In vivo dental plaque pH variation with regular and diet soft drinks

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Abstract

Purpose: Despite the presence or absence of artificial sweeteners in cola drinks, both regular and diet soft drinks still contain phosphoric and citric acid, which contributes to the total acidic challenge potential on enamel. The purpose of this study was to assess the plaque pH, in vivo, after a substrate challenge of diet and regular soft drinks.

Methods: Seventeen subjects were recruited for this study. All subjects were between the ages of 12 and 15 and had at least 4 restored tooth surfaces present. The subjects were given consent by their parents and were asked to refrain from brushing for 48 hours prior to the study. At baseline, plaque pH was measured from 4 separate locations using touch electrode methodology. Each subject was then randomly assigned to one of two groups. The first group was exposed to regular Coke followed by Diet Coke, while the second group was exposed to Diet Coke followed by regular Coke. Subjects were asked to swish with 15 ml of the respective soft drink for one minute. Plaque pH was measured at the 4 designated tooth sites at 5-, 10- and 20-minute intervals. Subjects then repeated the experiment using the other soft drink.

Results: The results showed that regular Coke had significantly more acidic plaque pH values at the 5-, 10- and 20-minute intervals compared to Diet Coke, (P=<.001), when subjected to a t test. The mean pH at 5 minutes for Coke and Diet Coke was 5.5±0.5 and 6.0±0.7, respectfully. At 10 minutes, the pH for Coke and Diet Coke was 5.6±0.6 and 6.2±0.7, respectfully. The pH at 20 minutes for Coke and Diet Coke was 5.7±0.7 and 6.5±0.5, respectfully.

Conclusions: These data suggest that regular Coke possesses a greater acid challenge potential on enamel than Diet Coke. However, in this clinical trial, the pH associated with either soft drink did not reach the critical pH which is expected for enamel demineralization and dissolution.(*Pediatr Dent.* 2002;24:350-353)

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There are several factors that contribute to an acidogenic environment within the oral cavity. Bacterial end products are responsible for the majority of acid production, which occurs shortly after exposure to dietary carbohydrates.[1] The common carbohydrate found in many soft drinks is either sucrose or fructose syrup. Oral bacteria, such as *Mutans streptococcus*, rapidly catabolize these carbohydrate molecules into acidic end products via the glycolytic pathway.[2]

By comparison, phosphoric acid and citric acid, which can be found in practically every commercial soft drink on the market, can have similar acidogenic effects on the enamel.[3-5] Together, phosphoric acid, citric acid and the acid produced by the dental plaque microflora can have a detrimental effect on the dentition. Artificial sweeteners, such as those found in diet soft drinks, are not metabolized by most of the oral bacteria.[6-7] Nevertheless, both regular and diet soft drinks contain phosphoric acid and citric acid. To date, there has been minimal information that has discussed the pH effects on dental plaque comparing regular and diet soft drinks.

The most common methods to monitor changes in intraoral pH include the use of in situ pH microelectrodes, pooling plaque samples from various sites followed by in vitro pH measurements, and the continuous in situ measurements of interdental plaque pH by means of intraoral probes.[6] By using these methods, a number of investigators have demonstrated decreases in acid production with in vitro and in vivo plaque assays utilizing various substrates.[8-14] This study evaluated the effects of diet and regular soft drinks on

Table 1. Comparison Between Plaque pH Changes Caused by Two Different Substrate Challenges: Cola (C) and Diet Cola (DC). Mean pH Values Based on Intervals Recorded at Baseline and at 5, 10 and 20 minutes. Number Based on 4 Tooth Sites per Subject (17 Subjects)

Group	N	Missing	Baseline	5 minutes	10 minutes	20 minutes
			Mean	Mean	Mean	Mean
DC	68	0	6.815±0.559	6.058±0.700	6.215±0.683	6.485±0.535
C	68	0	7.022±0.434	5.518±0.517	5.611±0.604	5.725±0.677
				t=5.115; *P*=<.001	*t*=5.470; *P*=<.001	*t*=7.265; *P*=<.001

plaque pH, using touch electrode methodology, in a pediatric population.

Methods

Seventeen healthy subjects were recruited for this study. Subjects were between 12 and 15 years of age and had at least 4 restored tooth surfaces present. There were no active caries in any of the subjects and all were being actively seen for preventive dentistry care on 6-month intervals. Eligible participants were given an information summary to read with their parent, then the study was verbally explained. Those interested in participating signed an informed consent form which was reviewed and approved by the University of Texas Health Science Center at San Antonio Internal Review Board.

