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Plaque pH and Dental Retention after Consumption of Different Types of Chocolates

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Objective: Retention of food particles on to the tooth surface is one of the factors which influence its cariogenicity. Higher the duration of retention, greater is the time for which plaque pH remains below critical pH. Objective of this study was to assess the effect of consumption of different types of chocolates on plaque pH and to measure the dental retention.

Methods: Ten healthy volunteers in the age range 20-30 years were included in the study. Five test products—white chocolate, milk chocolate, dark chocolate, caramel chocolate and 10% sucrose solution were administered to each participant. Plaque pH was measured at baseline and at 10, 20, 30 and 45 minutes after using the test products, by using pH indicator strips. Dental retention was assessed using the Patient Hygiene Performance index. Friedman's test was used to compare the mean plaque pH. Wilcoxon signed rank test was used to compare mean of dental retention for different types of chocolate from baseline to 45 minutes.

Results: Caramel chocolate had the maximum decrease in plaque pH at 20 minutes after consumption. The least drop in pH was noted for dark chocolate. At the end of 45 minutes, the dental retention was highest for the caramel chocolate.

Conclusion: Dark chocolate showed the least drop in pH of dental plaque and hence were considered as least acidogenic. Caramel chocolate showed the maximum drop in plaque pH. It also had the highest dental retention rate at the end of 45 minutes.

Keywords: cacao, dental plaque, oral hygiene, dental retention

Introduction

The question of "which tooth paste or tooth brush to use" is a query most commonly encountered by most of the dental professionals. There are numerous studies available in the dental literature comparing the efficacies of tooth brushes and dentifrices. When a parent asks as to what type of chocolate should be sent to school for his/her ward's birthday, we are in a dilemma to give an evidence based reply.

The science of dentistry has existed for long, ever since there has been theorizing about the cause of dental caries. It has been

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generally agreed that dental caries is a disease of microbial origin and that multiple factors influence the initiation and progression of the disease [1]. It is widely accepted that all foods containing "fermentable carbohydrates" have the potential to contribute to caries formation. After the consumption of a fermentable product, the microorganisms in the dental plaque produce acids that leads to lowering of pH and hence dissolution of the tooth structure. The duration for which this pH remains below the 'critical pH' and the capacity of the salivary buffering mechanisms to raise the pH of dental plaque to neutral values is a major determinant in causation of dental caries [1].

Fermentable products, which often have a high retention to the teeth and oral mucosa, give rise to prolonged acid production in dental plaque as compared to the foods that are more easily removed [2]. Retention of food particles on to the tooth surface is one of the factors which influence its cariogenicity. Higher the duration of retention, greater is the time for which plaque pH remains below critical pH. Many studies have been carried out in the past which have assessed the plaque pH after consumption of starchy snack products i.e., soft breads, potato chips, crackers, cheese doodles etc. These studies have not discussed the effect of chocolates which is frequently consumed by children and teenagers in between the meals [2].

Human plaque acidity tests for estimation of cariogenic potential of foods have been frequently used since plaque pH measurements were introduced by Stephen in 1940 [3]. The pH lowering ability differs in relation to caries activity. A limited number of studies have reported on in vivo dental plaque pH changes in relation to caries prevalence or activity [4].

Chocolate, being a source of the sugars, containing both sucrose and lactose, has been implicated as a cause of dental caries [5]. The relative cariogenicity of chocolates is dependent on their composition, texture, solubility, retentiveness and ability to stimulate salivary flow. The composition of the chocolates has profound impact on its cariogenic potential [6]. Chocolates usually contain cocoa in varying concentrations and it has been suggested that increasing concentrations of cocoa in chocolates prove to be less cariogenic [7].

There are a wide range of chocolates available in the market today of varying composition, texture, flavor and sweetness. It is thus natural that the cariogenic potential of these chocolates would also vary. Though there are several studies in western countries that assess the effect of chocolates available [7] and its possible effects on caries by influencing the pH of saliva, there is paucity of similar studies on the chocolates available in Indian market. One study did indeed assess the cariogenicity of filled and unfilled chocolates by comparing the pH of plaque at different time intervals. The study findings suggested that filled chocolates were more cariogenic than unfilled chocolates [8]. Comparing the acidogenic potential of chocolates may help a dentist to give an authenticate advice to parents, help school authorities in formulating a school policy. It may also be useful for policy makers to consider labeling the chocolates.

