جـامـعـة مـحـمـد بـن راشـد
لـلـطـب و الـعـلـوم الـصـحـيـة

MOHAMMED BIN RASHID UNIVERSITY
OF MEDICINE AND HEALTH SCIENCES

EROSIVE POTENTIAL OF DRINKS CONSUMED IN DUBAI

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Presented to the Hamdan Bin Mohammed College of Dental Medicine
Mohammed Bin Rashid University of Medicine and Health Sciences
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Prosthodontics
2019

ABSTRACT

Erosive potential of Drinks Consumed in Dubai

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Background: Acid erosion has become a common dental problem. Dietary acid, mainly in the form of drinks, is the main source of extrinsic acid. Although studies have tested drinks for chemical parameters in Europe, no studies have been done on drinks in Dubai. The aim of this study was to determine pH, titratable acidity and concentrations of calcium, phosphate and fluoride in a range of drinks available in Dubai.

Materials and methods: A variety of drinks were analyzed (n=17) including teas, fruit juices, still and carbonated water. All drinks were tested at room temperature but teas were also tested as hot drinks. Titratable acidity was measured by volume of 0.1M NaOH needed to bring acid drinks to pH5.5 and 7.0 and Ca, F and PO_4 meters were used to measure the respective concentrations in the drinks. A positive control was orange juice and the negative control was Volvic water.

Results: The pH of the drinks ranged from 7.56 for Ramzy Licorice drink to 2.56 for Hibiscus hot tea. Mean pH for groups of drinks in ascending order are as follows: Fruit juices 3.36; Carbonated drinks 3.97; Hot teas 4.70; Powdered reconstituted drinks 5.13; Cold teas 5.28. Fruit juices had a significantly lower pH than the negative control (one-way ANOVA F=3.514, $p<0.05$). Titratable acidity ranged widely from 54ml for Barakat orange juice to 0.5ml of NaOH for Rooh Afza fruit juice. Fluoride concentration ranged from 15.95ppm for Pran Litchi to 0.04ppm for Perrier water. Calcium ranged widely from 605ppm for Barakat orange juice to 0ppm for Pran Litchi and the highest phosphate concentration was for cold chamomile tea

(22ppm) with zero detectable phosphate in Red Bull, Sunquick, Rooh Afza, Pran Litchi and Barakat orange juice.

Conclusion: All drinks had erosive potential with fruit juices having the lowest mean pH. Certain local drinks such as Pran Litchi have low pH and high titratable acidity with zero calcium and phosphate and thus have significant erosive potential.

DEDICATION

This thesis is dedicated to my family, especially my lovely father and mother, whose support, prayers and continuous encouragement made me go through this knowledgeable experience.

To my faculty, colleagues and everyone who supported me during my journey.

DECLARATION

I declare that all the content of the thesis is my own work. There is no conflict of interest with any other entity or organization.

Name:

Signature:

ACKNOWLEDGMENTS

All praise and thanks to Allah, the Lord almighty for being with me all the way through my postgraduate journey. My highest appreciation and gratitude goes to my parents and beloved family who encouraged me to pursue my dream and who supported me during my residency.

I would like to take this opportunity to express my gratitude to all the people who contributed to the successful completion of this study, starting from my supervisor, Professor Alexander Milosevic for his continuous guidance and support from the first day we met till the end and for inspiring me to conduct a study in the erosion field.

Particular thanks goes to my clinical instructors Dr Moosa Abu Zayda, Dr Taeho Yoon and Dr Fatemeh Amir Rad for guiding and supporting me through the postgraduate program.

I am highly grateful for all of MBRU faculty who lectured me through my residency and taught me to the highest standards.

And through my residency lots of appreciation goes to my classmates for their support and friendship, and to my prosthodontics colleagues. During the residency I was blessed to have amazing colleagues who I truly now consider as family and made my journey much more enjoyable.

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List of Abbreviations

pH: Potential of Hydrogen

GERD: Gastroesophageal Reflux disease

Ka: Acid dissociation constant

Ppm: Parts per million

°C: Degrees Celsius

Ca: Calcium

P: Phosphate

F: Fluoride

H: Hydrogen

NaOH: Sodium Hydroxide

ANOVA: Analysis Of Variance

T.A.: Titratable Acidity

N: Sample Number

M: Molar

N/A: Not applicable

1. INTRODUCTION

Other forms of tooth wear as described in the literature include; Attrition which is defined as the physical wear that results from the effect of opposing teeth rubbing against each other. Abrasion: Physical wear as a result of mechanical processes involving foreign substances or objects.[1] Erosion is known as the gradual, chronic, painless loss of dental hard tissue that is caused by chemical dissolution without bacterial involvement.[2] It is a multifactorial condition and its severity is dependent on life style, diet, type of acid, duration of the exposure, saliva composition and minerals content of the dental hard tissue. Patients with salivary flow of less than 1mm/min were found to have five times greater risk than patients with higher flow rates.[3] The industrial revolution led to Dietary changes from eating raw unrefined foods to a much softer and easy to chew diet and this has resulted in a marked decrease in dental wear. Prehistoric humans had an average wear of 280-360 µm/year, while in modern human teeth wear at an average of 15-20 µm/year in the post canine region.[4]

