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A COMPARATIVE REVIEW OF CARIOGENICITY BETWEEN SUGAR AND STARCH CONTAINING FOOD

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Abstract:

Dental caries is a universal disease that can be found in population of any country. There are many factors that are associated with the formation of dental caries. Environmental changes has lead to a gross change in the habits of eating. Since the dietary changes there has been an increase in the caries incidence globally. Sugar and starch along with various fibre containing food are the main carbohydrates. Carbohydrates are involved in providing body 45-65% of total body calories. Sugars are mainly belonging to monosacchrides and disaccharides classification. Usually complex polysaccharides are starches. There are also sugar alcohols that are neither alcohol not sugars but are called so because they have properties half resembling sugars and half resembling those of alcohols. Review of various studies have shown that the sugars are considered to be more cariogenic as compared to the starches. Turku's study, Spuznar's study, Rugg Gunn's study and Hopewood house study are among the most famous. All of them directly or indirectly support that sugars have a more cariogenic action and that sugars when combined with starches can have a stronger cariogenic effect. And that xylitol containing chewing gums as well as xylitol candies can effectively help limit caries risk because they cannot be fermented by the oral bacteria. Furthermore, regular and moderate use of sugar and starch food and keeping a balanced diet plan along with maintenance of adequate oral hygiene can help reduce incidence of caries. And can ensure maintenance of a healthy oral and systemic health.

Keywords: *cariogenicity, sugar and starch.*

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INTRODUCTION:

The activity of teeth demineralisation and decay is the process of caries. Along with periodontal diseases it is one of the most common universally found disease in any country's population [1]. Even during the ancient Egyptian times when the skulls were examined the teeth were found to be affected by dental caries. Dental caries is one of the most common diseases whose source of origin is still a subject of study in the modern days. Various theories have been presented in regards to the development of dental caries. Hippocrates theory was that the dental caries is a result of deprivation of certain juices. This idea was held by Bourdet, Bell and Seere as late as 1788. Other theories were humoral theory of Galen and the worm theory of Musitanus. However, the modern theory presented by Miller suggests involvement of bacteria in the carious process. And this theory hold its significance up till now [2]

Dental caries affects the vast majority of population from 60-90% of school children to affecting individual in their adult life. The process of caries begins with small areas of demineralisation of enamel that cannot be seen with a naked eye. These areas maybe present at pits and fissures or the developmental grooves, the facial or lingual surfaces or the proximal surfaces above or below the height of contour gingivally or occlusally. These demineralised areas can undergo remineralisation under effective and efficient oral hygiene. However the acids produced by cariogenic food is fermented by the oral microflora causeing loss of calcium and phosphate ion into oral environment. This leads to demineralisation. This in turn reduces the pH of oral cavity. However if the oral hygiene is effective enough this demineralised area will undergo remineralization. And so there exists an equilibrium between demineralization and remineralisation process under normal conditions. However if the pH cross a certain value it will not lead to enamel remineralisation and demineralisation will extend into dentine increasing carious process ultimately leading to pulp of tooth. The pH below which the carious process begins to invade the tooth and demineralisation overtakes remineralisation is known as critical pH. It has a value of 5.5. [3]

Dental caries manifests as spontaneous pain in teeth that may be from sharp shooting pain or maybe prolonged and dull. It can also manifest as sensitivity especially on eating something sweet or drinking something hot or very cold. It may appear as black, brownish white discoloration on teeth and sometimes grossly decayed areas of teeth can also be seen. Pain can also occur when a person bites and the process leads to reversible or irreversible pulpitis if the pulp gets involved (this is inflammation of pulp tissue which can be very painful often times). [4] The cause of dental caries is dental plaque. Dental plaque is a biofilm of bacteria that is organised to a particular structure and function and allows bacteria to attach, adhere and colonize to tooth surface. This dental plaque is very sticky and not easily removed. If effective tooth brushing techniques are not applied this can further lead to bacterial overgrowth and the process of demineralization leads to formation of dental caries. [5] Various cariogenic food are involved in causing caries. The purpose of this article is to make a comparison of various food containing sugars and starches and reviewing the cariogenicity of the two in causing caries.

