred to as baking soda, sodium bicarbonate is not approved by the ADA, because using it alone does not prevent cavities or provide fluoride for remineralization. This method is cost-effective but not recommended by dentists to use due to its lack of antibacterial and cariogenic functions by itself[13]. Furthermore, calcium carbonate is considered the gold standard for an abrasive that was used in toothpaste because of its ranking on the Mohr scale of hardness ranging

from 3.0-3.5. This product has been used for a long time and is a fine, white, odorless, microcrystalline powder that is practically insoluble in water[3]. Calcium carbonate can also function to prevent dentine hypersensitivity by blocking the dentinal tubules by depositing them in the oral cavity.

Furthermore, silica and phosphates derivatives can be used as abrasive components in toothpaste. Silicon dioxide is often the form of silica that is incorporated in toothpaste as a thickening agent or abrasive[13]. This component to be used as an abrasive is often used in toothpastes that contain fluoride because it does not form an insoluble salt with fluoride. In addition, due to the compounds' low refractive index, this abrasive is a good selection to include in a clear gel toothpaste[5]. In addition, silica is often included in some whitening toothpaste formulations because it helps provide a quick brightening, which helps to convey blue covarine to pellicle-covered tooth surfaces. On the other hand, many different phosphate products are added as abrasives and serve to easily clean plaque and polish tooth surfaces[13]. Dicalcium phosphate is an odorless white powder that is a good cleaning vehicle for natural teeth along with composite restorative material. The addition of this product may cause more problems than it solves with excess consumption with conditions like kidney stones, arrhythmias confusion, headaches, nausea, and vomiting. Sodium metaphosphate is another phosphate material that is used in water-free toothpaste, which has strong antimicrobial activity but also has many known side effects. Calcium pyrophosphate is insoluble in water, but soluble in acids. This property gives it strong anti-calculus activity and prevents plaque formation[13]. The last main group of abrasives known to be tested in toothpaste is the alumina group. This abrasive was popular in the 1970s because it offered a cheaper option that posed to have anticaries properties for a long time.

Sudser

The second main component of toothpaste is the sudser or the foaming agent, which functions to disperse the toothpaste in the oral cavity and helps enhance the feeling for the patient. There are two common detergents used as sudsers in toothpaste: sodium lauryl sulfate (SLS) and sodium N-lauryl sarcosinate[7]. These components act to lower the surface tension of water so that multiple bubbles are formed to create a foam. This foam helps to remove particles from teeth because of its composition of an organic alcohol or fatty acid with an alkali metal. The foam created helps to remove debris that is knocked off from brushing and the abrasive component helps penetrate and remove plaque off the tooth enamel. The sudser helps to hold onto these components and remove them from the oral cavity when the toothpaste is expelled from the mouth. The most common sudser component is SLS, a white powder or crystals that are soluble in water and partly soluble in alcohol. SLS shows a high affinity for proteins and is a strong denaturing agent making it effective in removing harmful substances linked to causing caries in dental patients. Some patients have reported some irritation with SLS products creating recurrent aphthous ulcers, so other sudser components are recommended for less irritating effects[5]. The foaming agents are great at dispersion and cleansing in the oral cavity and are advantageous because most components are not toxic or irritating to users. Furthermore, the volume of the foam allows users to feel the thickness of the toothpaste and gives more satisfaction for the user. By lowering the surface tension of the liquid in the oral cavity, other components in toothpaste can gain contact with the tooth enamel. This process of the sudser helps to disperse the flavors of toothpaste and is responsible for the cleanliness feeling that patients describe.

Sweetener and Flavoring

Additionally, the next main components of conventional toothpaste are sweetener and flavoring additions. Arguably two of the most important additions to get patients to want to use toothpaste, the two components function to enhance the taste of the dentifrice. Sweeteners help to improve the flavor of toothpaste giving a mild, sweet, and refreshing taste[5]. Sodium saccharin is the most commonly used sweetening agent, as well as xylitol being a popular addition. Xylitol functions as a sweetener but also has been shown for anti-caries activity because it cannot be fermented by oral microorganisms[5]. Controversies among dentists have arisen with the addition of a sweetener concerning that the addition of sugar is causing more dental caries than it is preventing by using toothpaste. However, the ADA emphasizes that the organization does not approve or place the Seal of Acceptance on any toothpaste with sweetener or flavoring with amounts that could be linked to tooth decay[11]. Furthermore, the flavoring components are water-insoluble essential oils that add a sense of taste to the dentifrice. Common flavoring agents include spearmint, peppermint, and menthol which contribute to the refreshing taste of the toothpaste[7].