An appointment was arranged for each consenting subject to return. Subjects were instructed to stop brushing their teeth 48 hours prior to the dental appointment so that adequate plaque accumulation could occur. Previous clinical trials have demonstrated this time interval acceptable for plaque accumulation.[15-16] All appointments took place in the morning. Subjects were asked to refrain from eating and drinking (except water) until after their dental visit that day.

Upon subject arrival, compliance with non-brushing and refraining from eating and drinking was confirmed. A baseline pH was measured at 4 sites, (mesial of tooth #3, distal of #10, mesial of #19 and distal of #26). Each subject was then randomly assigned to one of two groups: the first group was exposed to regular Coke followed by Diet Coke; the second group was exposed to Diet Coke followed by regular Coke.

Subjects were asked to swish with 15 ml of the respective soft drink for one minute. Plaque pH was again measured at the selected sites at 5, 10 and 20 minutes. This aspect of time has been shown to be adequate for plaque pH to be buffered significantly.[15-16] The patient then rinsed with deionized water and was allowed to rest during a 20-minute "wash-out" period. The pH was again measured at the selected sites and the subject rinsed with 15 ml of the other soft drink for one minute. Plaque pH was measured at the selected sites at 5, 10 and 20 minutes.

During the entire study, in situ plaque pH was assessed directly using a Beetrode pH Touch Electrode (World Precision Instruments Inc., Sarasota, Fla) connected to a display unit (#BK 143804:pH134; Beckman Instruments, Inc., Fullerton, Calif). This miniature wire electrode was designed for measuring fast pH changes of small samples. Initially, the tips of new and sterilized Beetrode pH sensors were soaked in distilled water for several hours prior to use. Once prepared, the electrodes were stored in a reference buffer (pH 7.0) where calibrations were performed before each subject. In this study, the measurements for each subject were made on 4 predetermined sites. Before each examination where pH measurements were performed, subjects did not brush their teeth for approximately 48 hours prior to their visit. Once the electrode grounding device was placed sublingually, the tip of the electrode was placed into the plaque mass and held in place until the reading on the Beckman unit had stabilized and data was recorded. The electrode was rinsed in distilled deionized water between each reading to protect against cross-contamination.

Results

Power calculations were based on data from a previous unpublished study to determine an appropriate sample size.[15] The standard deviation of the area under the measurement time pH curve was estimated from an analysis of covariance–with the baseline area under the measurement time pH curve as covariate–to be S=0.33 for comparisons between groups. A sample size of 17 subjects completing the study was calculated to provide a power of at least 86% in comparisons between a sugar substitute group and regular group using one-sided testing at an alpha level of <0.05 significance. The power calculation assumed that exactly 4 sites would be measured for each subject.

Table 1 depicts a summary of the data recorded for the two groups analyzed at baseline and at 5-, 10- and 20-minute intervals. The statistical mean was calculated for each group using the *t* test. The difference in the mean values of the two groups at each time interval is greater than would be expected by chance (*P*=<.001). Consequently, there appeared to be a consistent statistically significant difference between the pH values of the two groups. At all three time intervals, regular Coke had a lower pH reading than Diet Coke. However, the lowest average pH was 5.5 at the 5-minute time interval following a rinse with Coke.

Discussion

There are many complex factors that contribute to the total cariogenic and acidogenic potential on enamel. Host, microbial and substrate factors all play a part in the ability or inability of the oral cavity to defend itself against attack.[17]

At first glance, the results of this study indicate that when the oral cavity is subjected to a substrate challenge, plaque

pH levels fall. Initially suspecting this observation to be solely substrate driven, one must also consider other variables that could have influenced the data. The buffering capacity of saliva as well as the flow rate vary amongst individuals and could subsequently create different results in other subject groups.[17] One study, for instance, has shown that plaque pH response was significantly less acidic in children aged 4 to 6 than in adults aged 16 to 35. The study also showed that plaque pH stayed below 6.0 for longer periods in adults.[18]

Other host factors such as the pattern of mastication and the frequency of consumption can contribute to the total acidogenic potential.[17] Weatherall, et al, showed that the pH varied from site to site within the mouth. Plaque on the posterior teeth accounted for a lower pH, whereas the anterior teeth showed a higher plaque pH. The maxillary teeth generally possessed a lower pH than did the mandibular teeth, which was correlated to the rate of oral clearance.[19] The pattern of plaque pH found in that study was also consistent with the data.

Another factor associated with this study's methodology was the way the drink was consumed. The subjects in this study were asked to swish for one minute with either drink. Grobler et al proposed that by drinking through a straw or swallowing a drink quickly, the acidogenic potential was decreased when compared to the swishing of a drink instead.[25] Ireland, et al, also reported that agitation, such as swishing, created a greater rate of loss of ions from enamel than in a static environment.[26] Hence, this report could have been altered had the subjects quickly swallowed either substrate or simply held the substrate still in their mouth.

