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Effect of soft drinks on proximal plaque pH at normal and low salivary secretion rates

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Abstract

Objective. The aim of this study was to investigate the effect of different types of drinks on plaque pH during normal and drug-induced low salivary secretion rates. ***Material and methods.*** Three drinks were tested in 10 healthy adult subjects: 1) Coca-Cola regular, 2) Coca-Cola light, and 3) fresh orange juice. pH was measured in the maxillary incisor and premolar region with the microtouch method. The area under the pH curve (AUC) was calculated. ***Results.*** During normal salivary condition, mouth-rinsing with Coca-Cola regular resulted in a slightly more pronounced drop in pH during the first few minutes than it did with orange juice. After this initial phase, both products showed similar and relatively slow pH recovery. Coca-Cola light also resulted in low pH values during the very first minutes, but thereafter in a rapid recovery back to baseline. During dry mouth conditions, the regular Cola drink showed a large initial drop in pH, and slightly more pronounced than for orange juice. After the initial phase, both products had a similar and slow recovery back to baseline. At most time-points, AUC was significantly greater in dry conditions compared to normal conditions for Coca-Cola regular and orange juice, but not for Coca-Cola light. Coca-Cola light generally showed a significantly smaller AUC than Coca-Cola regular and orange juice. ***Conclusions.*** The main conclusion from this study is that a low salivary secretion rate may accentuate the fall in pH in dental plaque after gentle mouth-rinsing with soft drinks.

Key Words: *Dry mouth, oral health, plaque pH, saliva, soft drinks*

Introduction

The consumption of soft drinks is increasing worldwide [1–3]. A large variety of these products have the ability to influence both general and dental health [4–7]. Previous studies have shown that not only product-related factors but also individual-related factors are important in determining their influence on dental health [8–11]. In this regard, saliva is of great importance. The plaque pH response during drug-induced low salivary conditions has previously been evaluated during consumption of solid foods [12,13]. However, little is known with respect to consumption of soft drinks in connection with reduced salivary secretion rate. To date, most studies of plaque pH in relation to the consumption of drinks have been performed on healthy individuals with normal secretion rate [14], although it is well known that the numbers of both children and adults with reduced salivary secretion rate due to diseases and medicines are high [15–20] and that their consumption of different types of soft drinks is common.

Our aim in the present investigation was therefore to measure variations in plaque pH response at proximal sites to various soft drinks in a group of healthy adults during normal and induced low salivary conditions. Our hypothesis was that soft drink consumption promotes a larger pH fall in dental plaque during low, compared to normal, salivary secretion rate.

Material and methods

Subjects

Ten healthy adult volunteers (5 M and 5 F, mean age 38.5 years, range 23–63 years) with a DMFT of 11.5 ±6.9 (range 1–22) were included. They all had a normal salivary secretion rate and buffer capacity

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and were regular test subjects at the Department of Cariology, i.e. subjects in whom it was known that plaque pH would be lowered by at least 1 pH unit after a sugar challenge. The study was approved by the Ethics Committee at Göteborg University and informed consent was signed prior to the study.

Study design and test products

The subjects were asked to attend the Institute of Odontology, Göteborg, Sweden on three different occasions. They refrained from oral hygiene for 3 days and from eating or drinking (except for water) for 2 h before each visit. Each test session comprised two plaque pH experiments carried out one after the other; the first during normal salivary conditions, the second during low salivary conditions (dry mouth). After measuring pH at the normal salivary secretion rate, reduced salivary flow was induced by injection of 0.4 ml methylscopolamine nitrate (Skopyl®, 0.5 mg/ml, Apoteksbolaget, Stockholm, Sweden) submucosally in the labial sulcus, as previously described by Hase and Birkhed [12]. Dry mouth was established within 30 min and lasted for about 1 h, after which the salivary flow gradually recovered over approximately 8 h. In the normal salivary state, the mean $\pm$SD of secretion rate for paraffin-stimulated whole saliva was 2.2 ± 0.8 ml/min, and in the dry mouth state, 0.3 ± 0.3 ml/min.

