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The Erosive Potential of Acidic Candies: An Ex Vivo Study

Andressa Feitosa Bezerra Oliveira[1*], Aida Ghazvini[2], Renzo Alberto Ccahuana Vásquez[3], Ingrid Andrade Meira[4], Juliellen Luiz Da Cunha[5], Nayanna Lana Soares Fernandes[6] and Bennett Tochukwu Amaechi[7]

[1]Morphology Department, Health Science Center, Federal University of Paraíba, Campus I - Cidade Universitária, João Pessoa, Brazil.
[2]Alegre Dental, San Antonio, TX 78229, USA.
[3]Procter & Gamble, German Innovation Center Campus Kronberg, Frankfurter Strasse, 145 61476 Kronberg, Germany.
[4]University of Campinas, Faculty of Dentistry of Piracicaba, Graduate Program in Dental Clinic, Piracicaba, Brazil.
[5]Federal University of Paraíba, Department of Morphology, Scientific Initiation Program, Undergraduation in Dentistry, João Pessoa, Brazil.
[6]Federal University of Paraíba, Faculty of Dentistry, Graduate Program in Dentistry, João Pessoa, Brazil.
[7]Comprehensive Dentistry Department, University of Texas Health Science Center, 7703 Floyd Curl Dr, San Antonio, TX 78229, USA.

Authors' contributions

This work was carried out in collaboration among all authors. Authors AFBDO, AG, RACV and BTA did conceptualization, methodology and software. Writing the review & editing and visualization done by Authors AFBO, AG, RACV, IAM and BTA. Authors AFBDO, IAM, JLDC, NLSF and BTA did validation and writing the original draft. Formal analysis, resources and data curation done by authors AFBDO, RACV and IAM. Authors AFBDO, RACV and BTA did Investigation, supervision and project administration. All authors read and approved the final manuscript.

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**Corresponding author: E-mail: andressafeitosaboliveira@gmail.com;*

ABSTRACT

Aim: The aim of this study was to evaluate the erosive potential of saliva on dental enamel sucking the acidic candies, and their effects on the pH, titratable acidity (TA) and buffering capacity (β) of saliva.
Methodology: Human enamel specimens (n = 216) were randomly in 17 acidic candy groups and one negative control (paraffin wax) group. Three human volunteers sucked each candy for 5 min while spitting into a covered and chilled vial. The pH, TA and β were measured immediately after the saliva collection. For erosive challenge, each specimen was immersed in saliva at room temperature for 120 min without agitation. The erosion was measured by surface microhardness (SMH) tester and with 3D non-contact optical profilometer for depth of surface loos (DSL). Percentage of SMH change (%SMHC) was calculated. ANOVA followed by Tukey test and Pearson correlation were performed (α=0.05).
Results: All candies lowered saliva pH below 5.5, and produced significant DSL ($P<0.05$) and %SMHC ($P<0.01$) on enamel, when compared to negative control. The Baby bottle Pop candy presented the lowest erosive potential. No significant differences were observed in DSL between all candies and the negative control, except for the PicoSitos candy. However, for the %SMHC almost all the candies were significantly different from negative control. Correlations were observed between the pH and TA and β, between TA and β, and between the %SMHC and DSL variables ($P<0.05$).
Conclusion: Acidic candies can lower the saliva pH, hindering its buffering effect. The DSL and %SMHC analysis showed enamel dissolution with all candies investigated.

Keywords: Acidic candies; tooth erosion; buffering capacity; saliva; surface loss.

1. INTRODUCTION

Dental erosion, known as the dissolution of minerals from the dental surface by acids of non-bacterial origin, is usually progressive and can wear away either enamel or root surfaces [1,2]. Unlike dental caries, in the dental erosive process there is no involvement of biofilm [3]. Erosion can be visibly detected when the original luster of the tooth dulls and when shallow concavities become present as the disease progresses [1,4,5]. The amount of mineral dissolved from the dental surface depends on pH, concentration of the acids, and length of exposure to acid [6].

Acidic agents that can cause dental erosion can either be of extrinsic or intrinsic origin. Extrinsic factors would include dietary habits in which different kinds of foods with relatively low pH, such as acidic beverages, are supplied to the oral cavity over a long period of time [5,1,7]. Intrinsic factors include those conditions that subject teeth to frequent contact with acidic gastric juice, such as gastro esophageal reflux or medical conditions/lifestyle associated with alcoholics and frequent vomiting among bulimics [5,8].