Fluoride

Fluoride is a very important element that has changed the face of dentistry based on its ability to provide anticaries effect in the oral cavity. With the routine use of fluoride, caries formation can be decreased at any age. Fluoride has been added to toothpastes, mouthwashes, and drinking water to increase the reduction rate of caries in populations. Fluoride promotes the remineralization of the tooth structure and decreases the incidence of caries and is most effective when the mouth is not rinsed after use[5,14]. As mentioned in the history of toothpaste, fluoride dentifrices were not recognized until 1960 as effective in preventing tooth decay. The market

from that point exploded with fluorinated dentifrices and only toothpaste with fluoride is approved by the ADA[11]. The figure below[15] *Figure 1,* represents this demineralization and remineralization process that is occurring on the tooth enamel.

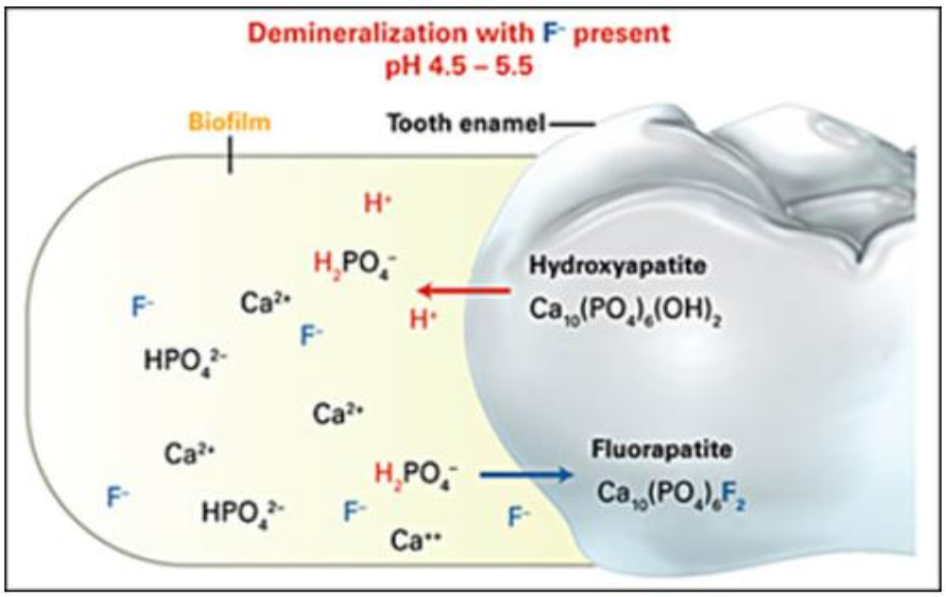

Figure 1: Fluoride Reactivity

Figure 1 is a representation of what is happening on the tooth enamel surface composed of the inorganic mineral hydroxyapatite. The yellow portion of the diagram represents a biofilm formation on the tooth surface or dental plaque. A biofilm is bacteria in an organic matrix that is capable of breaking down the hydroxyapatite outer layer, releasing calcium and phosphate ions into the biofilm[15]. This process is called demineralization of the tooth surface. Remineralization of the tooth enamel in the presence of calcium, phosphate, and hydroxide ions forms hydroxyapatite on the demineralized tooth enamel. On the other hand, if there are fluoride ions present, in adequate proportions, fluorapatite will be formed on the tooth surface supporting the

remineralization process of the tooth[14]. *Figure 2* represents what is happening at the molecular level with this remineralization process with fluoride-containing toothpaste. The replacement of this blue fluoride molecule into the crystal structure of hydroxyapatite results in fluorapatite that is less soluble than hydroxyapatite. With this property, fluorapatite is less likely to experience demineralization with the future formation of biofilm on the tooth surface. This is inherently due to the critical pH of fluorapatite being lower than that of hydroxyapatite, 4.5 to 5.5, respectively[5] . Fluorapatite is less resistant to acids and will also form hydrogen fluoride (HF) when fluoride is present for anti-bacterial actions on the tooth surface. HF can penetrate the bacterial cell membrane and dissociate into H^+ and F^-, leaving fluoride ions available for remineralization[4]. Using fluoride products in daily oral hygiene care will help the oral cavity remain saturated with fluoride and contribute to this process of remineralization[15]. Toothpaste is the main vehicle for this fluoride to get directly onto the tooth surface[5].

