Enamel solubility potential of commercially available soft drinks and fruit juices in Saudi Arabia

Jyothi Tadakamadla a, Santhosh Kumar a,*, Abrar Ageeli b, Nandimandalam Venkata Vani b, Mahesh Babu T c,1

a Population and Social Health Research Programme, Griffith Health Institute & School of Dentistry and Oral Health, Griffith University, Gold Coast, Australia
b College of Dentistry, Jazan University, Jazan, Saudi Arabia
c Department of Oral and Maxillofacial Pathology, GITAM Dental College and Hospital, Vishakapatnam, India

Received 27 August 2014; revised 27 November 2014; accepted 27 November 2014
Available online 26 December 2014

Abstract  Aim: To evaluate pH, titratable acidity and in vitro enamel solubility potential of different commercially available soft drinks and fruit juices in Saudi Arabia.  Methods: Thirty two popular soft drinks and juices were tested for their enamel solubility potential. In addition, bottled drinking water was used as the control. Each drink was evaluated for its pH, titratable acidity which was measured by adding 0.1 N NaOH (sodium hydroxide) to a chosen end point. In addition, one enamel slice was immersed in each test beverage and percentage weight loss in the enamel slice was calculated after intervals of 6 and 24 h.  Results: The pH of all the test drinks ranged from 1.64 to 3.89. Mean pH of 2.84 in soft drinks was significantly lower than in the fruit juices. There was a significant difference between them for percentage weight loss after 6 and 24 h immersion with carbonated beverages causing greater enamel loss than the fruit juices. Colas and non-colas did not differ statistically for pH, titratable acidity and percentage weight loss of enamel slices.  Conclusions: The pH of all the test drinks was below the critical pH of 5.5 for enamel dissolution. Carbonated drinks were observed to have more enamel solubility potential than fruit juices while regular or diet variants and colas or non-colas had comparable solubility potential.

© 2014 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Dental erosion is a chemical process that involves loss of dental hard tissue by dissolution or chelation without any microbial involvement.1 Acids of intrinsic (gastrointestinal) and extrinsic (dietary and environmental) origin are the main aetiologic factors.2 Soft drinks and fruit juices have been
extensively investigated over a long period for causing acid dissolution and erosion of dental enamel.\textsuperscript{1,3} The modern fast-track lifestyle has led to an increased consumption of readily available carbonated drinks and juices. Fruit juice consumption has been popularized as a healthy alternative to other beverages\textsuperscript{4} and this had led to many parents feeding their children with commercially available fruit juices. It has been reported that, over 10\% of American preschoolers consume at least 350 mL of fruit juices daily which is way above the limit of 118–177 mL per day.\textsuperscript{5} A study done in Riyadh reported that the intake of soft drinks and juices constituted 51\% of total fluid intake among a sample of 12–13 year old adolescents.\textsuperscript{6} Consumption of soft drinks and beverages leads to fall in salivary $p$H, however decrease in salivary $p$H caused by a drink depends on its intrinsic $p$H value as well as the buffering capacity.\textsuperscript{7} For enamel dissolution, a $p$H of 5.5 is usually regarded as ‘critical $p$H’ but loss of mineral may be initiated even at higher $p$Hs.\textsuperscript{8} However, there are many other factors involved with the process of enamel dissolution which include the type/concentration/amount of acid, calcium chelating properties, exposure time, temperature, buffering capacity of saliva, flow rate and saliva content.\textsuperscript{9}

Few studies have been conducted in the past in Saudi Arabia to determine the levels of minerals and microbial contamination in bottled fruit juices and drinks.\textsuperscript{10,11} However, no study could be traced that evaluated the enamel solubility potential of commercially available drinks in Saudi. In view of the high consumption of fruit juices among Saudi population and the lack of studies addressing this subject in this region, the purpose of this study was to evaluate $p$H, titratable acidity and in vitro enamel solubility potential of different commercially available soft drinks.