SUGARS IN FOOD:

There are three basic macronutrients necessary to sustain a healthy life. Carbohydrates, proteins and fats. Carbohydrates are present naturally in many fruits, vegetables, dairy products and grain foods in varying amount. Carbohydrates mainly involves sugars, starches and fibres. Carbohydrates are mainly a combination of 3 basic elements. The carbon, hydrogen and oxygen. Thus the theoretical definition of carbohydrates is any compound containing these 3 elements and having twice as many hydrogen atoms as oxygen and carbon. [6]

When we talk about sugars the word simply brings in mind the table sugar in our kitchen cabinets used as sweetener in various desserts and cooked food. However when we talk about sugars it includes a vast group of complex carbohydrates that we use in our daily lives. They are present in various fruits, vegetables, cereals and other milk and dairy products in differing quantity. [7]

Sugars can be classified as monosacchrides, disaccharides or polysaccharides.

Monosacchrides are those that contain simple sugars examples are glucose, fructose and galactose. When 2 simple sugars join by a chemical bond they form a disaccharides. The most common example of which is table sugar present in our homes. Other examples are maltose and lactose. When more then two sugars join together by a chemical bond they form a polysaccharides. Similarly there are sugar alcohols also known as polyols. These are carbohydrates that one half of it resembles a sugar and one half of it resembles an alcohol whereas they do not belong to sugars or alcohol family. They are also sweeteners and they are not completely absorbed from the body and contribute less to calorific intake of the body and thus helps in weight loss and also has less cariogenic affect

that will be discussed later on. Polyols include sorbitol, mannitol, xylitol,lactitol and isomalt etc they are also used as sweeteners for patients of diabetes. [8]

CARIOGENICITY OF VARIOUS SUGARS:

Caries is mainly caused by the interaction of certain bacteria in oral microflora with the sugar in diet. Sucrose is considered as 'archcriminal' in causing dental caries. [9] There are five main factors that are the responsible cause for the production of dental caries. They are tooth susceptibility, saliva, bacteria, dietary sugars and time of sugar in contact with bacteria. Caries is caused when there is an alteration in the residing oral microflora especially at sites if the dentition is showing stagnation of saliva. Changes in oral flora can also produce microbial imbalance and select certain bacteria that are associated with caries. Brathall stated that dental plaque and microorganism in plaque are directly associated with the process of caries. These caries causing organisms mainly involve the streptococcus mutans and streptococcus sobrinus species. s. Mutans adheres to the teeth in absence of Sucrose because of inherent ability to adhere and cause fermentation of lactose. Thus acid production by s. Mutans mainly depends on sugar intake especially of Sucrose. If there is an excessive use of Sucrose it effects the pH of oral cavity. While the s. Mutans and s. Sobrinus species mainly depends on the fermentation of monosacchrides especially those of glucose and Sucrose and individually through degradation of complex carbohydrates by enzymatic activity of amylase or the combined activity of other bacteria by degrading plaque matrix or salivary mucins.

One study has shown that there are Sucrose specific glucosyltransferases in mutans streptococci that also strongly indicates towards relationship of Sucrose and s. Mutans. it is believed that the bacteria ferment the Sucrose into glucose and fructose by action of s. Mutans invertase, fructosyltransferase or GFTs. The glucose and fructose then undergo a series of glycolytic enzymatic action that leads to production of lactic acid and also alcohol, acetic and formic acids. [10]

There is also little difference in the cariogenic potential of Sucrose and other monosacchrides. A two year longitudinal study carried out in Sweden involved small number of preschool children who had just a mixture of glucose and fructose that if replaced with Sucrose resulted in a lower caries increment in that population. However the difference didn't reach a statistical value. [11] The production of extracellular polysaccharides in plaque similarly depends on Sucrose and that the smooth surface caries will only develop with plaque that adheres due to the formation of extracellular polysaccharides. More recent clinical studies suggest the involvement of glucans and dextrans that have ability to alter plaque ecosystem. It can lead to porosity in plaque which can allow further penetration of dietary sugars and more production of acids adjacent to the tooth surface hence increasing susceptibility to caries production.

Prevalence of caries also depends on consumption and frequency of sugars. It also depends on the adhesiveness from liquid sugars to sticky food and consistency of sugar food in between the extremes. Liquids that mostly are responsible for causing rampant decay as reported by Ericsson [12] or as evident by liquids causing nursing bottle caries [13] and also in experimental human studies investigation by Von arch fehr et Al [14] and Geddes et Al [15]
Vipehol study similarly correlates to frequency and consumption of confectionery and sugar containing gums and found DMF score in a study conducted on 14 years old caucasian, Hawaiian and Japanese school children in Hawaii. An intake of 5 or more sweets per day was followed by a DMF score that mainly reached to the conclusion that frequency of intake was more associated to the cariogenic potential than the consumption. However with the increase in one factor there is an obvious increase in the other factor. [16]

It is also considered in one study that it is actually the low pH that is responsible for increase in s. Mutans species in oral flora than the sugars in diet. The volunteers were asked to rinse with a low pH buffer and an increase in s. Mutans concentration was noticed. Nonetheless, the decrease in pH and sugar are also strongly correlated. Similarly there are many products that have hidden sugars such as marmalades, breakfast cereals, flavoured crisps, caviar, ketchup and in many countries bread. Lactose has less cariogenic potential than other sugars such as Sucrose. [17] However, the following study mainly concerns with the comparative review of cariogenicity of sugar and starches. The hidden sugar in foods and it's cariogenic potential can be documented as a separate topic as well.