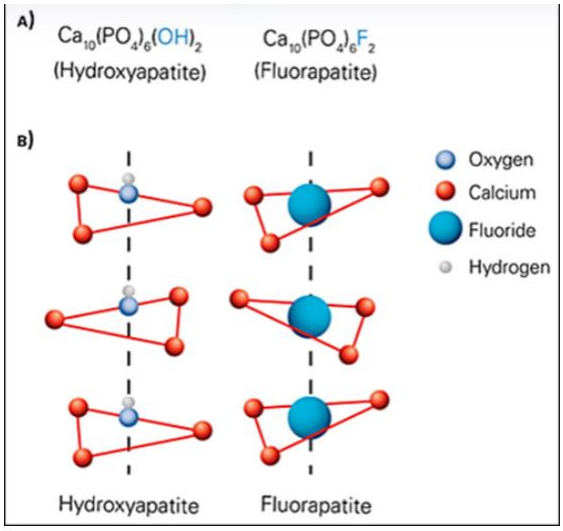

Figure 2: Fluorapatite Formation

Furthermore, there are different forms of fluoride that are included in the formulation of toothpaste and differences in delivering the fluoride for the remineralization process. Fluoride can help protect our teeth from bacteria and acidic materials that break down our tooth enamel[4]. The ADA states that the anticaries agents that are approved are fluoride-containing compounds in the form of sodium monofluorophosphate, sodium fluoride, and stannous fluoride[11]. These are the three main forms of fluoride used in toothpaste formulation due to their compatibility with the active fluoride components and abrasive systems used. The amount of fluoride included in

toothpaste is around 0.10 -0.15% in formulations that are approved by the ADA[5]. It is important to maintain a stable fluoride ion in the toothpaste construction and to not form an insoluble salt with the abrasive system, otherwise, the fluoride ion is not free to incorporate into the remineralization process. Sodium fluoride and stannous fluoride dissociate when entering the oral cavity to provide free fluoride along with the respective cation[15]. Sodium fluoride needs specific compatible abrasives for achieving anticaries benefits and not creating insoluble salts with the fluoride ion. Stannous fluoride is sufficient at adhering to the tooth enamel and forming a protective layer to shield the enamel from the effects of harmful acids. The stannous fluoride component can also cause bacterial reduction for twelve hours after brushing and microbial reduction after four hours, especially with no ingestion of fluids after using the product[16]. Sodium monofluorophosphate is different and requires enzymatic hydrolysis by a salivary enzyme, alkaline phosphatase, to cleave the covalent bond between the phosphate and fluoride, and release the fluoride for remineralization[15,16]. Numerous studies that have been completed by many researchers comparing the effects of different fluoride additions, and which is most effective. The results all depend on the formulation of the toothpaste and how compatible the fluoride is with the other ingredients. With this being said all researchers and the ADA emphasize the importance of using fluoride-containing products to enhance the remineralization process. To earn the ADA Seal of Acceptance, all fluoride-containing toothpastes are evaluated by the ADA's Council on Scientific Affairs to study the amount of available fluoride, fluoride release in one minute, and fluoride absorption in the normal and weakened tooth surface. A complete list of ADA Accepted Toothpastes can be found on the ADA website and each ingredient is listed in and a product evaluation is provided[11].

With the use of fluoride, there have always been concerns with using too much and causing further damage to the human body. Toothpaste in the United States, all contain labels outlining to call the Poison Control Center or doctor in case of excessive digestion of fluoride. This is because of the concern of developing a fluorosis condition because of the high toxicity of fluorine salts that are capable of causing overdoses, ruining bones and teeth, nervous system problems, and cognitive deficits. The risk of developing these symptoms is very low even when using fluoride toothpaste with a high concentration. When comparing the anticaries and antibacterial benefits, fluoride poses many advantages to patients who use fluoride products on a routine basis. The worldwide use of toothpaste with fluoride has shown a significant impact on caries control[16].

Other Components

In addition to the main components described above, there are additional additives to help give toothpaste form and improve its function. An additive known as a binder helps to give form to the toothpaste and prevents the separation of powder and liquid ingredients[5]. Binders function to bind water to help the toothpaste from drying out, especially during storage. Binders also play a role in the speed of the sudser, rate of product dispersal, and the appearance of toothpaste on the brush. Carboxymethylcellulose (CMC) is a widely used binder, because it is physiologically inactive, dissolves in water, shows compatibility, and is a cheaper component for formulation[5]. In addition to the binder, solvents are important in toothpaste formulation. The most common solvent that is sufficient for mixing and dissolving components is water. Also, humectants are included to prevent the loss of water and hardening of the paste in a tube and provide a creamy texture. Common humectants include short-chain polyalcohol like glycerol or sorbitol to achieve this function. Mineral oil is included for the desired softness of the material on the tissues in the

oral cavity[7]. Throughout the advancement of toothpaste and newly emerging research, many different components have been added to manufacturing over the years. Many components have proved successful and beneficial in enhancing the function and performance of toothpaste in the oral cavity.