Dental erosion may be intrinsic or extrinsic. Intrinsic sources include recurrent vomiting and regurgitation of acid contents seen in conditions such as gastro esophageal reflux disease, anorexia or bulimia nervosa. Extrinsic sources may include carbonated drinks, fresh juices especially citrus fruits.[4] Milosevic found a significant relationship between consumption of 0.5L cola drink and gastro esophageal disease and dental erosion.[5]

The critical pH in respect to enamel demineralization ranges between 5.5 to 6.5 and is inversely related to the concentration of calcium and phosphate present in saliva.[6] Saliva on the other hand provides a protective mechanism against erosion by the salivary pellicle which acts as a semi permeable membrane. Second, it acts as a diluent. Third, according to the flow rate it aids in clearance of the acid by swallowing. Fourth, the buffering capacity of saliva neutralizes the acidity present. Fifth, saliva is supersaturated with calcium, phosphate and fluoride that aid in remineralization of the tooth structure after the acid attack.[7]

Diagnosis of dental erosion can be established by clinical examination, and questioning the patient. Clinical presentation of an eroded lesion varies from a smooth silky appearance in the early stage to change in morphology in the advanced stage. Cusps flatten and concavities become present, the width of which clearly exceeds its depth. Further progression of occlusal erosion leads to a rounding of the cusps, grooves on the cusps and incisal edges, and restorations rising above the level of the adjacent tooth surfaces. In severe cases, the whole morphology of the occlusal surface disappears.[6]

Over the past few decades, interest in erosion and it pathogenesis has increased, leading to various studies on soft drinks and it erosive effect on the dentition. Limited information is available about commonly consumed traditional drinks in the Arab league countries other than worldwide brands such as soft, energy or sports drinks. A link has been found between herbal traditional drink (Hibiscus) and erosion in a study conducted in Sudan.[8]

The erosive characteristics of drinks are linked to several parameters: endogenous pH, the total acid content (titratable acidity), concentration and the type of acid, also the length of the exposure, fluoride, phosphate and calcium may modify the erosive effect of the drinks. A drink with high titratable acidity has greater potential for apatite dissolution before returning to equilibrium.[9]

The erosive potential of 24 Designer drinks and a positive control of orange juice reported that surface loss of enamel slabs following immersion ranged from 1.5 to 13.5 µm when compared to orange juice 3.3 µm. There were marked differences in erosive potential of different commercially available orange juices, depending on the harvest time of year and weather conditions.[10]

According to the world bank, the Arab league population of the nations is approximately 424 million as of 2016[11], but limited data has been found on the prevalence of dental erosion and its severity in different age groups. The prevalence of erosion in 403, 5 year old preschool children in Sharjah, UAE, was found to be 58%.[12] Another study conducted by Al-Majed et.al in Saudi Arabia on 243, 5-6 and 862, 12-14 year-old boys, reported pronounced dental erosion into dentin in was 34% and 26% respectively. The study concluded that dental erosion is comparable to the UK in the same age groups.[13]

The erosive potential of sport drinks conducted by Chochran et al. in Australia found that the products had a pH of 2.81 to 3.55, titratable acidity from 35.81 to 59.22 mmol OH/L and low levels of calcium (<0.19 mM). The high titratable acidity can be attributed to the high content of citric acid and sodium citrate contained in these beverages.[14]

2. LITERATURE REVIEW

Dental erosion is multifactorial in its etiology and is dependent on the interplay of various chemical, biological and behavioral factors.[15] A systematic review study done was to assess the influence of diet in tooth erosion presence in children and adolescents with the age range of 8-19 years old and it concluded that Some dietary components such as carbonated drinks, acid snacks/sweets and natural acidic fruits juice increased erosion occurrence while milk and yogurt had a protective effect.[16]

To understand what may or may not influence the erosive potential of the diet, a basic knowledge of chemistry is required. During chemical erosion the hydrogen ions (H^+) present in acids become dissociated and interact with the hydroxyapatite crystals in enamel leaving the structure weakened. The chemical erosive potential of a dietary acid depends on the pH value (the H+ ion concentration), titratable acidity (the total available H^+ ions as the pH value changes), calcium chelation properties, buffering capacity (the ability to maintain a pH at the current value) and the mineral content, (specifically calcium and phosphate levels).[17] The pH value is the most widely used predictor of erosive potential, particularly at the start of an erosive challenge.

Key factors In Dental Erosion

- The chemical factors include pH of the acid, titratable acidity (amount of base needed to neutralize the acid) and the mineral content of the solution.
- Biological factors comprise of factors such as the presence of acquired pellicle, tooth structure and its relation to soft tissues.
- Behavioral factors embrace eating and drinking habits, abnormal swallowing patterns such as swishing the drink in mouth and dehydration secondary to regular exercise and alcoholism. All these factors have been linked to play a role in the progression of dental erosion.[15]

2.1. Chemical Factors

2.1.1. The type of acid

Erosive potential depends on acid type and concentration of the acid. At pH 2.0, lactic acid presented the highest erosive potential; while at pH 3, acetic acid was the most erosive acid. For all pH values, phosphoric acid was shown to have the lowest erosive potential.[18] Another comparison showed that maleic, tartaric and citric acids were the least erosive acids, while phosphoric, ascorbic and lactic acids were the most erosive.[19] However, in the latter study the acids were compared under different concentrations and pH values. Therefore, it is very difficult to isolate only one chemical factor when predicting the erosive potential of different acids.