Certain salivary factors can protect the tooth surface against oral environmental changes in pH [2]. Those factors include salivary clearance, buffering and remineralization capacity [2,8]. The buffering system consists of conjugate acid-base pairs that regulate the pH of the oral environment. The buffering capacity (β) of saliva can become vulnerable if the oral cavity is frequently exposed to acidic conditions, with the consequence of risk of erosion to the teeth [9,10,11].

Cultural factors may also contribute to the presence of this dental disorder [12,13]. The growth in the consumption of acidic candies has increased the prevalence of dental erosion in United States and other countries [12-17]. Over the last decade, several candy manufacturers have introduced the sour or tangy versions of original-flavor candies [7,11,15]. They are of particular concern not only for its high levels of free sugars, but also because of the high acid concentrations (e.g., lemon juice concentrate, milk-derived acid), and prolonged oral contact [7,11,12,15,18,19]. Citric acid, which is a main ingredient in these candies, is the most erosive compound found in foods and beverages [20]. This level of acidity is known to overwhelm the β of saliva following prolonged and frequent use of these candies, with consequent development of dental erosion [9].
There is lack of studies in the literature related to acidic candies, hence the present study, and the

objectives were to (1) evaluate the erosive potential of saliva on dental enamel during the sucking of acidic candies and (2) determine the influence of the acidic candies on the pH and β of saliva. The null hypothesis was that there is no significant difference between the tested candies and the negative control (paraffin wax).

2. MATERIALS AND METHODS

This was a double blind in vitro study, to evaluate the effect of different acidic candies on saliva pH and β, and on human enamel specimens. The study protocol was reviewed and approved (Approval #: HSC20130286H) by the Institutional Review Board of the University of Texas Health San Antonio (UTHSA). The experiment was conducted in accordance with the Declaration of Helsinki and following the guidelines of Good Clinical Practice. Informed consent was obtained from all saliva donors included in the study.

2.1 Selection of Candies

Seventeen popular commercial acidic candies from grocery stores located in San AntonioTexas were chosen for this study (Table 1). The selected candies were presented in the form of hard (solid), powder, liquid, gummy and soft and chewy candies. Stimulated saliva produced by chewing paraffin wax was used as a negative control. All candies were stored according to manufacturer recommendations prior to use.

Table 1. Basic information of the ingredients and presentation of all analyzed candies, as listed on their respective packaging

Candies	Ingredient list	Presentation type
Sweet Tarts / Wonka	Dextrose, corn syrup, hydrogenated coconut oil, maltodextrin, and *less than 2% of malic acid*, calcium stearate, egg albumen, natural flavors, mono- and diglycerides, carnauba wax, blue 1 lake, blue 2 lake, red 40 lake, yellow 5 lake, yellow 6 lake	Hard
Fun Dip / Wonka	Dextrose, *2% or less of citric acid*, maltodextrin, natural flavors, calcium stearate, blue 1, blue 1 lake, blue 2 lake, red 40 lake, yellow 5	Powder with a lik stix
Gummi Bursts – Starburst	Corn syrup, sugar, water, gelatin; *less than 2% of apple juice from concentrate, citric acid*, modified potato starch, corn starch, pectin, sodium citrate, natural and artificial flavors, colors (red 40, yellow 5, blue 1)	Liquid filled gummies
Acirrico sour and hot chilli powder with salt and lemon	Salt, chili powder, *citric acid*, fresh lemon, silicon dioxide, tricalcium phosphate	Powder
Lucas Gusano – Chamoy Liquid	Water, iodized salt, *citric acid*, modified corn starch, chili powder, xanthan gum, sodium benzoate and potassium sorbate as preservatives, color fd&c red 40, artificial flavor, sucralose	Liquid
Sour Patch Kids	Sugar,invert sugar,corn syrup,modified corn starch,contains *less than 2% of tartaric acid,citric acid,natural* and artificial flavor,yellow 6,red 40,yellow 5,blue 1.	Soft and chewy candy
Sour Punch bits Lemons-Lime	Corn syrup, sugar, wheat flour, *citric acid, malic acid, tartaric acid,* food starch modified, palm oil, glyceryl monostearate, sodium citrate, glycerin, artificial flavors, color added blue 1, yellow 5 (tartrazine), red 40.	Gummy candy
Beer salt – Lemon Line	Salt, *citric acid*, sodium citrate, natural lemon, natural lime and tricalcium phosphate (flow agent).	Powder
Lucas Bom Vaso	Spice: sugar, water, corn syrup, iodized salt, *citric acid*, dextrose, chili powder, sorbitol, sodium lactate, guar gum, xanthan gum, sodium benzoate and potassium sorbate as preservatives, artificial flavor, color FD&C Red 40. Chewing Gum: sugar, dextrose, corn syrup, gum base, artificial flavors, *citric acid*, glazing agents (Carnauba Wax, Beeswax, Shellac, Vegetable Oil	Spice candy with gum