The objectives of the present study were to assess the effect of consumption of different types of chocolates on plaque pH and to check their dental retention after consumption.

Materials and Methods

An interventional study was undertaken in January to February 2013. The study protocol was reviewed and ethical approval was obtained by the institutional ethical committee (ABSM/EC/3/2011).

1. Study subjects

Ten healthy volunteers in the age range 20 to 30 years, were enrolled in the study after the nature of procedures and possible discomforts and risks had been fully explained and were willing to sign the informed consent. The mean age of the subjects was 19±1.25 years and mean decayed, missing, and filled permanent teeth was 2.5±0.85. The subjects having at least 25 natural teeth in the permanent dentition and willing to refrain from any form of dental treatments during the study period were included in the study.

Subjects having allergy to the chocolates used, or with systemic diseases and using antibiotics and those undergoing orthodontic treatment or using intra-oral artificial prosthesis were excluded from the study.

2. Test products

A preliminary prophylaxis was carried out to remove plaque, calculus and stains from all the teeth. All the subjects maintained proper dental hygiene and were in good dental health, without restorations on any of the designated teeth and further cleaning was not necessary [9]. During each test session one of the following five products (5 g each) was tested: white chocolate (12.9% milk solids, sugar, liquid glucose, partially hydrogenated vegetable oils, minerals and emulsifiers), milk chocolate (21.9% milk solids, sugar, cocoa butter, cocoa solids and emulsifiers), dark chocolate (sugar, fat and cocoa butter and no milk solids), caramel chocolate (caramel, vanilla and chocolate) and 10% sucrose solution (10 ml).

3. Procedure

The subjects were asked to rinse with the sucrose solution for one minute. For the solid test products one minute was given for consumption. The 5 test products were tested on all the subjects. The chocolates were given to each participant at the

same time of the day. The 5 test sessions were administered in a randomized order.

4. Measurement of plaque pH

The volunteers were asked to avoid tooth brushing and all other oral hygiene measures 24 hours before the test procedure and not to eat or drink anything but water for 1 hour prior to the measurements. Baseline/before and at 5, 10, 20, 30, and 45 minutes after using the test products, plaque pH was measured at 2 interproximal sites—the premolar and molar region of the first and the third quadrant respectively [4]. The pH indicator strips (pH 4.0 to 7.0, Spezialindikator; Merck, Darmstadt, Germany) were cut into four pieces (2 mm in width) and inserted into the interproximal site for 10 seconds. The pH value (one decimal) was assessed by comparing the color of the strip with the color index scheme supplied by the manufacturer.

5. Measurement of dental retention

Patient Hygiene Performance (PHP) index developed by Podshadley and Haley [9] was used to score the dental retention from both the buccal and lingual/palatal surface of the 6 index teeth—16, 11, 26, 36, 31, and 46. For assessment, a two tone disclosing agent was used. The disclosing agent was applied with cotton and rinsed after 1 minute. Each tooth surface (facial and lingual) was divided into 5 sections by imaginary lines—mesial third, distal third and middle third. The middle third was further divided horizontally into gingival, middle and occlusal sections. A score of '0' was assigned if plaque/debris was absent and score '1' was assigned if plaque/debris was present. The score was calculated by adding all the values for each sub-division on both buccal and lingual surfaces for each tooth. PHP Index score was calculated by adding all the values for each sub-division divided by the number of teeth examined and interpreted as follows.

Excellent=0
Good=0.1-1.7
Fair=1.8-3.4
Poor=3.5-5.0

Professional cleaning and fluoride application was carried out for all the subjects participating in the study at the end of all the recordings.