INTERACTION OF SUGARS AND BACTERIA:

Caries is associated with a lowering in pH and increase in acidogenic and acid tolerant bacteria especially in the oral environment. Not all bacteria have ability to survive at low pH. S. Mutans and other cariogenic species like fusobacterium, lactobacillus and S. Sobrinus and S. Sanguis are the ones that are able to thrive and overgrow at lowered pH. So there is a direct

effect of Sucrose on the number of these microorganisms in the mouth. Some studies show slight decrease in S. Mutans concentration with a decrease in intake of sugars. While others report that there is 2-5 fold decrease in the S. Mutans concentration with a decrease in uptake of sugars after 8 weeks. There are studies that also suggest caries susceptibility that is inherent among certain individuals. It has been concluded that "individuals with a high risk of caries incidence are almost by definition exposed to a cariogenic diet". Within 5-10 minutes of intake of sugar diet, there is fermentation of the sugar by the S.mutans species and other bacteria that leads to a lowering of pH of oral cavity. This pH decreases until it reaches the critical pH and causes demineralization of enamel and dentine by causing release of calcium and phosphate ions in the oral environment and thus initiating the carious process [18]

SUGAR SUBSTITUTES AND PREVENTION OF CARIES RISK:

With the commercial development and an increasing demand to substitute sugar with some other material that could be used as sweetener in our food has increased the demand of alternative ways to sweeten food. Systematic studies were carried out in Europe on alternate sweeteners and their effect on caries prevention and were published. Aspartame is a dipeptide that is composed of two naturally occuring amino acids that became available in US in 1982. Sugar substitutes can be categorised as intense sweeteners and bulk sweeteners. Intense sweeteners include aspartame, saccharine and sulfame while bulk sweeteners include sorbitol, xylitol and mannitol and so on. Intense sweeteners can not be metabolised by oral bacteria and thus can not produce caries. They are added along with sugars to fruit flavoured soft drinks and other beverages. Naturally occuring sugars in drinks like Sucrose, fructose and glucose can also cause caries. Citric acid and phosphoric acid in beverages can cause dental erosion that can make teeth susceptible to caries. However intense sweeteners seems to have a caries preventive affect.

Bulk sweeteners on the other hand are partially absorbed by intestine leading to osmotic diarrhea. They are not suitable to be given to children under 3 years of age due to this reason. Bulk sweeteners include polyols whereas xylitol is among the most famous for its non cariogenic affect. Turku's chewing gum study [19], the Ylivieska study [20], the Montreal study [21] and the most recent Belize study [22] all have involved use of xylitol chewing gums on their subjects and have shown that xylitol helps in prevention of dental caries. Similar are the xylitol chewing candies that are equally effective as xylitol gums and can be introduced in school based caries control programs. Xylitol though superior to sorbitol at caries prevention still require a more direct evidence based study to compare the xylitol cariostatic action to those of other polyols.

STARCHES IN FOOD:

Starches in food are a major component of our diet. It mainly include cereal grains and are often the primary source of calories, protein, minerals and vitamins. Starches belongs to polysaccharides group of carbohydrates. They may be chains or can form networks of branched chains. Examples are amylose and amylopectins. Cereal starch such as oat, wheat, potatoe, corn and rice have an amylose content varying from 17-28%. Although certain varieties of corn, barely, rice starch contain no amylose and consists entirely of amylopectin [23] The starch in food cannot be taken up by the bacterial cell wall and thus it is hydrolysed by the salivary and bacterial amylase into glucose that is taken up by the bacterial cell wall leading to formation of acids and thus can initiate the process of dental caries. [24]

CARIOGENICITY OF FOOD STARCHES:

Food starches have cariogenic affect similar to those of sugars. However their cariogenic affect varies with their form i.e raw or cooked or whether the starch is in refined form or other. There are certain factors that can establish a sound relationship between food starches and caries potential. There are several critical cariogenic determinants and they are:

1. Intensity (amount and frequency of exposure of tooth surfaces to both sugars and starches)
2. Bioavailability of starches
3. Nature of microbial flora of dental plaque
4. The pH lowering capacity of dental plaque
5. Flow rate of saliva [25]

Similarly cooked and uncooked starches have varying affect on teeth. Cooked starches are thought to be more cariogenic as compared to uncooked starches. At high temperature the starch granules are damaged by heat and the process is termed as gelatinization. These gelatinized starches are more susceptible to enzymatic breakdown and are available to bacterial action hence initiating dental caries. Experiments carried out on suspension of white wheat flour or starch have been found to be highly cariogenic when boiled. Increasing level of plaque acidogenicity of wheat have been presented as;-

Steam flaked < dry autoclaved < extrusion cooked < drum dried < popped wheat. [26]

Likewise, it has been observed that bread is retentive for a longer duration in mouth as compared to potatoes and rice whose rate of clearance is found to be faster than that of bread. Brudevold et Al in 1985 conducted a study to see effect of intraoral demineralization test using enamel slab and the results had shown that the cooked starch was completely hydrolysed in 2 minutes while raw starch required 30 minutes. This significantly showed that cooked starches are cariogenic while uncooked starches have an insignificant cariogenic activity. Commercially available refined starches are also more readily hydrolysed as compared to unrefined starches. This rapidity of hydrolysis of refined starches makes then available to oral microflora that can lead to increase susceptibility to caries. [27]

Starches are broken down into maltose, maltotriose and dextrans in oral cavity by the action of salivary and bacterial amylase. Dextrans together with glucans cause the bacterial plaque to adhere to tooth surface and makes it more sticky in nature. The oral microflora causes fermentation of hydrolysed starch to cause production of acids in oral cavity that reduces pH and the process of demineralization begins to initiate the caries activity.

A COMPARISON OF SUGAR AND STARCH CARIOGENICITY:

45-65% of calories intake of children and adults need a total of 130 gms/day of carbohydrates for proper brain function. The consumption of starch or sugar in food is mainly affected by the meal times and snacking in between the meals. Starch exhibit a more sticky nature as compared to sugars. Due to this reason starch tend to stick to soft tissues and teeth more as compared to sugars. There have been several studies in the past that have tried to maintain a possible correlation of retention of starch diet and dental caries. However, the studies have not shown much significance since the correlation between starch diet and caries risk cannot be assessed properly since retention on soft tissues was associated with caries formation. (Bibby et Al 1951; Gustafson et Al 1953; Ludwig and Bibby 1957; Caldwell 1970)

Kashket et Al 1991 had studied retention of starch diet on teeth like potatoe chips. The studies significantly found out the relationship of sticky starch food as to be one of many causes of caries production on teeth. Thus the study clearly showed that the potatoe chips exhibit a high cariogenic potential similar to that of Sucrose.

Sugar and starch when combined in diet produces an even stronger cariogenic effect than the two consumed indiviually. In vipeholm study sugar in the form of candies and toffees were given to children during meals and in between meals and caries risk and assessment was carried out. The study observed that the caries risk was less on consuming sugars along with meals whereas the caries risk was higher in individuals who took candies in between meals. Similarly the hopewood house study involved giving children a lactovegetarian diet. Caries risk was found to be lower in such children. [28]

Sucrose produce a maximum pH drop of 5.37 of saliva among various food consumed. Maltodextrin and glucose syrup have high cariogenic potential. Refined cereals have been found to be less cariogenic than sugars. Rugg Gunn et al studied correlation of fruits and apples with dental caries. He found no relation between apple and fruits and dental caries increment. [29]

Saliva plays a major role in caries control. Due to its cleaning action, it's buffering property and presence of lysozymes and antimicrobial IgAs and IgGs. A high rate of its secretion together with mastication helps to eliminate sugar and food particles from oral cavity. Since the rate of clearance of sugar diet is rapid as compared to starch diet which has a sticky and retentive nature. The pH drop produced by sugars rapidly return back to neutral pH. On the other hand, the pH drop produced by starches takes up a slower course of returning the pH to normal due to its retention on teeth. Rate of saliva production can also significantly affect rate of clearance of sugars and starches in diet. Saliva production is affected in a number of diseases like malnutrition, sjogren syndrome, mental disorder, use of antidepressants and as a side effect of radiotherapy and chemotherapy. This leads to condition of xerostomia and increases susceptibility of teeth to dental caries. [30]

With time there has been found to be significant variation in the pattern and incidence of caries occurrence. This is probably due to the change in virulence and number of cariogenic organisms. As well as because of changes in environment, changes in diet and other social factors. Changes in breast feeding patterns and sugar consumption [31].