2.1.2. Strength of the acid

Three factors are known to be the determinants of acidity within a solution:

1- The total amount of acid available, or titratable acidity

2- The amount of acid present in the solution H+ ion measured by pH.

3- and the strength of acids given by their acid dissociation constant (Ka) values.[20] The most useful way of describing the strength of acids is the pKa value which is the negative logarithm of the Ka value. When the pH value of a solution equals the pKa of a weak acid the acid exists as 50% anion and 50% undissociated acid molecule, providing hydrogen ions to the solution. In the case of erosion as the hydrogen ions interact with the apatite mineral the acid equilibrium shifts providing more hydrogen ions to continue the erosion.[21]

Table 1: Dissociation constants of acids at 25 C

Type of Acid	*Formula*	***p*K**a$_1$	***K***a$_1$
Acetic	CH_3CO_2H	4.76	1.75 x 10 -5
Lactic	$HCH_3H_5O_3$	3.86	1.38 x 10-4
Citric	$C_6H_8O_7$	3.13	7.4 × 10−4
Phosphoric	H_3PO_4	2.15	6.9 × 10−3
Tartaric	$H_2C_4H_4O_6$	3.04	1.0×10-3
Carbonic	H_2CO_3	6.35	4.5 × 10−7
Oxalic	$C_2H_2O_4$	1.25	5.6 × 10−2

2.1.3. The pH, critical pH and Titratable acidity

The chemical factors include pH of the acid, titratable acidity (amount of base needed to neutralize the acid) and the mineral content of the solution.

Experiments that evaluated the addition of Calcium Fluoride to acidic solutions to prevent erosion showed no protection was conferred even when the concentration of Fluoride was increased up to 20 ppm if the pH of the solution was below 3.[15]

The ability of a drink to resist pH changes brought about by salivary buffering may play an important part in the erosion process. The buffering capacities of pure fruit juices, non-fruit-based carbonated drinks, fruit-based carbonated drinks, flavored spring waters, and plain carbonated mineral water found that fruit juices and fruit-based carbonated beverages had the highest buffering capacities, which may induce a prolonged drop in oral pH.[22]

The erosive potential prediction of enamel loss using pH and titratable acidity for yogurt drink was twice as high when compared with other erosive drinks, this result is opposing to the results of the calculated enamel loss, which showed enamel loss is less than the half of the other erosive drinks. This may have been because yogurt drink is a naturally high calcium beverage, which can reduce enamel demineralization or does not soften dental hard tissues. In this case, it is demonstrated that using only the pH and TA parameters was insufficient to predict the erosive potential of high calcium products, and yet the study supported calcium containing beverages being able to delay enamel erosion.[23]

The critical pH varies over a wide range, its value depending on the concentrations of calcium and phosphate in the solution, it is the pH at which a solution is just saturated with respect to a particular mineral, such as tooth enamel. If the pH of the solution is above the critical pH, then the solution is supersaturated with respect to the mineral, and more mineral will tend to precipitate out. Conversely, if the pH of the solution is less than the critical pH, the solution is unsaturated, and the mineral will tend to dissolve until the solution becomes saturated.

The concept of critical pH is applicable only to solutions that are in contact with a particular mineral, such as enamel. Saliva and plaque fluid, for instance, are normally supersaturated with respect to tooth enamel because the pH is higher than the critical pH, so our teeth do not dissolve in our saliva or under plaque. However, these fluids cannot be supersaturated with respect to individual ions, such as calcium or phosphate.[24]

Dental enamel is composed primarily of hydroxyapatite (HA), $Ca_{10}(PO_4)_6(OH)_2$, but it also contains several impurities such as carbonate, magnesium and fluoride. Because the proportions of these impurities vary from person to person, and indeed from tooth to tooth, and because the impurities can influence enamel solubility, that solubility is not fixed and varies slightly from person to person. Nevertheless, the factors that influence the solubility of enamel’s primary component, HA, also influence the solubility of enamel.

If a small amount of HA dissolves, releasing calcium, phosphate and hydroxyl ions are released. This process continues until the water is saturated with respect to HA. At that point, the rate of the forward reaction (mineral dissolution) is equal to the rate of the backward reaction (mineral precipitation). Solubility of HA increases about 10-fold for each unit decrease in pH. At pH 7, the solubility of HA in water is about 30 mg/L, whereas at pH 4 it is about 30 g/L.

Enamel that has suffered surface erosion by acid cannot be recalcified, because there is no suitable matrix for crystal growth. An enamel surface eroded by acid becomes covered by an acquired enamel pellicle of salivary and bacterial proteins as soon as it contacts the saliva, and this pellicle inhibits mineral deposition.[24]

2.2. The Erosive potential

The erosive potential not only depends on the chemical composition and physical properties of a product, but also the natural oral environment and individual consumption habits.

Erosive lesion occurs in three stages:

- Early demineralization and softening of the tooth tissue without surface loss.
- Microscopic material loss.
- A clinically visible erosive lesion.

Lussi et al. listed three factors that influence the erosive potential of acidic beverages:

Chemical factors: pH and buffer capacity of the beverage, type of acid, adhesion of the product to the dental tissue, chelation properties, presence of calcium, presence of phosphorous and presence of fluorine.