Candies	Ingredient list	Presentation type
	(Soy Oil), Ethanol), glycerin, colors (FD&C Red 40, FD&C Yellow 5, FD&C Yellow 6, FD&C Blue 1, FD&C Blue 2), BHT (to Maintain Freshness).	
Pulparindo – hot and salted tamarind pulp	Sugar, *tamarind pulp*, corn syrup, iodized salt, *citric acid*, ground chilis mixture and sodium benzoate	Hard
Lucas Pelucas – Cucumber flavor Lollipop with chilli powder	Lollipop: glucose, sugar, *lactic acid*, artificial flavor, polysorbate 80, vegetable oil (soy oil), colors fd&c yellow 5, fd&c blue 1. Powder: iodized salt, *citric acid*, sugar, chili powder, dextrose, silicon dioxide, color fd&c red 40 lake	Lollipop hard and powder
Lucas Muecas Tamarind flavored lollipop with chilli powder	Lollipop: sugar, corn syrup, less than 2% of: *lactic acid*, natural and artificial flavors, sodium lactate, caramel color class iv, mono- and diglycerides, soybean oil; Powder: iodized salt, sugar, *citric acid*, chili powder, dextrose, less than 2% of: silicon dioxide, fd&c red 40 lake	Lollipop hard and powder
Lucas Pulpadip – Tamarind flavor	Water, sugar, iodized salt, *citric acid*, chili powder, xanthan gum, carboxymethylcellulose, gum arabic and modified corn starch, caramel color, sodium benzoate and potassium sorbate as preservatives, *ascorbic acid* as antioxidant, artificial flavor	Liquid
Rago Pullp – Chamoy candy	Water, corn starch,,iodized salt, sodium benzoate as preservative, artificial color & chilli powder.	Liquid
Picositos – Fruit seasoning	Sugar, *citric acid*, salt, chili powder, silicon dioxide and artificial color (red 40)	Powder
Baby bottle Pop	Glucose syrup, sugar, water, dextrose, gelatin, contains 2% or less of sorbitol, lactose, *citric acid*, natural & artificial flavors, *malic acid*, coconut oil, pectin, carnauba wax, red 40 lake, red 40, blue 1, yellow 5, carbon dioxide	Powder
Rips Licorice Strawberry Belts	Glucose syrup, sugar, wheat flour, *malic acid, pineapple juice,* artificial flavors, and artificial color (FD&C Red 40)	Soft and chewy candy

2.2 Sample Preparation

Freshly extracted human teeth were collected at various clinics of UTHSA school of dentistry and stored in 0.1% thymol solution for no more than thirty days. The teeth were examined, and those without cracks, fractures, stains, or carious lesions were selected. A total of 216 enamel blocks (3 x 3 x 2 mm) were obtained from the buccal and lingual surfaces of the selected teeth, using a double-sided diamond disk in a precision cutting machine (Isomet Low Speed Saw, Buehler, Lake Bluff, IL, USA) under slow-speed and constant irrigation. The specimens were embedded in a self-cured acrylic resin (Varidur - Buehler, Lake Bluff, IL, USA) fixed on a metallic base for polishing. A flat surface on each outer enamel surface was obtained using a plain back diamond lapping film in a Multiprep Precision Polishing machine (Allied High Tech, USA). Following 5 min sonication in water using an ultrasonic device, the enamel surface was arbitrarily divided into three portions. While the middle third (central portion 1 mm width) was left uncovered, the two side thirds were covered with an adhesive tape as a reference area for surface microhardness and profilometer analysis.