6. Statistical analysis

The results obtained were tabulated and subjected to statistical analysis using SPSS statistical package ver. 15.0 (SPSS Inc., Chicago, IL, USA). Comparison of mean plaque pH at various intervals among different types of chocolates was done using Friedman's test with the level of significance of the study fixed for $p<0.05$. Wilcoxon's signed rank test was used to compare mean of dental retention for different types of chocolate from baseline to 45 minutes.

Results

1. Plaque pH

Mean plaque pH for milk chocolate was 6.47 at baseline, which decreased to a minimum of 5.92 at 10 minutes and was 6.37 at the end of the 45 minutes period. The baseline mean plaque pH for white chocolate was 6.49, which dropped to 5.63 at 20 minutes and was 6.14 at 45 minutes. For caramel chocolate mean pH at baseline was 5.96, that dipped to 4.82 and was 5.48 at 45 minutes. A mean pH of 6.45 was noted for dark chocolate, which reduced to 5.78 at 20 minutes and reached 5.91 at the end of 45 minutes. The baseline mean pH for sucrose solution was 5.97, which decreased to 4.97 at 20 minutes and rose to 5.34 at the end of 45 minutes.

Caramel chocolate had the maximum decrease in plaque pH at 20 minutes after consumption when compared to the other types of chocolates. The least drop in pH was noted for the dark chocolate. When compared between different types of chocolates, the pH of plaque started dipping from 0-20 minutes and thereafter a rise in pH was seen. The changes in mean plaque pH were statistically significant according to Friedman's test as seen in Table 1. Figure 1 graphically depicts the changes in mean plaque pH against time for all the test products.

2. Dental retention

Maximum dental retention was seen for the milk chocolate at baseline followed by caramel chocolate, dark chocolate and sucrose solution. However, at the end of 45 minutes, the dental retention was highest for the caramel chocolate and least for sucrose solution as seen in Table 2. The differences in the mean retention were statistically significant according to Wilcoxon signed rank test.

Discussion

Sucrose is considered as the 'arch criminal' for dental caries. Chocolate, being a source of the sugars, sucrose (from table sugar) and lactose (from milk), has been implicated as a cause of dental caries [5]. There is large evidence that has shown both the positive and negative association of chocolate with dental caries [6]. However, the role of chocolate in the causation of dental caries is still questionable as dental caries is a disease of multifactorial origin which results due to the interaction of host, agent and environment.

The formation of dental caries in humans results from the fer-

Table 1. Comparison of mean plaque pH at various intervals among different types of chocolates

Type of chocolate	Time (min)	Number	pH (mean±SD)	Median	Mean rank	Friedman's test
Milk chocolate	0	10	6.47±0.09	6.5	5.9	χ^2=31.948
	5	10	6.25±0.44	6.3	3.4	$p<0.05$, significant
	10	10	5.92±0.46	6.0	1.9	
	20	10	6.09±0.43	5.9	2.5	
	30	10	6.21±0.41	6.1	3.1	
	45	10	6.37±0.42	6.4	4.0	
White chocolate	0	10	6.49±0.18	6.5	5.4	χ^2=29.145
	5	10	6.01±0.27	6.3	3.8	$p<0.05$, significant
	10	10	5.64±0.48	5.8	2.1	
	20	10	5.63±0.54	5.6	1.8	
	30	10	5.99±0.62	5.7	3.7	
	45	10	6.14±0.58	5.8	4.1	
Caramel chocolate	0	10	5.96±0.10	6.0	5.8	χ^2=33.418
	5	10	5.11±0.47	5.3	3.5	$p<0.05$, significant
	10	10	4.84±0.41	4.9	2.2	
	20	10	4.82±0.31	4.8	1.5	
	30	10	5.17±0.39	5.1	3.2	
	45	10	5.48±0.29	5.3	4.6	
Dark chocolate	0	10	6.45±0.15	6.5	5.6	χ^2=19.249
	5	10	6.10±0.09	6.3	3.5	$p<0.05$, significant
	10	10	5.94±0.30	5.5	3.2	
	20	10	5.78±0.49	5.3	2.3	
	30	10	5.87±0.53	5.8	3.1	
	45	10	5.91±0.66	6.1	3.0	
Sucrose solution	0	10	5.97±0.09	6.0	5.9	χ^2=35.810
	5	10	5.42±0.25	5.5	4.1	$p<0.05$, significant
	10	10	5.21±0.25	5.3	2.8	
	20	10	4.97±0.25	5.0	1.5	
	30	10	5.14±0.38	5.0	2.6	
	45	10	5.34±0.27	5.4	3.9	

SD: standard deviation.