Measurements of plaque pH

Plaque pH was measured using the microtouch method with a microelectrode ($\varnothing = 0.1$ mm; Beertrode, MEPH-1; W. P. Instruments Inc., New Haven, Ct., USA). The electrode was connected to an Orion SA 720 pH/ISE Meter (Orion Research Inc., Boston, Mass., USA) equipped with a reference electrode (MERE 1; W. P. Instruments Inc.). A salt bridge was established in a 3 M KCl solution between the reference electrode and a finger of the test subject. The electrodes were calibrated before reading the test values; this in accordance with Scheie et al. [21]. Plaque pH was measured at three locations: 1) proximally in the maxillary premolar region on the left side, 2) proximally in the maxillary premolar region on the right side, and 3) proximally between two maxillary central incisors. None of the adjacent measured proximal surfaces were restored or showed any clinical signs of dental caries. Plaque pH was investigated before, during, and after a careful mouth rinse for 2 min with 10 ml of the drink at room temperature. Subjects were requested to rinse gently and to hold the drink in the mouth with only minor oral movements and to be silent during the entire test period. The experiment was repeated with all test products. Plaque pH was measured before rinse of the drink (baseline = 0 min) and 1, 2, 3, 5, 7, 10, 15, 20, 30, 40, 50, and 60 min after the start of the test. The 1-min value was therefore recorded while the drink was still in the mouth.

The stimulated salivary secretion rate was tested before and after injection with methylscopolamine; the unstimulated salivary secretion rate was tested before the measurements during the normal salivary condition. All measurements were performed at the Department of Cariology in Göteborg by one and the same investigator (A.K.J.).

Test products

During each test session, two of the following three products were tested: 1) Coca-Cola regular© (Coca-Cola Bottling Company, Saudi Arabia, degassed; 2) orange juice (Cortina©, Modern Dairies, Saudi Arabia); and 3) Coca-Cola light© degassed (Coca-Cola Bottling Company, Saudi Arabia). The products were brought from Saudi Arabia to Sweden and it was ascertained that their shelf life had not expired at the time of the experiment. The pH of each of the three soft drinks was measured and found to be 2.5, 3.8, and 3.2, respectively. Each session started with measurements during a "normal" salivary state, after which measurements during an induced dry-mouth state were performed. The baseline pH was always re-established before the induction of dry mouth. Products were administered in a randomized order; two individuals did not test Coca-Cola light because they could not attend the test session.

Statistical methods

Mean pH curves for the three sites were calculated and used for descriptive purposes. For the area under the curve ($AUC_{5.5}$ and $AUC_{6.2}$), the measurements of the two premolar sites were combined and the mean value was used, while the central incisor site was used independently. AUC was calculated using specially designed software [22] and calculated for three different time intervals, i.e. 0–10 min, 0–30 min, and 0–60 min. Student's paired *t*-test was used to analyze differences in AUC between normal and dry states. The Kruskal Wallis test was used for testing within-group differences in AUC for the three drinks during both normal and low salivary states. Statistical analyses were performed on an IBM Personal Computer using the Statistical Package for Social Sciences v. 14 (SPSS Inc., Chicago, Ill., USA). Values of $p < 0.05$ were considered statistically significant.

Results

Changes in plaque pH

The mean pH responses during both normal and dry mouth conditions are presented in Figures 1 and 2. The most pronounced fall in pH for all drinks was

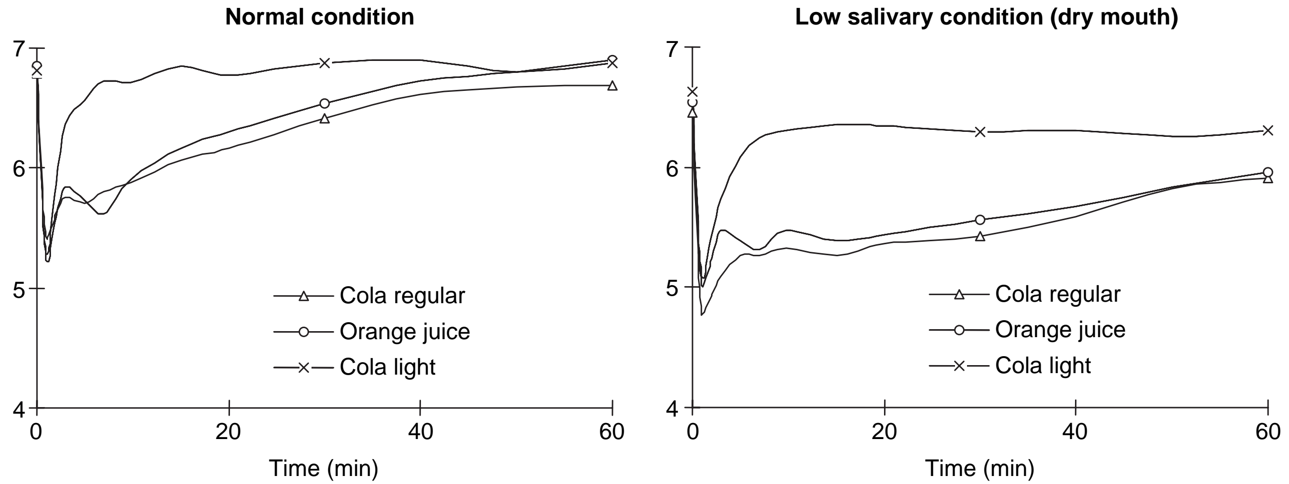

Figure 1. Mean plaque pH of the three sites during normal and low salivary conditions (dry mouth) with Coca-Cola regular ($n=10$), orange juice ($n=10$), and Coca-Cola light ($n=8$).