2.3 Saliva Collection

Saliva was collected from three healthy non-medicated volunteers without active caries with good saliva flow rate. Volunteers neither eat, drink nor brush their teeth at least 1h before the study [6]. The experiments were performed during the mornings (9-11am) on 18 consecutive days by use of one candy or paraffin each day. The candies were given in a randomized order and the volunteers were blinded as to which candy they were having. The volunteers sucked each candy for 5 minutes, while spitting the stimulated saliva into a vial placed in ice blocks. The vial was always kept tightly closed except when spitting saliva. Ten milliliter of the stimulated saliva was collected saliva for pH measurement and titratable acidity (TA) evaluation, and another 20 ml was collected for the dental erosive challenge.

2.4 Measurement of pH, TA and β

Immediately, after the collection of the stimulated saliva, pH and TA were measured at room temperature. The pH was measured with a previously calibrated pH meter (Thermo Orion Fisher Scientific Inc. Waltham, MA, USA) while the saliva was being stirred with a non-heating magnetic stirrer until a stable reading was observed.

The TA was determined as the volume of a standard 0.5M NaOH solution required to increase the pH of 10 mL of each saliva sample to 5.5 and 7.0. This was added in 0.02 ml increments while stirring with a non-heating magnetic stirrer until a stable pH reading was obtained. The β was calculated according to Lussi et al [9], using the following equation: $\beta = \Delta C/\Delta pH$, where ΔC is the total amount of base used to raise the initial pH to 7.0 and ΔpH is the change in the pH of the solution.

2.5 Erosive challenge

For the evaluation of the erosive potential of the saliva on dental enamel, the 216 enamel blocks were randomly assigned to experimental 18 groups (12/group), corresponding to 17 candies and one negative control (paraffin wax). The 12 blocks in each group were assigned to 3 subgroups corresponding to the 3 saliva donors, and the 4 blocks in each subgroup were fixed on a glass slide and subjected to acidic challenge by immersion into 20 ml of the saliva of their respective donor. The saliva was stimulated with each candy or paraffin wax individually on separate days. The challenge was performed at room temperature (22-25ºC) for 120min with no agitation [21]. At the end of the exposure time, the specimens were rinsed with deionized water and stored in a humidity-controlled environment to prevent drying until profilometer and microhardness analysis.

2.6 Measurement of enamel surface microhardness

The surface microhardness (SMH) of each enamel block was examined using a Knoop diamond indenter with a load of 25 g for 15 seconds (Shimadzu HMV AD Easy Test Version 3.0.00). For the SMH evaluation, three indentations spaced 100μm from each other were made at the uncovered central portion of the enamel surface. An average per block was obtained. Firstly, a baseline measurement (SMH0) was performed before acidic challenge, and then a post-challenge measurements were taken (SMH1), using the same parameters. Following the SMH measurement, the percentage SMH change (%SMHC) was calculated thus: $\%SMHC = (SMH1 - SMH0/SMH0) \times 100$

2.7 Measurement of depth of enamel surface loss

A 3D non-contact profilometer (Proscan 2000, Scantron, Taunton, England) was used to measure the depth of enamel surface loss. The adhesive UVPC tapes covering the rest of the enamel surface were carefully removed for the analysis. An area 2 mm long (X) x 1 mm wide (Y) was scanned, covering sound and eroded surfaces. The step size was set at 0.01 mm (X axle) and 0.1 mm (Y axle) and the number of steps 200 in the (X) axle and 10 in the (Y) axle. The unprocessed data file for each specimen was saved. With the use of software, the depth of surface loss (DSL) (μm) in the eroded area was calculated based on the sound reference surfaces. A 3-point height tool was applied.

2.8 Statistical analysis

Statistical procedures were performed with the SPSS statistical software (SPSS, Inc., Chicago, IL). The assumptions of normal distributions were checked for all the variables (Shapiro–Wilk test) and data had a Gaussian distribution. The DSL and %SMHC value were obtained from the mean of all of enamel blocks belonging to each group. While the pH (pH of stimulated saliva), TA for pH 5.5, pH 7 and β the mean per group was obtained by the measurements of the three volunteers. Multiple comparisons were performed using ANOVA, followed by Tukey post-hoc for intergroup comparisons. Pearson's rank correlation was used to correlate DSL with %SMHC, the pH with TA for pH 5.5, pH7 and β. The level of significance established was 5%.