Behavioral factors: Eating habits, lifestyle, high intake of fruit and vegetables, excessive consumption of acidic foods and drinks, the habit of plying children with acidic drinks at night time and oral hygiene practices.

Biological factors: flow, composition and buffer capacity of the saliva, acquired pellicle, composition and dental structure, anatomy of the soft tissue in relation to the tooth and the physiological movement of the soft tissue.[25]

2.2.1. Methods for measuring erosive potential of drinks

Sometimes erosive potential is determined solely on the basis of chemical parameters of a product; most frequently pH, titratable acidity and buffer capacity. According to many authors, the best determinant of erosiveness is titratable acidity. However, some authors indicate both

Ph and titratable acidity or buffer capacity are reliable prognostics of the erosive process; to make it more accurate it should be said pH characterizes erosive potential better when a beverage is consumed in large quantities and its time of contact with dental tissue is short, whereas titratable acidity is a better determinant if a small amount of beverage is mixed with saliva and stays in the oral cavity longer. Both pH and titratable acidity, or buffer capacity, provide an approximate indication of the erosive potential of a product as many other factors are also involved.[26]

2.2.2. Methods for reducing the erosive potential

Two most frequently cited erosive acids are citric and phosphoric acid. Organic acids are the basic ingredients of many beverages. With the main acids in fruit drinks being citric acid and malic acid. Cola-type soft drinks contain mainly phosphoric acid, sometimes ascorbic and lactic acid or in the case of fizzy drinks, carbonic acid formed by carbon dioxide in solution. While tartaric acid dominates in wine and grapes and, in smaller amounts, malic acid, citric acid and succinic acid. Oxalic acid is contained in sorrel and rhubarb.

Lactic acid present in food products is a metabolic product of Lactobacillus bacteria in the fermentation process; it is contained in dairy products, as well as in pickled vegetables. Chemical dissolution of tooth tissue may be caused by both H^+ ions and anions capable of binding or complexing calcium.

2.2.3. Acidity reduction by drink modification

Modification of beverages by increasing their pH >3.8 and lowering of titratable acidity may result in a considerable reduction of erosive potential, as these parameters are good determinants of erosiveness. However, such modifications are not favorable for because of shorter shelf-life and sensory reasons with the loss of the refreshing taste. It should be emphasized that increasing a product's pH, even to the value of 7.0 does not make the drink completely safe for teeth as some acid anions as (citrate > lactate > phosphate) maintain the ability to bind calcium.

The effect of the exposure time and the influence of a cola-type soft drink and a soy-based orange juice on the surface and subsurface erosion of primary enamel found that longer exposure to the beverages resulted in greater reduction of enamel microhardness. Changes in the enamel microhardness at different depths were evident for both beverages up to 150 µm. The cola-type soft drink have produced more accentuated primary enamel alteration than the soy-based orange juice. Artificial saliva that contains calcium, phosphate and fluoride was used as a control because it exerts the same remineralizing effect as that of fresh human saliva, as the control specimens showed gradual microhardness gain up to the 30th day and stabilization thereafter.[27]

2.3.Mineral Content

Calcium, fluoride and phosphate, effects were studied on specimens of enamel that were demineralized with different beverages: A: Coca-Cola, B: Sprite, C: Sprite light, D: orange juice. Either 1.0 mmol calcium (Ca) or a combination of 0.5 mmol calcium plus 0.5 mmol phosphate plus 0.031 mmol fluoride (0.6 ppm F) was added to the beverages. Samples of each group were subdivided into three subgroups (original solution, Ca, and a combination). Remineralization was accomplished by rinsing with artificial saliva. The authors concluded that modification of the test beverages with low concentrations of calcium, phosphate and fluoride was able to reduce the erosive potential of the drinks. However, with these low concentrations enamel dissolution could not be completely prevented.[28]

2.3.1. Calcium

Most investigations aimed at reducing the erosive potential of acidic products have focused on the addition of calcium. According to the Law of Mass Action, the rate of hydroxyapatite dissolution could be slowed if the solvent contains the products of this reaction: the calcium and phosphate ions. Indirect evidence supporting this phenomenon is because acidic dairy products with their naturally high calcium and phosphate content, have very small, sometimes undetectable, erosive potential despite the presence of lactic acid (pH ~4.0). Theoretically, beverages saturated or supersaturated with respect to hydroxyapatite are not expected to cause enamel dissolution; however, such modification might result in an unpleasant taste and be harmful. Barbour et al.[29] found an approximate threshold condition for citric acid (pH 3.3) defined by a calcium concentration of 120 mM and a phosphate concentration of 0.57 mM. Despite being highly under saturated, the solution showed no significant erosive potential with respect to enamel and using greater concentrations of calcium did not provide any additional benefit. However, when consuming more than 520 ml of such modified citrus beverages there is a risk of exceeding the tolerable upper intake level of calcium (2.5 g per day), resulting in adverse effects (nausea, vomiting, constipation, suppression of intestinal absorption of other mineral nutrients, such as zinc, magnesium and phosphates, and an increased risk of kidney stones). Obviously, the addition of calcium can play an important role in the prevention of this nutrient deficiency in the organism, but considering consumer health safety, it is preferable to establish an optimal anti-erosive and tolerable level of anti-erosive additive.