found during the period of rinsing, i.e. during the first 2 min. Even at 1 min, there was a pronounced drop in pH. The most pronounced pH fall during normal salivary was in the first minute after consumption of Coca-Cola light, but this initial phase was followed by a quick recovery back to baseline. The two sugar-containing products (Coca-Cola regular and orange juice), however, resulted in a similar but slightly less-pronounced pH fall during the initial 2 min period, but thereafter recovered slowly back to baseline. Both these products resulted in the lowest pH values at most time-points. Dry mouth salivary condition resulted in an overall more pronounced initial pH fall and in delay of the pH recovery for all three products at all time-points. The most attenuated pH drop during the entire time period (0–60 min) was found for the regular type of Cola and for orange juice.

The mean values ($\pm$SD) for $AUC_{5.5}$ at the central incisors and at the premolars, under both normal and dry mouth conditions, are given in Table I. When comparing AUC under the normal and dry condition, no significant difference was found for Coca-Cola light, while for Coca-Cola regular and orange juice the difference was significant at most time-points. On comparing the three drinks within each of the two conditions, Coca-Cola light was found to have a significantly lower AUC at the majority of the time-points and especially during the dry condition, but not as frequently during normal salivary secretion. A similar picture was found for $AUC_{6.2}$ (data not shown).

Discussion

The pH curve in plaque after intake of a food product such as a soft drink follows the typical "Stephan curve" [23]. This is the net result of three main factors: 1) ingredients of the product, such as acids and sugars, 2) individual-related factors, such as salivary condition, amount of plaque and type of microflora, and 3) the pattern of food and drink consumption [24,25]. The solubility of hydroxyapatite in enamel and dentine is greatly affected by the pH of the surrounding saliva and dental plaque [26]. The "critical pH" is believed to be around 5.5 for enamel and 6.2 for dentine, even though these values may vary due to post-eruptive maturation and to fluoride content of the mineral [27,28]. When comparing the pH fall for Coca-Cola regular and

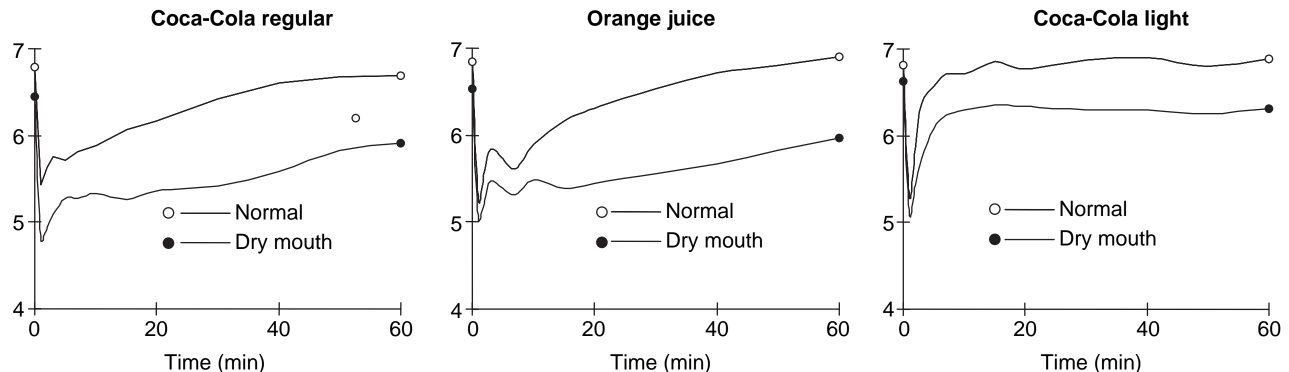

Figure 2. Mean plaque pH of the three sites and the three drinks during normal and low salivary conditions (dry mouth) with Coca-Cola regular ($n=10$), orange juice ($n=10$), and Coca-Cola light ($n=8$).