3. RESULTS

Table 2 shows significant difference ($P<0.05$) in pH of the stimulated saliva between all 17 candy groups and the negative control. The 17 candy groups were also significantly difference among themselves based on the mean values of the pH (pH of stimulated saliva), TA for pH 5.5 and 7, and the β. All the candies lowered the pH of saliva below the critical value (<5.5) for enamel dissolution. The lowest pH was observed with Picositos–Fruit seasoning, however the highest TA for 5.5 and 7 and the β values were found in Pulparindo–hot and salted tamarind pulp. Analyzing the chemical parameters, the lowest erosive potential and the most 'enamel-friendly' parameters were observed with the Baby bottle Pop.

A significant correlation was observed between the data obtained by the two methods of analysis %SMHC and DSL) used in the present study (r=0.516, *P*<0.001). With the chemical variables, significant correlation were observed between the pH and the TA for pHs 5.5 (r= -0.415, *P*=0.002 and7.0 (r= -0.470, *P*=0.000), and β (r= -0.466, *P*=0.000). Also, a strong correlation was seen between TA for pH 7.0 and β (r= 0.983, *P*=0.000).

Table 2. Comparison of the means of initial pH, titratable acidity (quantity of mmol/l NaOH to raise pH 5.5 and 7.0) and buffering capacity between candy groups*

CANDIES	pH (initial) (Stdv)	Titratable Acidity (mmol/l NaOH) to pH 5.5 (Stdv)	Titratable Acidity (mmol/l NaOH) to pH 7.0 (Stdv)	Buffering Capacity (Stdv)
Negative Control (Parafin wax)	7.53 (0.16)^{a}	---	---	---
Sweet Tarts / Wonka	4.77 (0.68)^{b,d,e}	0.24 (0.28)^{a}	0.50 (1.18)^{c,f}	11.94 (5.12)^{c,d,h}
Fun Dip / Wonka	4.38 (0.42) ^{b,c,d,e}	0.49 (0.25) ^{a}	0.82 (0.19)^{c,f,g}	15.57 (1.19)^{c,d,h}
Gummi Bursts – Starburst	4.71 (0.44) ^{b,c,d,e}	0.22 (0.17) ^{a}	0.47 (0.18)^{c,f,g}	10.01 (2.15)^{c,d,h}
Acirrico sour and hot chilli powder with salt and lemon	3.17 (0.76)^{b,c}	3.18 (1.99)^{a}	2.58 (1.12)^{d,g}	32.63 (9.15)^{b,e,f,g,h}
Lucas Gusano – Chamoy Liquid	3.96 (0.43) ^{b,c,d,e}	0.67 (0.41)^{a}	0.99 (0.35) ^{b,c,d,e,f,g}	16.14 (3.92)^{c,d,h}
Sour Patch Kids	4.72 (0.72) ^{b,c,d,e}	0.16 (0.15)^{a}	0.28 (0.08)^{c,f,g}	6.21 (0.48)^{c,d,h}
Sour Punch bits Lemons-Lime	5.07 (0.79)^{d,e}	0.16 (0.18)^{a}	0.29 (0.12) ^{c,f}	6.94 (2.29)^{c,d,h}
Beer salt – Lemon Line	3.54 (0.51)^{b,c,d}	1.77 (0.91)^{a}	1.75 (0.35)^{b,c,d,e,f}	25.15 (1.58)^{d,e,f,g,h}
Lucas Bom Vaso	4.13 (0.99) ^{b,c,d,e}	2.17 (0.75)^{a}	3.10 (0.75)^{g}	55.34 (8.59)^{e,f,g}
Pulparindo – hot and salted tamarind pulp	3.57 (0.39) ^{b,c,d}	13.2 (7.53)^{b}	13.60 (2.38)^{a}	197.07 (13.38)^{a}
Lucas Pelucas – Cucumber flavor Lollipop with chilli powder	4.64 (0.79) ^{b,c,d,e}	0.33 (0.35)^{a}	0.53 (0.21) ^{f,g}	11.00 (0.97) ^{c,d,h}
Lucas Muecas Tamarind flavored lollipop with chilli powder	3.43 (0.50) ^{b,c,d}	0.62 (0.68)^{a}	3.73 (0.25)^{d,e,g}	52.64 (11.22)^{f,g}
Lucas Pulpadip – Tamarind flavor	3.94 (0.41) ^{b,c,d,e}	0.80 (0,48)^{a}	1.11 (0.51)^{b,c,d,e,f,g}	17.67 (5.58)^{c,d,e,g,h}
Rago Pullp – Chamoy candy	4.50 (0.58) ^{b,c,d,e}	0.25 (0.18)^{a}	0.52 (0.20)^{f,g}	10.34 (2.73)^{c,d,h}
Picositos – Fruit seasoning	2.95 (0.31)^{c}	2.79 (1.12)^{a}	4.15 (0.48)^{b,d,g}	55.55 (2.19)^{g,h}
Baby bottle Pop	5.45 (0.77)^{e}	0.04 (0.03)^{a}	0.08 (0.50)^{c,f}	2.58 (0.53)^{c,h}
Rips Licorice Strawberry Belts	4.10 (0.24) ^{b,c,d,e}	0.90 (0.27)^{a}	1.18 (0.33) ^{b,c,d,e,f,g}	20.16 (4.08)^{h}