Calcium was found to be effective in reducing the erosive potential of most of the tested beverages (Calci-Cola, Calci-sports, Minute Maid Ca), while the effect of phosphorus and fluoride, in association with calcium, was less clear and should be investigated further.[30]

It was found that the addition of 1–1.5% POs-Ca Phosphoryl-Oligosaccharides of Calcium could significantly reduce enamel erosion by apple juice maintain an acceptable taste.[31]

Supplementation of orange juice with calcium 42.9 mmol and phosphate 31.2 mmol did not erode enamel after immersion for 7 days. showing that even lower concentrations of calcium, phosphate together with fluoride were able to reduce enamel dissolution and demineralization.[32]

Fifteen volunteers participated in a split-mouth study to evaluate if calcium pre-rinse could increase the fluoride rinse protection against enamel erosion. 3-phase, crossover study design wearing a palatal appliance containing four sterilized bovine enamel slabs, for 10 days.

In the 1st phase, five participants followed protocol A: daily rinse with a Ca lactate (CaL, 150 mmol/L, 1 min), followed by F (NaF 12 mmol/L, 1 min). Another five participants followed protocol B: daily rinse only with F, while the remainders followed protocol C: no rinse. The appliances were removed from the mouth and one side of the palatal appliance was exposed to a daily erosive challenge (0.05 M citric acid, 90 s); the other side served as control (deionized water – no erosion). In the 2nd phase volunteers were crossed over to other protocol and in the 3rd phase volunteers received the remaining protocol not yet assigned. Specimens were evaluated for surface loss using an optical profilometer. Study results showed that the CaL pre-rinse followed by NaF rinse significantly decreased surface loss of enamel when performed prior to an erosive challenge in comparison with the condition in which NaF only was used.[33]

2.3.2. Phosphates

The addition of single orthophosphate ions in the form of 0.21% monosodium orthophosphate does not lower the erosive potential of acidic drinks as effectively and permanently as monocalcium phosphate. However, in another study 1% NaH2PO4 reduced erosive potential in vitro and in vivo. It was observed in earlier in vitro studies that the application of polyphosphates and metaphosphates before hydroxyapatite erosive exposure reduced erosive potential by 20– 50%. In the process of enamel dissolution by an acidic drink, phosphate groups of polyphosphate probably bind with hydroxyapatite, reducing the surface area available for dissolution and replacing HPO_4^{2-} groups, hence inhibiting detachment of subsequent ions. The anti-erosive effect of polyphosphates is definitely weaker in relation to dentine, as this tissue contains much less inorganic substance in the form of hydroxyapatite than enamel. Although polyphosphates in a concentration ranging from 0.01 to 1.0 g/L are believed to reduce the erosive potential of acidic drinks, their effectiveness under in situ conditions proved to be different.

2.3.3. Fluoride

Many older studies with rats fed with experimental solutions revealed that fluoride in the form of sodium fluoride reduced the erosive potential of an acidic solution in the following concentrations: 50 ppm in grape fruit juice, 15 ppm in an experimental sports drink, 5 ppm in a solution of citric acid and Coca-Cola, 2 ppm in fruit juices, and 1.9 ppm in grapefruit juice. Also, 40 ppm of fluoride as sodium monofluorophosphate reduces the erosive potential, but not to such a large extent as monocalcium phosphate. In contrast, enriching a 0.3% solution of citric acid and fruit juices with 1 ppm of fluoride reduced erosiveness even at lower pH.

Currently, calcium is considered as the most effective supplement in reducing erosion for high risk individuals who cannot reduce their dietary acidic intake. It must be noted that product modification may involve a lower sensorial quality, reduced availability of some natural nutrients, storage time shortening or precipitation of the modifier.[26]

Topical treatment with Prevident 5000 (contains 5000 ppm fluoride in the form of 1.1% NaF in a dental cream. Significantly increased enamel resistance to erosion by orange juice and should be considered as a treatment choice in patients susceptible to acidic dental erosion.[34]

2.4. Patient-related factors

2.4.1. Drinking Habits

A high frequency of dietary acid consumption plays an important role in the risk of erosion. The first step regarding preventive measures for this condition is to identify the frequency, amount and time of the day when erosive products are consumed using dietary and behavior records over four days. It has been noted that four or more dietary acid intakes per day in patients with other risk factors for erosion resulted in a higher risk of erosive tooth wear.[35] In order to achieve appropriate prevention, it is important to reduce the frequency of consumption and the contact time with the teeth of potentially harmful food and drink. Patients must avoid the retention of dietary acid in the mouth before swallowing, and not swish them around the teeth or even sip the erosive dinks over an extended period. The use of straws positioned toward the back of the mouth is also recommended when drinking any potentially erosive drink. [27]

2.4.2. Lifestyle

The literature has a few studies regarding the prevalence of erosion in individuals with vegetarian or vegan diets but the results are contradictory. Other unhealthy lifestyles such as use of illicit drugs and alcohol abuse, are often linked to an increase the risk of erosion.