2. Material and methods

The current study tested 32 popular commercially available soft drinks and fruit juice brands in Saudi Arabia for their enamel solubility potential. In addition, bottled drinking water was used as the control. Among the total beverages, 16 were fruit juices while the other half were carbonated beverages (soft drinks). There were 7 colas and 9 non-colas making a total of 16 carbonated beverages. There were only 4 carbonated beverages (coca, pepsi, 7up and mountain dew) which were commercially available in both regular and diet variants.

Each beverage was evaluated by estimating its $p$H and titratable acidity immediately on opening. A digital $p$H meter (Mi 150, Martini Instruments) was used to measure $p$H while titratable acidity was evaluated as the amount of 0.1 N NaOH (sodium hydroxide) required to bring the $p$H of 10 ml of test beverage to 5.5 (critical $p$H) and 7 (neutral $p$H). In addition to $p$H and titratable acidity, the percentage of weight loss in enamel slices caused by each test drink was measured at intervals of 6 and 24 h to assess its enamel solubility potential.

The methodology for measuring weight loss was adopted from a previous study of Jain et al.\textsuperscript{12} Sound permanent teeth that were freshly extracted for orthodontic reasons were collected and stored in saline until their enamel was sliced. An alloy grinder (AG04, Ray Foster high speed alloy grinder) loaded with carborundum disc was used to cut enamel of permanent teeth into small slices which approximately measured 1 mm $\times$ 3 mm $\times$ 3 mm (thickness $\times$ length $\times$ width). One enamel slice was immersed in each test drink. Pre-immersion weight, weights at 6 and 24 h intervals of enamel slices were measured using microbalance (XP 1203S, Mettle Toledo). Weight loss at each interval was measured as percentage weight loss when compared to pre-immersion weight.

Data were entered into excel sheet (Microsoft Excel 2010) and SPSS 17.0 was used for statistical analysis. Descriptive statistics were conducted and are presented as means and standard deviations. Independent samples $t$ test was used to analyse the significance of difference for $p$H, titratable acidity, percentage weight loss between the categories of drinks.

3. Results

The $p$H of all the test drinks ranged from 1.64 (Smart carbonated cola) to 3.89 (Danao Orange milk, Al-Safi-Danone) on opening. Mean $p$H of 2.84 in carbonated beverages was significantly lower than that in fruit juices (Table 1). In addition, there was a significant difference between them for percentage weight loss (in milligrams) after 6 and 24 h immersion with carbonated beverages causing greater enamel loss than the fruit juices. Though insignificant, titratable acidity to reach critical and neutral $p$H was greater among fruit juices than the carbonated drinks. The $p$H of bottled drinking water was approximately neutral (7.1), titratable acidity was very minute while the % of weight loss observed was negligible (not presented in the tables).

Table 2 demonstrates that regular drinks had less $p$H, greater titratable acidity and caused greater weight loss than the diet variants. However, the difference was insignificant. It is clear from Table 3 that non-colas required a greater amount of 0.1 N NaOH in order to reach $p$H of 5.5 and 7.0 than cola drinks, however this difference was also insignificant. Colas and non-colas did not differ statistically for $p$H and percentage weight loss of enamel slices.

4. Discussion

Fruit juices and other beverages are frequently consumed in Saudi Arabia, especially among children and youth. So the

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Mean $p$H, titratable acidity and percentage weight loss in enamel slices caused by carbonated beverages and fruit juices after 6 h and 24 h intervals of immersion.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p$H</td>
<td>Titratable acidity at 5.5 (ml)</td>
</tr>
<tr>
<td>Carbonated</td>
<td>2.84 ± 0.18</td>
</tr>
<tr>
<td>Fruit drinks</td>
<td>3.38 ± 0.30</td>
</tr>
</tbody>
</table>

Independent samples ‘$t$’ test.