**Different lowercase letters indicate statistical differences between groups for the same column (ANOVA, P<.05)*

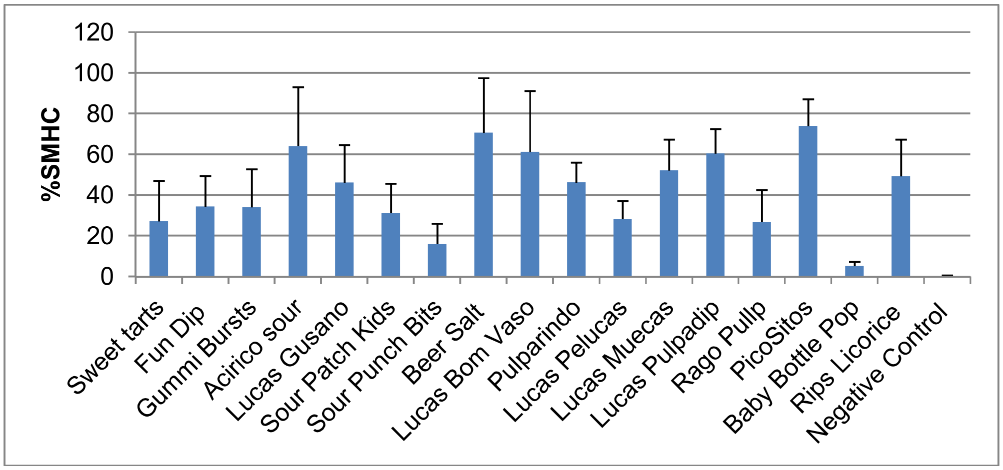

Fig. 1. Comparison of the means of %SMHC between the groups, after treatment (ANOVA test, *P*<.05)*