Studies have shown that increasing waiting periods before brushing after erosive challenges probably enhances the abrasion resistance of enamel, due to the remineralization of the surface. It is important to bear in mind that the role that pH and calcium have in determining the erosive and softening potential of and the drinks active ingredients in dentifrices, such as fluoride, can reduce the progression of erosive tooth wear.[36,37]

2.4.3. Reflux

Gastroesophageal reflux corresponds to brief episodes of esophageal peristalsis followed by increased saliva flow aimed to remove and neutralize gastric contents entering the esophagus. Gastroesophageal reflux is a physiological phenomenon, different from the gastroesophageal reflux disease (GERD), in which the gastric contents entering the oesophagus promote pH fall below 4 during a certain time. In patients with GERD, erosion is more common and more severe compared to healthy controls.[36]

A study on the prevalence of dental erosion in young Icelandic adults (19–22 years old) and patients with gastroesophageal reflux disease (GERD), in relation to their soft drink consumption used a detailed frequency questionnaire of soft drink consumption followed by a clinical examination. Erosion was scored for incisor and molar teeth separately. No significant difference was observed in the prevalence of dental erosion between young adults and GERD patients. However, by combining the two study groups a three-fold higher risk of having erosion in molars or incisors was found for subjects drinking Coca-Cola three times a week or more often. Additionally, significantly higher erosion scores were found in molars among subjects drinking more than 1 litre of carbonated drinks (all brands) per week. It was concluded that the frequency of soft drink consumption is a strong risk factor in the development of dental erosion.[38]

2.4.4. Vomiting

Bulimic individuals show binge eating and self-induced vomiting episodes (more than twice a week) to avoid body weight gain, in which the intrinsic acid present in the stomach, which is highly erosive, makes contact with the tooth surfaces. Vomiting can also occur during the first trimester of pregnancy, but can be only considered a risk factor for developing erosion when it is frequent over an extended period of time.[36]

2.4.5. Saliva

Saliva is the most important biological factor affecting the progression of dental erosion[39] for many reasons:

- it is the main contributor to the formation of the acquired pellicle;
- it acts directly on the erosive agents, diluting, clearing and buffering the acids;
- being supersaturated with respect to the tooth mineral, it reduces the rate of demineralization and enhances remineralization, providing calcium and phosphate to enamel and dentine;
- many proteins present in saliva and acquired pellicle are able to modulate the rate of erosive tooth wear.[40]

Despite the role of saliva in reducing deleterious effects of acidic beverages, regular consumption of acidic beverages markedly decreases the saliva buffer capacity, which results in demineralization of tooth structure.[41]

The salivary flow rate is the best indicator of the protective ability of saliva, since it directly influences the above-mentioned salivary parameters. The average unstimulated salivary flow rate is around 0.3–0.4 ml/min. The main causes of decreased flow rate are therapeutic drugs, especially when many drugs are combined, as well as Sjogren’s syndrome and radiation treatment for head and neck cancer. An association was found between reduced salivary flow and increased prevalence of erosive tooth wear.[3]

2.4.6. Acquired pellicle

It is a thin acellular film formed on the tooth surface by selective adsorption of proteins mainly, but also containing lipids and glycoproteins. Most of the proteins present in the acquired pellicle originate from the salivary glands. It acts as a physical barrier or a permeable membrane, preventing direct contact between acids and the tooth surface, thus reducing the dissolution of hydroxyapatite and protecting the tooth against erosive attacks. The initial phase of pellicle formation occurs within seconds of enamel exposure to saliva.[36]

The thickness of the acquired pellicle varies around the mouth such that the thickest pellicle occurred on the lower lingual surface, and the thinnest pellicle occurred on the upper anterior palatal surface. In the lower arch, pellicle was significantly thicker in the anterior lingual surface compared with the anterior labial surface at a ratio of 2:1, while the posterior lingual surface had a significantly thicker pellicle than the posterior buccal surface, also at a ratio of approximately 2:1.[42]

2.4.7. Dentin Hypersensitivity

The presence of dentine hypersensitivity is an indicator that acids maybe present in the diet. Presence of erosive tooth wear have been linked dentine hypersensitivity.[43]

Cervical hypersensitivity is a dental problem several risk factors including the indiscriminate use of soft drinks. Soft drink intake is the most important factor related to dentinal tubule exposure which may lead to dentine hypersensitivity, since the consumption of acidic drinks has increased considerably. After root dentine exposure, dentine wear can be easily provoked by erosion and/or abrasion.

Dentine root surfaces exposed using a diamond bur followed by scaling resulted in a smear layer, followed by application of energy drinks on the exposed region. The authors Concluded that energy drinks can be an important etiological factor for cervical dentine hypersensitivity.[44]

A study that included 350 participants found a direct relationship between clinical dentine hypersensitivity and dietary acid consumption within the previous hour.[45]

2.5.Diet related factors

2.5.1. Acids within the diet

It is important to be able to identify the range of food, drinks and medications that have erosive potential. Most fruits are acidic, with perhaps fruits such as bananas and peaches being on the lower end of the acid spectrum.[43] Citrus fruits have been implicated in multiple epidemiological studies to have a significant erosive risk. An American study investigated the erosive potential of 379 commercially available soft drinks. They identified 39% were extremely erosive (pH <3), 54% were considered erosive (pH = 3–3.99) and only 7% were identified as minimally erosive (pH ≥4). Lemon juice was found to have the lowest pH (pH 2.25), followed by cola drinks (2.32–2.39). Importantly, sugar-free drinks are as erosive as their sugar-sweetened counterparts. 20 different sparkling mineral water has low erosive potential even though it has a relatively low pH from the carbonation because it has a low titratable acidity and is therefore a weak acid.[46]