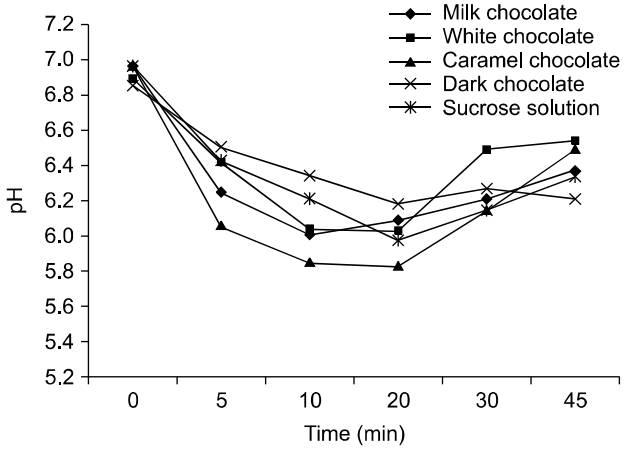

Figure 1. Comparison of mean plaque pH at various intervals among different types of chocolates.

mentation of carbohydrates leading to the production of acid by bacteria on the surface of the teeth which causes a fall in the pH

Table 2. Dental retention for different types of chocolates

	Baseline	After 45 minutes	Wilcoxon signed rank test
Milk chocolate	0.59±0.11 (0.60)	1.06±0.01 (1.06)	Z=−2.809 $p<0.05$, significant
White chocolate	0.59±0.10 (0.59)	1.02±0.04 (1.03)	Z=−2.805 $p<0.05$, significant
Caramel chocolate	0.58±0.12 (0.59)	1.08±0.02 (1.09)	Z=−2.814 $p<0.05$, significant
Dark chocolate	0.59±0.01 (0.59)	1.04±0.03 (1.06)	Z=−2.825 $p<0.05$, significant
Sucrose solution	0.58±0.01 (0.59)	0.59±0.10 (0.60)	Z=−0.877 $p<0.05$, significant

Values are presented as mean±standard deviation (median).

of plaque. When the pH of dental plaque falls below the critical pH of 5.5, it results in demineralization of the tooth. However, due to the protective mechanisms of the saliva, the acids get neutralized and the pH once again rises to the normal resting pH [1].

The relative cariogenicity of any snack food is dependent upon their composition, texture, solubility, retentiveness and the ability to stimulate salivary flow. One of the approaches to estimate the cariogenic potential of food involves estimation of plaque pH changes following ingestion. Foods may be classified as 'cariogenic' or 'cariostatic' [7].

The American Academy of Pediatric Dentistry states that "There is evidence that food containing milk casein, calcium, phosphorus and cocoa, all of which are found in chocolate, may be less likely to contribute to dental caries than sucrose alone or other snack foods" [10].

Kashket et al. [11] conducted a study which demonstrated that soluble, fermentable sugars remained associated with particles of food through-out the time that these were retained on the dentition. Several investigators have studied food retention, but these studies involved measurements of whole-mouth food or the brushings from the teeth and gingivae. Only Ludwig and Bibby (1957) and Kashket et al. [11] measured retention on the teeth [9]. The present study is an attempt to measure the retention of various forms of chocolates on the tooth surfaces, which is a more objective measurement of its harmful effects.

Chocolate is a range of products derived from cocoa, mixed with fat (i.e., cocoa butter) and finely powdered sugar to produce a solid confectionery. There are several types of chocolate according to the proportion of cocoa used in a particular formulation. Chocolates have been mainly classified under three categories—milk, dark, and white chocolate [12]. 'Milk chocolate' is solid chocolate made with milk in the form of milk powder, liquid milk, or condensed milk added. 'White chocolate' is a confection based on sugar, milk, and cocoa butter without the cocoa solids. 'Dark chocolate', also called 'black chocolate', is produced by adding fat and sugar to cocoa. In the present study, we have also included caramel chocolates [12].