$^* t < 0.01.$

$^p < 0.05.$
An association between the ingestion of acidic drinks and erosion has been recognized. Soft drinks usually contain citric and phosphoric acids along with the carbonic acid for aeration. The pH of these may be as low as 2.6 and they have been shown to cause erosion. When the pH of the solution is less than the critical pH, the solution is unsaturated, and the mineral from tooth enamel will tend to dissolve until the solution becomes saturated and the critical pH is the pH at which a solution is just saturated with tooth enamel. However, it is not only the pH value but also the calcium, phosphate and fluoride contents of a drink or foodstuff that are important factors in determining the degree of saturation with respect to tooth minerals, which is the driving force for enamel dissolution. However, measuring endogenous pH of the acidic drinks can be a useful method to evaluate their potential for enamel dissolution. The methodology of evaluating the weight loss as a proxy measure of enamel solubility might not be as accurate and precise as actual measures, but it gives a relative indication of the solubility potential of the drink and this methodology has been used in many of the previous studies.

Furthermore, the reason for immersing the enamel slices in test drinks for the 6 and 24 h is to simulate the effect of several short in vivo exposures in chronic consumers of acidic drinks. Although we have considered bottled mineral drinking water in our study, their results have not been presented in the tables and were not considered in statistical analysis as pH, titratable acidity and enamel weight loss caused by it was negligible. This finding confirms the evidence that mineral water shows minimal effect on enamel dissolution and thus mineral water has been proposed as a healthy alternative to erosive acidic beverages.

The pH of all the test drinks ranged from 1.64 to 3.89 which are far below the critical pH. Though many presume that the readily available fruit juices are healthy, they have been observed to cause tooth erosion due to their higher buffering capacity (because of the added preservatives) alike carbonated beverages. However when pH was compared, mean pH of fruit juices was significantly greater than that of carbonated beverages which is in accordance with the previous findings of a study from Nigeria. It is not just the pH that is important but rather the titratable acidity that plays an active role in causing tooth erosion. Although we observed no significant differences for titratable acidity between carbonated drinks and fruit juices, nevertheless the amount of base required to reach critical and neutral pH was less for carbonated drinks than the fruit juice group. This implies that fruit juices require a large amount of alkaline saliva to be neutralized than the carbonated beverages in spite of having higher pH on opening. It is evident from the literature that fruit juices have higher titratable acidity than the carbonated beverages. Another reason for fruit juices producing less weight loss in enamel slices might be due to their greater viscosity. The viscosity of a drink, together with contact angle and surface tension, determines its ability to penetrate into a capillary space such as pores in enamel.

It has been previously observed that sugar-free soft drinks often have comparable erosive potential as sugar-containing soft drinks. In accordance, we have observed no significant difference between the regular and diet drinks for all the three measured parameters. Furthermore, we have observed that colas and non-colas demonstrated comparable solubility potential as there was no statistical difference observed between them for any of the parameters which is in contrast to a study where non-colas were found to have lower pH and caused greater percentage of weight loss in enamel slices than the colas. This might be probably due to the inclusion of “Smart carbonated cola” (trade name) in colas that had the lowest pH among all the test drinks which would have influenced in bringing down the mean pH of the colas.

Lastly, the current study is not free of limitations with the major drawback of the study being its in vitro design that involved evaluation of only few factors (pH, titratable acidity and percentage weight loss in enamel slices) that are related to enamel solubility. Therefore, the findings of this study cannot be generalized to real clinical situation.

5. Conclusion

The pH of all the test drinks was below the critical pH for enamel dissolution. Carbonated juices were observed to have more enamel solubility potential than fruit juices while regular and diet variants had comparable solubility potential. Colas and non-colas did not differ in mean pH, titratable acidity and percentage weight loss of enamel slices after both 6 and 24 h intervals.
Acknowledgement

We sincerely thank Dr Faisal Tobaigy, Dean of the College of Dentistry for his support in conducting this project.

References