A final area to be aware of is the acidic potential of vinegars and pickles. There are diets which advise frequent consumption of vinegars. It was observed that those who consumed apple cider vinegar weekly were 10 times more likely to have severe erosive wear.[47]

Individuals consuming citric fruits more than twice a day have a 37 times greater risk of developing lesions through erosion than those who do not. Similar risks appear to occur with the consumption of apple vinegar (10 times higher), sports drinks (4 times higher) or sodas (4 times higher), when consumed every day. The advancing loss of dental structure through erosion could be as much as around 1 μm per day.[48]

2.5.2. Frequency of dietary acid intake

While the erosive potential of specific dietary acids is important, it is important to look at the overall pattern of consumption. The frequency of dietary acid intake has been recognized as one of the primary risk factors for erosive tooth wear progression.

Those who consumed acidic drinks twice a day between meals were over 11 times more likely to have moderate or severe erosive tooth wear. This was halved when drinks were consumed with meals (patients who drank two acidic drinks per day with meals were 6.8 times more likely to have tooth wear compared to those who did not drink acidic drinks daily). Increased consumption of acidic drinks is a risk for erosive tooth wear whether they are consumed between or with meals. In contrast, fruit consumption with meals was not associated with erosive tooth wear and fruit consumption between meals did represent increased risk.[35]

2.5.3. Quantity of dietary acid intake

While most studies focus on the frequency of acid intake, with limited assessment of the quantity of acid intake, some studies aimed to investigate the association between dental erosive wear and potential background, behavioral and dietary risk indicators and to assess whether there is a dose-response relationship between the level of acidic beverage consumption and dental erosive wear among adolescents. The result indicates a dose-response relationship between the daily consumption of acidic drinks and dental erosive wear.[47]

2.6. Physical Factors

2.6.1. Temperature

Investigations of the erosive potential of soft drinks are usually performed at room or body temperature, but drinks are more frequently served chilled, with ice, or occasionally hot. Since the rate of chemical reactions usually increases with temperature, and the acid dissolution constant is temperature dependent, erosion increase with temperatures. The correlation between enamel softening, enamel erosion, and temperature found a statistically significance difference between nanomechanical properties and erosion depth at all temperatures, with softening and erosion increasing with temperature. While other drinks showed a slight softening and virtually no material loss, and temperature had no statistically significant impact on erosion. The difference between the drinks can be explained by their composition but generally for the erosive drink, material loss increased, and Nano hardness decreased, linearly with temperature.[47]

Temperature sensors have been used to investigate the intraoral temperature changes while drinking hot tea and observed that the highest temperatures reached when drinking hot tea were present on the buccal surfaces of the upper incisor surfaces. These are surfaces that some studies have reported to be strongly associated with dietary erosive tooth wear.[43]

2.7. Types of Drinks

2.7.1. Soft Drinks

A variety of carbonated soft drinks (both regular and diet versions) were placed in 5.0 mL screw-cap plastic containers and the specimens were weighed at 24–48 hour intervals for a total of 14 days (336 hours). The enamel dissolution was two to five times greater ($p < 0.05$) among non- cola drinks than among cola beverages. In addition, enamel dissolution in canned iced tea was some 30 times greater than that produced by brewed black tea and coffee. The amount of enamel dissolution from coffee and brewed black tea was seven times greater than that of both water and root beer, while cola drinks dissolved enamel 55–65 times more than both water and root beer. Enamel dissolution from non-cola drinks was 90–180 times greater than dissolution from water. Reducing the length of time of beverages are in the mouth by would be beneficial.[49]

The difference between regular and light Coca-Cola drinks influences the wear of enamel subjected to erosion followed by brushing abrasion. Regarding chemical characteristics, light cola had a pH of 3.0, 13.7 mg Ca/L, 15.5 mg P/L, and 0.31 mg F/L, while regular cola had pH 2.6, 32.1 mg Ca/L, 18.1 mg P/L, and 0.26 mg F/L. The light cola promoted less enamel loss than its regular counterpart. There was not a significant difference between erosion and erosion plus abrasion for light cola. However, for regular cola, erosion plus abrasion resulted in higher enamel loss than erosion alone.[50]

Four commercially available soft drinks in Taiwan were analyzed to measure pH, titratable acidity, and ion contents. The erosive potential of the soft drinks were measured based on the amount of loss of human enamel following exposure to the soft drinks tested for different periods of 20 minutes, 60 minutes, and 180 minutes and tested for enamel loss using a confocal laser scanning microscope. The pH values of the soft drinks were below the critical pH value 5.5 for enamel demineralization, ranging from 2.42 to 3.46. All tested soft drinks were found to be erosive.