Whitening Toothpastes

Conventional toothpaste provides many benefits for patients, but many long for more from their toothpaste like whitening effects. The consumer market has played a major role in the demand for products in the research field to achieve whitening effects on teeth. From the beginning of toothpaste and finding a cleaning product for teeth, whiter teeth have been desired and associated with a professional and successful individual. Conventional toothpaste shows no whitening effects, but components included in whitening toothpaste aim to provide aesthetic improvements along with therapeutic benefits like anti-caries effects[9]. Whitening toothpaste and their advertisements should be considered for use with caution, due to many companies providing more claims that the product can provide, and the function of whitening toothpastes may cause harm to the oral cavity. The color of teeth is influenced by a combination of intrinsic and extrinsic stains, and the appearance depends on light absorption and scattering of the enamel and dentine. The color of dentine varies between patients and plays a major role in the overall tooth color[17]. The extrinsic color is linked to what comes in contact with the surface of the enamel through smoking, colored foods, or beverages, and yellowing effects can be amplified by poor brushing techniques. There is a wide range of products on the market claiming to whiten teeth, but abrasives and different chemical agents were focused on for their whitening effects for this research.

As discussed previously, the abrasive component is the main part of toothpaste formulation to maintain adequate hardness for cleaning power, but also not damage the tooth enamel. Whitening toothpaste with a more aggressive abrasive has been shown to whiten the teeth more but could cause roughness on the enamel[9]. With continued use of the abrasive components, the adhesion of dental biofilms can be reduced, and the coloration of the tooth pigmentation can be altered. Brightness and the reflectance on the enamel are possible with excessive use of the more aggressive abrasive components in toothpaste, but the continuous wear down of the enamel is a concern[9]. The primary removal ingredient in toothpaste of stained tooth pellicle formed on the teeth is the abrasive component. The abrasive can remove the stain because the abrasive is usually harder than the stain, but softer than the tooth enamel. However, the abrasive can be limited in its function due to the lack of ability for the toothpaste and brush to reach interproximal areas and areas around the gums[17]. Overall, the abrasive component is effective at removing and preventing the extrinsic stains on the tooth enamel in the oral cavity. With concerns of damage to the dentine and other areas of the oral cavity, additional chemical agents were analyzed to determine their ability to provide whitening effects for the patient.

Furthermore, there are chemical agents like charcoal, optical pigments, and hydrogen peroxide that are added in conjugation with the ingredients in traditional toothpaste to provide enhanced whitening effects. First, charcoal has been a component that has been included in toothpaste for a long time, even in homemade dentifrices. This component has been popular in recent advertisements claiming whitening benefits, but from multiple research articles, there has been little evidence proven that charcoal is a good whitening agent for short-term or long-term effects. The capacity for charcoal to whiten is based on its ability to retain and absorb chromophores in the oral cavity. Charcoal can be activated and is highly porous resulting in high

surface area that is effective in cleaning the tooth. Compared to other methods, charcoal has no immediate effect on whitening when observed during a study in 2018[18]. Another method for whitening teeth is including an optical pigment in the toothpaste. An optical pigment, like blue covarine, is included that will modify the appearance of the tooth enamel. The yellow discoloration is modified by depositing a thin, semi-transparent blue layer on the enamel. When thinking about the color spectrum, blue opposes yellow and will create a whiter, brighter appearance for the tooth by shifting the color with this new film[18]. Additionally, another chemical agent that is popular in whitening formulas is hydrogen peroxide. The peroxide functions to penetrate the tooth tissue and remove the stain molecule, producing a white appearance for the enamel. This method is common in many household bleaching techniques and professional whitening treatments. Hydrogen peroxide is effective in removing both intrinsic and extrinsic stains on the tooth enamel and is not harmful to the tooth structure.

In conclusion, most toothpaste with the technology described above showed a statistically different effect to whiten the teeth compared to the conventional toothpaste with no whitening agents included. The most effective toothpaste was shown to include hydrogen peroxide as the whitening agent[18]. The research that has been completed on whitening toothpaste is helpful to guide professionals in helping their patients select a product that can help them achieve their aesthetic whitening goals. The effectiveness of all these agents is all under the visual perception and daily conditions of patients and professionals.