**See Table 3 for statistical results of the comparison.*

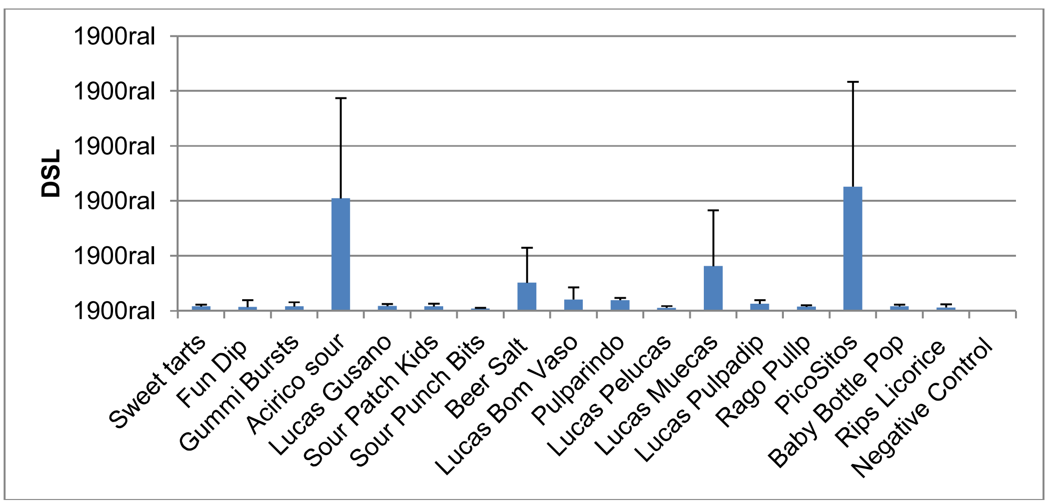

Fig. 2. Comparison of the means of depth of surface loss (DSL) between the groups,
after treatment (ANOVA test, P<0.05),*See Table 3 for statistical results of the comparison*

Table 3. Comparison of all the candy groups with the negative control (Paraffin wax) based on their DSL and %SMHC data

Variables			**Negative group (Paraffin wax) P value***	
Candy	**DSL**	**%SMHC**	**DSL**	**%SMHC**
Sweet Tarts / Wonka	0.4092	27.1667	1.000	0.056
Fun Dip / Wonka	0.3525	34.3442	1.000	0.002
Gummi Bursts – Starburst	0.4017	34.0908	1.000	0.002
Acirrico sour and hot chilli powder with salt and lemon	10.2342	64.1592	0.000	0.000
Lucas Gusano – Chamoy Liquid	0.4333	46.0950	1.000	0.000
Sour Patch Kids	0.3975	31.2525	1.000	0.010
Sour Punch bits Lemons-Lime	0.2242	15.9792	1.000	0.844
Beer salt – Lemon Line	2.5483	70.5300	0.973	0.000

Variables			Negative group (Paraffin wax) P value*	
Candy	DSL	%SMHC	DSL	%SMHC
Lucas Bom Vaso	1.0317	61.0917	1.000	0.000
Pulparindo – hot and salted tamarind pulp	0.9008	46.1708	1.000	0.000
Lucas Pelucas – Cucumber flavor lollipop with chilli powder	0.2717	28.2317	1.000	0.036
Lucas Muecas Tamarind flavored lollipop with chilli powder	4.0617	52.1117	0.426	0.000
Lucas Pulpadip – Tamarind flavor	0.6425	60.4533	1.000	0.000
Rago Pullp – Chamoy candy	0.3667	26,8483	1.000	0.063
Picositos – Fruit seasoning	11.2950	73.8425	0.000	0.000
Baby bottle Pop	0.3975	5.1242	1.000	1.000
Rips Licorice Strawberry Belts	0.3033	49.3033	1.000	0.000

** Statistical significance values P<.05 (ANOVA, followed by Tukey)*

4. DISCUSSION

Previous studies have linked the increase in dental erosion to the consumption of acidic candies, particular due to the fact that the candies are typically held in the mouth for a considerable period during the dissolution period [15-17,22]. The present study investigated the erosive potential of stimulated saliva on dental enamel during the sucking of acidic candies. Based on Reddy et al. [23] classification, 5.9% of the candies tested were extremely erosive (pH <3), 35.3% were erosive (pH 3-3.99) and 58.8% were minimally erosive (pH >4). However, to measure their erosive potential, the candies to be dissolved first in saliva to release their acidic compounds [19].

The present study was able to show the erosive potential of acidic candies under a controlled environment. The candies were chewed in the mouth and after dissolution in saliva, analysis were performed using the saliva. Saliva is the medium for the candies compounds and plays an important role for the effect of these foodstuffs on teeth [2,16]. The increased salivary flow rates, which increased the bicarbonate (Alkaline) content of the saliva, may lower the erosive potential of the acidic saliva sufficiently to prevent enamel demineralization and the associated irreversible tissue loss [24]. Thus, the tested candies could have provoked less damage on the enamel surface compared to other studies that diluted the candies outside the mouth, using natural saliva, artificial saliva or distilled water [7,9,11,15,17]. These findings may also contributed to the low DSL values observed, despite the low pH values. However, the result of the present study contrasts with the findings of Carvalho et al. [15], where low pH of the analyzed candies showed high DSL values. Considering that saliva can theoretically protect against dental erosion [24], we speculate that the values of %SMHC and DSL obtained in the present study may be closer to values expected within the oral environment (*in vivo* or *in situ*).