Some reports have shown comparisons between caries-free groups with groups that have multiple carious lesions. They reported that caries-free groups had generally higher plaque pH scores than did the high-caries groups.[27,28] Had this study utilized a group with multiple caries and active lesions, different data may have been obtained.

Certain microbial factors also play a role in the acidogenic equation. The concentration of acid or base produced by different oral bacteria can lead to either a demineralizing or remineralizing process.[17] However, Aamdal-Scheie, et al, reported that the pH response to sucrose was the same, regardless of the presence or absence of *Mutans streptococcus.*[20] Although this study did not analyze the actual composition of each subject's saliva or the quantity of plaque, further studies could show different results if subjects had a saliva analysis performed prior to the study. In this study, subjects were asked to refrain from brushing for 48 hours to accumulate plaque.

As Luoma, et al, showed in 1970, there is a positive correlation between the magnitude of pH decrease and the amount of plaque present.[21] This idea could also be incorporated into future studies by asking subjects to refrain from brushing for 72 hours vs 48 hours. Consideration of possible irreversible damage to enamel surfaces would definitely have to take priority if such a study were to be done.

In light of the influences that host and microbial factors have on plaque pH, this study primarily focused on the acidongenic potential of two common substrates, Coke and Diet Coke. Coke and Diet Coke have an intrinsic pH of 2.4 and 3.1, respectfully.[4,22] Reports have shown that it is not only the pH of a drink itself that has the potential to erode enamel, but also, more importantly, its buffering effect.[4] Fruit juices, in particular, have a greater effect on enamel erosion, due in part to their organic acid content.

Edwards, et al, reported on the pH effects in vitro on a number of drinks, including fruit juices and carbonated beverages. They concluded, through titration analysis, that fruit juices are more difficult to buffer to a point of neutrality than carbonated beverages. The initial pH value of all the drinks analyzed gave no indication of the underlying buffering capacity, which indirectly is associated with erosion potential. Interestingly, the fruit juices they used all had an initial pH value higher than the carbonated beverages but resulted in a lower buffering capacity.[23]

Various processed drinks also have different levels of sugar and degrees of carbonation, all of which can exert an attack on enamel. One study compared the effects upon enamel microhardness utilizing various sugar-sweetened drinks. The study concluded that, despite the different proportions of glucose, fructose and sucrose found in all of the drinks studied, the effect on the drop in pH remained the same; all sugars were found to have the same effect on plaque pH (24). Since this study compared Coke to Diet Coke, any other brand of sugar-sweetened soft drink that could have been used would probably have made little difference in the results.

Although this study excluded fruit juices, there are some common features between diet and regular soft drinks that need to be considered. Carbonated beverages, in general, have been shown to possess an acidogenic potential due to the presence of carbonic acid formed by carbon dioxide in solution.[23] Since both Coke and Diet Coke are carbonated, it could be deduced that the erosive potential caused by carbonic acid is the same with either drink. This study does not support this erosive potential concept due to the relatively mild reduction in plaque pH.

The presence of phosphoric and citric acid are common ingredients found in either regular or diet soft drinks. It was demonstrated that diet soft drinks caused less of a decrease in plaque pH when compared to regular soft drinks at 5, 10 and 20 minutes following consumption. Studies that have analyzed the pH of various soft drinks, including diet soft drinks, found that the buffering capacity of diet soft drinks may be higher than in regular soft drinks. One study suggested that the sugar content of a regular soft drink created more saliva flow than with diet soft drinks, thereby providing for a greater buffering potential.

The study, however, showed that regardless of the saliva production, regular soft drinks still maintained a lower plaque pH than diet soft drinks. The effect diet soft drinks had on plaque pH remained small and unimportant.[25] Another report also showed that Diet Coke did not lower the pH below 6.0 at any given time, even after a one-minute time interval after consumption. Coke, by contrast, remained

below a pH of 6.0 for over 18 minutes.[22] In this study, the focus was on the change in plaque pH within the first 5 minutes following consumption of either a diet or regular soft drink. As the results showed, regular cola maintained a lower pH than diet cola at the 5-, 10- and 20-minute intervals evaluated.

Conclusions

The consumption of a regular soft drink caused a significantly greater decrease in plaque pH at 5-, 10- and 20-minute time intervals when compared to the consumption of a diet soft drink. However, the pH with either regular or diet soft drinks did not reach the critical pH which is expected for enamel demineralization and dissolution.

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