Table I. Means and standard deviation (SD) for $AUC_{5.5}$ for three types of drinks during normal and low salivary conditions (dry mouth). The results from both the central incisors and premolars during 0–10 min, 0–30 min, and 0–60 min are shown. Student's paired *t*-test (P^1) was used to analyze differences in AUC between normal and dry conditions, while the Kruskal Wallis test (P^2) was used for testing differences in AUC among the drinks

	Central incisors – Proximally					Premolars – Proximally				
	Normal			Dry		Normal			Dry	
AUC/drink/ P^2	Mean	SD	P^1	Mean	SD	Mean	SD	P^1	Mean	SD
$AUC_{5.5}$ 0–10 min										
Coca-Cola regular	0.62	1.02	0.010	2.98	2.51	1.05	1.36	0.010	3.89	2.46
Coca-Cola light	0.26	0.42	NS	0.64	0.38	0.25	0.46	NS	0.54	0.70
Orange juice	0.85	0.98	NS	2.23	2.09	0.67	0.77	0.009	2.99	2.58
P^2	NS			0.047		NS			0.017	
$AUC_{5.5}$ 0–30 min										
Coca-Cola regular	1.76	2.97	NS	6.56	7.64	1.96	2.36	0.014	9.93	7.93
Coca-Cola light	0.26	0.42	NS	0.64	0.39	0.25	0.46	NS	0.54	0.70
Orange juice	2.54	5.23	NS	5.98	6.49	0.87	1.06	0.008	9.38	8.53
P^2	NS			0.038		NS			0.013	
$AUC_{5.5}$ 0–60 min										
Coca-Cola regular	1.77	3.00	NS	10.67	14.02	2.06	2.47	0.014	15.50	14.02
Coca-Cola light	0.26	0.42	NS	0.64	0.39	0.25	0.46	NS	0.54	0.70
Orange juice	2.92	6.42	NS	10.38	12.81	0.87	1.06	0.017	15.29	15.98
P^2	NS			0.017		NS			0.005	

orange juice, there were relatively small differences. It may therefore be concluded that the cariogenic and erosive potential of these two products is more or less the same. This concurs with previous studies comparing Cola-type drinks and fruit juice [9], although contradictory results have been reported [29]. The plaque pH curve for Coca-Cola light on the other hand showed another shape, which has also been demonstrated in children and adults with normal salivary flow [30,31]. The difference in pH response between Coca-Cola light and the two sugar-containing drinks could also be attributed to the carbohydrate metabolism by bacteria in the dental plaque by the latter two products. The fact that there is a pronounced initial pH fall during and directly after consumption means that Coca-Cola light, and other similar sugar-free drinks, may be a risk factor for dental erosion. Such drinks may be especially erosive if consumed frequently and kept in the mouth for a long period of time. Dry mouth conditions, as shown in the present study, will further enhance the risk of erosion [32,33]. The study group was asked to rinse gently and to hold the drink in the mouth with only minor oral movements. Other drinking techniques, such as using a straw or glass, or swishing the drink in the mouth, will affect intraoral pH differently [9,34]. In general, commonly used sugar-containing soft drinks have about the same "cariogenicity" [14].

The results from the present investigation showed that with dry mouth conditions the plaque pH after rinsing with Coca-Cola regular and orange juice was <5.5 for more than 40 min and <6.2 during the entire 60-min test period. None of the drinks tested reached the baseline value within the 1-h test period. This stresses the importance of avoiding these soft drinks especially when the salivary flow is decreased. In comparison between the three drinks, during both the normal and the dry mouth condition the similarity in pH drop between the regular Cola and the orange juice was striking and the overall cariogenic load much higher with a reduced salivary secretion rate. Consequently, a subject with a low, compared to a normal, salivary secretion rate following consumption of a drink such as those tested in this study would show a more accentuated pH fall which would remain lower for a longer period of time.

The experimental model used in the present study for inducing dry mouth condition has been used in previous studies [35,36]. It is useful for scientific purposes and has the advantage that products can be tested in one and the same group of individuals instead of having two parallel groups, one with low and one with normal salivary secretion. In the present study, the flow rate differed in the two conditions by a factor of 7–8, i.e. 2.2 vs 0.3 ml/min (for stimulated whole saliva). Thus, when testing the drinks under dry mouth condition, the salivary flow rate was extremely low and the participants experienced subjectively that the mouth felt very dry. Methylscopolamine-induced dry mouth resembles the condition seen in many individuals, both children and adults, due to medication or disease [15–20]. It is clear from the results in this study that such an oral environment increases the risk for dental caries during consumption of regular soft drinks. Thus, our hypothesis that soft drink consumption promotes a larger pH fall in dental plaque during low salivary conditions compared with normal is supported.

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