PREVENTION AND CONTROL:

"A clean tooth will not decay" stated J Leon Williams (1852-1931) the first president of American Dental Association. Stephan and Miller provided evidence for this statement saying that the pH of oral cavity drops from 6.5 to 5.0 after rinsing mouth with a Sucrose solution and the pH drop remains same for at least 40 minutes. However, after adequate tooth brushing the

pH drop returns to neutrality and doesn't drop again clearly reflecting that an adequate oral hygiene has strong influence in control of caries risk and initiation. Caries prevalence risk is affected by several factors that are difficult to manage. They include dietary mineral content (i.e the fluoride, calcium and phosphorus in diet), healthcare, oral hygiene habits and education level. Bacterial plaque activity is controlled by saliva flow rate as well as fluoride secretion in the oral cavity.

Rugg Gunn et Al and Burt et Al showed an increase in caries risk from 0.05 to 0.13 new surfaces of carious teeth that had caries per year in children of ages 11-15Y for each tablespoon (20 gms) increase in daily sugar intake. Szpunar et Al found that an additional 5g/day intake of sugar was associated with a 1% increase in incidence of developing caries in a 3Y interval. These studies give an indication that there is a need to have a dietary control and limitation of sugar use in our daily life to prevent caries incidence from occurring. The primary objective to control caries risk can be effectively practised if certain control measures such as those provided by American Dental Association are followed.

There should be use of topical fluoride and water fluoridation of 1ppm should be carried out at public places as well as at community level. Proper nutritional guidelines as well as proper tooth brushing techniques should be followed. Use of fluoridated tooth pastes have also been found to be effective at controlling caries. However, saying that tooth pastes are an enough requirement to control caries would be unrealistic. Proper tooth brushing techniques on tooth surface and proximal surfaces have lead to a gross reduction in proximal caries but little reduction effect has been seen on the pits and fissures caries in children as well as young adults. There should be moderation and balance in the intake of dietary sugars and starches. Since dietary habits regarding consumption of natural sugars and added sugars include frequency of eating, the form of sugar containing food, the sequence in the meal, the presence of buffers such as calcium and the duration of exposure greatly affect caries risk and should be addressed in the dietary recommendation. Balanced diet rich in whole grains, fruits and vegetables along with maintaining a good oral hygiene to maximize optimum oral and systemic health should be taken to reduce the caries risk. A combination of food should be used to avoid risk of caries as well as dental erosion. Use of chlorhexidine mouth rinses, sugarless chewing gums (especially those of xylitol based that stimulate the process of enamel remineralisation) should be incorporated in daily use. Foods that can help bring the pH to neutrality should be eaten. Cheese should be eaten if a person has taken fermentable carbohydrates. It is believed that cheese can help neutralise pH of oral cavity and bring the lowered pH back to normal. Also because cheese has a high quantity of calcium it is a healthy food for teeth and bones. Sugarless gums can stimulate salivary flow rate. For children that are bottle fed, mother's should avoid to feed them with milk, sweetened juices and other beverages at the time of putting children to bed as this can lead to rampant caries.[31] And children should be taught adequate tooth brushing techniques when they learn to eat and drink on their own. Simple tooth brushing techniques that are easy to learn should be taught. There should also be regular dental check-ups after every 6 months to the dental surgeon. And pit and tissue caries should be treated as early as possible in order to avoid further decay of teeth.

CONCLUSION:

There are many factors associated with the production of caries that need to be a topic of further discussion. Changing habits of individuals associated with the changing environment has lead to an increased risk of caries in general population. However, due to unique uptake of disaccharide molecule by S. Mutans species, sugars particularly Sucrose are the most cariogenic of all carbohydrates. Starches such as potatoes, rice and bread have cariogenic potential but they are not as cariogenic as the cooked starches and refined starches. If the sugar and starch are present together in diet they have a caries risk similar to that produced by Sucrose alone. And sometimes the combined effect of sugar and starch is more cariogenic than their effect alone. Thus it can be concluded that sugar play a major role in causing caries whereas starches also play their role which is not as significant as that produced by sugars. Specific measures to prevent caries thus should be followed and dietary habits should be modified such that a balanced diet rich in adequate calories through carbohydrates, proteins and fats should be included in daily routine with appropriate and regular tooth brushing techniques and maintenance of oral and systemic health.

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