Dark chocolate is a colloidal suspension of 65% to 70% cocoa particles and sugar in continuous fat (cocoa butter) phase. Cocoa particles and cocoa butter are constituted in to the matrix through cocoa liquor, while sugar as well as additional cocoa butter is added subsequently in the process. Particle size of sugar and cocoa particles is controlled to <30 μm to avoid grittiness and obtain a smooth in-mouth flow. The fat matrix is tempered to obtain crystal homogeneity of polymorphic β Form-V distribution for desired surface gloss, hardness, product stability and melt-in-mouth character. Milk chocolate differs from dark chocolate notably through the presence of milk solids (milk powder) and milk fat [12]. Composition of chocolates plays a major role in the retention of these chocolates on the tooth surface and their oral clearance. Dark chocolates require relatively greater chewing strokes and oral processing time to be transformed into a ready-to-swallow state. The milk chocolate having a lower apparent solid fat index (at and before 37^{o}C) resulting from the presence of milk fat, is a relatively softer product, while it also demonstrated melting properties relating to an earlier onset and faster rate of melting, as well as lower energy requirements for complete liquefaction as compared to dark chocolate. Milk chocolate is perceived ready-to-swallow before the dark chocolate, and requires lesser chewing activity to be processed to a swallowable state [13].

The changes in the plaque pH were determined by pH indicator strips in the pH range of 4.0 to 7.0 (Spezialindikator). The indicator pH strips are made up of firm plastic material which is easy to shape and fit the interproximal area and does not become soft when wetted. The indicator material is non-bleeding and allowed to be used in food, and thus may be considered as harmless for intra-oral use. Previous study has shown that pH strip method could determine changes in plaque pH to the same extent as 'microtouch method' (correlation coefficient 0.99) [4]. Hence, this easy to handle method was considered for assessment of plaque acidogenicity in the present study.

The results of the present study showed that caramel chocolate had the maximum decrease in plaque pH at 20 minutes after consumption when compared to the other types of chocolates. The least drop in pH was noted for the dark chocolate. When compared between different types of chocolates, the pH of plaque started dipping from 0 to 20 minutes and thereafter a rise in pH is seen. However, the drop in pH was statistically significant only at 5 minutes after consumption of the chocolates. The initial dental retention (0 minutes) was the most for milk chocolate but after 45 minutes, the caramel chocolate showed maximum retention.

The increased drop in pH from 0 to 20 minutes after consumption of caramel chocolate may be due to the increased rate of retention seen for caramel chocolates. It is seen that milk chocolate shows a gradual decline in pH from 0 to 10 minutes and then a steady rise in pH when compared with white chocolate and dark chocolate. This finding suggests that milk chocolate is more acidogenic than the other two. It has been suggested that when milk is added to chocolates to make milk chocolates, the milk may cancel out the beneficial properties of the cocoa mass and make it more cariogenic than the rest [14].

When considering the pH, the dark chocolate seemed to be least acidogenic. The lesser acidogenicity of dark chocolate may be because of the fact that dark chocolate boost the antioxidant levels and also have higher concentrations of un-

saturated fatty acids like oleic acid, fatty acid, palmitic acid and stearic acid [15].

Conclusion

Based on the results of the present study it was concluded that,

・Dark chocolates containing high concentration of cocoa and low concentration of sugar showed the least drop in pH of dental plaque and hence considered least acidogenic.

・Caramel chocolate showed the maximum drop in plaque pH and is considered as most acidogenic. It also had the highest dental retention rate at the end of 45 minutes.

All chocolates may not be having the same acidogenic potential and may not be equally harmful. Labelling the chocolates with their ability to cause a fall in plaque pH may be considered, which can be beneficial for the policy makers. Strip pH method for measuring plaque pH may be used as a simple chair side procedure to educate the patient if found to be effective.

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