In accord with previous studies [7,11,17,22], the present results highlighted the significance of erosive potential of acidic additives in foodstuffs, such as citric, malic, tartaric, ascorbic and lactic acids, recording relatively low pH and high TA, β and % SMHC values. The lower pH may also be due to the addition of extra acidic flavorings to the candies to preserve their taste [9,10]. For all the tested candies, besides the acids, the chili powder, tamarind pulp and/or natural lemon and lime were included. These components were present at the most erosive candies analyzed, and could also have contributed to the increase of their erosive potential [l7]. In the present study, the citric acid and the chili powder were the ingredients in common with the most erosive candies (Picositus, Acirrico sour, Lucas Muecas, Beer salt, Pulparindo, Lucas Gusano, LucasPulpadip). Thus, the high erosive behavior of these candies may be attributed to the known fact that in an aqueous medium the citric acid presents itself as hydrogen ions, acid anions (citrate) and non-dissociated acid molecules. This means that at more acidic pH, the hydrogen ions act by dissolving the hydroxyapatite crystals, and at higher pH values, citrate acts as a chelator, forming complex with the calcium and removing it out of the crystals [20]. In addition, exceptionally, for erosion there is no fixed critical pH value [4], like for caries, and the multiple chemical aspects of an acidic candy have to be taken into consideration.

The titratable acidity and β are other important variables to determine the erosive potential of acidic candies [10,11]. The relation between them should be carefully analyzed by the quantity needed to raise the pH, reflecting the speed that the saliva could be neutralized [20,22]. The positive statistical correlation found between the amount of NaOH added to raise the pH of the saliva to 5.5 and 7 and β observed in the present investigation was confirmed by previous studies [9,15,25].

Another interesting aspect is the presence of suitable concentrations of Ca and P as ingredients in these candies, considering that these ions has been shown to reduce the severity of erosive tooth wear [26,1]. Studies have found that lower levels of enamel demineralization were found in Ca-containing foods than in those without Ca [1,26]. The calcium was present in the ingredient list of four candies (Sweet tarts, Fun dip, Acirrico sour, Beer salt) analyzed. It was seen that Sweet tarts and Fun dip candies had the highest pH values and the presence of the calcium could have acted as an acid scavenger. Looking at the Acirrico sour and Beer salt, the tricalcium phosphate probably was responsible for raising the pH. The acidic ingredients in their formulas were chili powder, citric acid, fresh lemon for Acirrico sour, while the Beer salt had citric acid, natural lemon and natural lime. However the amount of the acidic ingredients in the candies formulas are not well discriminated. In addition, this is why only speculations were made in view of the analysis carried out in the present study.

Measuring the change in SMH is a simple, low-cost, non-destructive and accurate method to detect softening and reduced mechanical strength of enamel [I1,19]. In addition, the profilometer analysis provides a valid measure for assessing irreversible tooth surface loss [27]. All tested candies had some impact on tooth enamel shown by the %SMHC and the DSL, thus supporting the report of previous studies [7,17]. A positive correlation was detected between the two methods, however, due to the pH challenge used, %SMHC showed higher values than DSL. This finding demonstrated that due to the different detection methods the low DSL values indicated that the enamel losses were not profound. On the other hand, the softening of the enamel due to mineral loss was presented by the higher %SMHC values. The significance of %SMHC among most groups compared to the negative control confirmed that the SMH is a sensitive method for detecting changes in initial erosion lesions [28-30]. The detection of the superficial weakening of the dental enamel reflects the ionic losses caused by the acid attack [27, 31]. Also, as enamel erosion is an irreversible process, low DSL values may indicate that remineralization was involved in the process as reported by several studies about enamel remineralization [20,32-35].

Also, in relation to acidic candies, another relevant aspects that were reported by several authors were adhesion, frequency of consumption and quantity consumed [1,4,14,24]. These factors should also be taken into account when comparing the erosive potential of the acidic foods.

5. CONCLUSIONS

In conclusion, the present study confirmed the erosive potential of all the popular sour acidic candies that are commercially available in the state of Texas in United States of America. Thus, with dental erosion becoming an emerging problem in many countries due to convenient access to these acidic food and candies, the result of the present study should be considered during advice on behavioral change for prevention of dental erosion.

CONSENT

Informed consent was obtained from all saliva donors included in the study.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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