Discussion

The importance of toothpaste and its complexity in functioning in the oral cavity has been the highlight of this research. The specific ingredients play a role in the performance and maintaining good oral hygiene. As stated previously, part of the ADA's recommendations for

maintaining good oral hygiene includes using fluoride-containing toothpaste twice a day[11]. The recommendation by dentists and oral health professionals for the use is toothpaste is very important, but to maintain good oral health it is more than just toothpaste. Toothpaste is a great preventative technique for dental caries and other oral diseases. Dentifrices also function very well for cleaning and providing patients with a way to practice good oral hygiene in the comfort of their own homes. However, good oral hygiene is more than just toothpaste. The selection of a toothbrush, the technique utilized, mouthwash, and floss are important. As well as, maintaining a healthy diet that is low in sugars, to prevent tooth decay from food and drink consumption. On top of this, visiting a dental professional on a regular basis and trusting their advice on treatment plans and preventive techniques are essential to sustain excellent oral health.

When selecting a toothpaste in today's market, consumers can be easily overwhelmed with advertisements and an array of products available for purchase in a local drugstore. Many times, dental therapeutics are selected based on price, convenience, and advertisements that claim to provide all the benefits for the patient and more. This research emphasized the importance of selecting a toothpaste based on what a dental professional recommends considering the patient's oral health condition and goals for their smile. To select the right conventional toothpaste for a patient, there are several components to consider. First, the abrasive component should be analyzed for its hardness and size in functioning to give a clean appearance to the teeth without damaging the enamel. The hardness of this abrasive molecule is selected to not damage the tooth enamel but to be strong enough to remove plaque and other debris in the oral cavity. In addition, whitening toothpaste tends to incorporate a more aggressive abrasive to provide a whiter and brighter smile for the patients. Hardness and size were a major challenge to toothpaste formulations to be effective in cleaning the oral cavity but not damaging

to the areas. Furthermore, the sudser component was emphasized in toothpaste formulation to offer cleanliness feeling for the patient. The sudser is responsible for the volume of the thickness of the toothpaste and helps to disperse other ingredients in toothpaste, such as fluoride throughout the oral cavity. Another component that was highlighted was the sweetener and flavoring included in toothpaste. The main function is to add taste to make it pleasurable for the user when cleaning the teeth.

Lastly, the mechanism of delivering fluoride to the teeth for remineralization of the decaying tooth enamel was highlighted. Fluoride has changed the face of dentistry in providing anti-caries effects and with routine use can provide effects at any age for patients. The ADA only places its Seal of Acceptance on fluoride-containing toothpaste, because toothpaste is a major vehicle for delivering fluoride in the oral cavity. When available in the oral cavity, fluoride is capable of incorporating itself into the enamel destroyed by acidic foods and bacteria in the oral cavity. This fluoride creates fluorapatite that is stronger and less soluble than hydroxyapatite to further demineralization. With this knowledge and understanding of remineralization, a fluoride-containing toothpaste is recommended by all dentists and the ADA for regular use.

All of the main components listed that are involved in the formulation of toothpaste, must be compatible with each other to be effective in the oral cavity. If an insoluble salt is produced with fluoride, or a certain combination is irritating to users, then it is not an effective dentifrice. When selecting a toothpaste, all of the ingredients listed above are important to consider, especially a fluoride component. Considering conventional and whitening toothpaste selections, consumers should not get lost in advertising schemes and claims. Just as with any product companies want consumers to purchase their product and will claim any result to increase sales. The demand for new products by consumers for aesthetic improvements to smiles will drive

research for those products. When selecting a new treatment or toothpaste, users should be cautious, investigate what the components of the product are, and consult a dental professional to evaluate the intended use.

This research on the importance of toothpaste and the main elements shows how far the industry has come, where it is now, and what advancements can be made to help prevent dental diseases. Health professionals should advocate for scientific-based clinical practice for recommendations for patients to achieve the best possible treatment plan[19]. With restoration and prevention, being a large part of dental professionals' day-to-day jobs, the benefits of toothpaste in preventing oral diseases are extensive. Following the ADA's recommendations for continuing good oral health, could prevent a patient from developing a painful oral disease and save the patient money for restorative treatments. Connecting to my future career aspirations, I hope I can use this research and passion to understand the chemical processes behind topics to further my education and impact future patients in the field of dentistry.

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