Soft drinks with high calcium contents have significantly lower erosive potential. Low pH and high citrate content may cause more surface enamel loss. Although pH was believed to be a better predictor, the titratable acidity to pH 7 may be a predictor of the erosive potential for acidic soft drinks. The erosive potential of the soft drinks may be predicted based on the types of acid content, pH value, titratable acidity, and ion concentration.[51]

2.7.2. Sparkling Water

The role of flavored sparkling water drinks is unclear. A study conducted in the UK aimed to determine the pH, titratable acidity and in vitro erosive potential of a selection of these drinks. The pH values recorded for the flavored water drinks ranged from 2.74 to 3.34, and those with the lowest pH were the lemon and lime, peach, and grapefruit flavors. Exposure of an enamel surface to the flavored water drinks for 30 min resulted in changes in the pitting of the surface with each of the flavors examined. All of the drinks exhibited noticeable dissolution potential that is almost similar to or greater than the comparator, pure orange juice. pH levels were observed to decrease after exposure of the drinks to air for 30 min prior to their use in the dissolution assay. Whilst there was not an appreciable change in the pH of the sparkling waters after exposure to air, there was a decrease in titratable acidity ranging from 26% to 48%. This decrease in titratable acidity is assumed to be the result of loss of carbonic acid caused by the carbonated nature of these drinks.[52]

Dental erosion is an increasingly prevalent problem in Australian schools. The composition and erosive potential of beverages exhibited erosive potential but found no significant differences in erosivity between sugar and non-sugar-containing carbonated beverages.[53]

2.7.3. Fruit Juices and Smoothies

The surface roughness of primary enamel after exposure to three different brands of grape juice immersed for 2 min, 3 times per day, for 9 days and stored in artificial saliva between immersion found the roughness parameters were determined again in addition to the pH and titratable acidity of the grape juices. The surface roughness did not differ significantly among groups. The pH had a weak correlation with the acidity values and the juice with highest acidity showed greater erosive.[41]

While four commercially-available fruit smoothie drinks were assessed for both initial/baseline pH and titratable acidity and orange juice drink was used as a positive control. Baseline pH and titratable acidity were measured, until pH 7 and pH 10 were reached. Each of the fruit smoothies investigated demonstrated a low baseline pH and had relatively high titratable acidity. Owing to both their low pH and high titratable acidity, the author advised to limit the consumption of such fruit smoothies to meal times.[54]

2.7.4. Mouthwash

The erosive potential of mouthwashes has been investigated and the majority of mouthwashes were slightly acidic. Listerine had the lowest pH similar to Nestle orange juice. Only two of the mouthwashes had pH above 5.5. Although this study did not find significant association between mouthwash use and erosion; dental care products that come in contact with teeth should be formulated at safer pH instead of acidic pH. Studies concluded better efficacy of Fluoride at neutral pH in causing remineralization and inhibiting demineralization than acidic ph.[15]

2.8. Recommendations

The odds of having erosion increases with the number of soft drinks consumed daily. Dietary recommendations in dental practice should aim to:

- Reduce the frequency and amount of consumption of acidic drinks and foods.
- Recommend that acidic drinks not be added to infant feeding bottles.
- Suggest that if soft drinks are consumed, they should preferably be chilled, consumed in 1 sitting, and limited to mealtimes.
- Discourage the consumption of acidic sweets, especially between meals.
- Encourage the consumption of water and nutritious beverages such as milk, and also the consumption of fresh fruits, when part of a healthy and balanced diet.
- Recommend the consumption of a neutralizing food, such as cheese, after the intake of an acidic drink or food.[55]

Many dental procedures and treatment may be affected if the patient is frequently and regularly exposed to acidic drinks. Dental sensitivity may increase with frequent consumption of acidic drinks as smear layer is dissolved by acidic drinks. Acidic solutions not only cause a decrease in the hardness of tooth substance but the longevity of tooth colored restorations such as micro filled composites and resin modified glass ionomers is also compromised, therefore the dentist needs to be aware of the choice of filling materials in patients suffering from dental erosion.[15]

2.9. Statistical Analysis

All data was entered into an SPSS v20. Continuous data such as mean pH of all drinks were compared using one-way ANOVA with significance set as 5%. Correlation coefficients were also determined for the relationship between T.A. and pH.

2.10. Aims

The following study aims to determine the erosive potential of drinks consumed in Dubai.

2.11. Objectives:

1. To measure the pH and titratable acidity of drinks available in Dubai.
2. To measure calcium, phosphate and fluoride concentration
3. To compare the acidity of different types of drinks.

3. MATERIALS AND METHODS

3.1.Study Design

This was an experimental study analyzing the erosive potential of 20 consumed drinks in Dubai. The samples were purchased from supermarkets in Dubai and stored in the laboratory according to the manufacturer's recommendations. Testing was carried in the Mohammed bin Rashid College of Medicine and Health Sciences Physiology laboratory. All tests were carried out by single examiner.

3.2.Samples

The samples used in the study were divided into carbonated and non-carbonated drinks. Carbonated drinks were divided into energy and soda drinks, while non-carbonated was divided into fruit and other/Herbal drinks. A positive control was orange juice and Negative control was still water (Volvic). Table 2 shows the samples tested in the study.

3.2.1. Inclusion and Exclusion criteria:

Table 2 shows most commonly consumed drinks in the Dubai that are examined in the study. Dairy products were excluded.

3.3.Measured variables:

1- Acidity (pH)
2- Temperature (Degrees Celsius)
3- Titratable acidity (NaOH 0.1M / 50 ml) at pH 5.5 and 7.0
4- Fluoride (ppm)
5- Calcium (ppm)
6- Phosphate (ppm)

Table 2: Samples tested in the study

	Criteria	Drink Type	Brand	Expiry
Control Drinks	Positive Control	Orange Juice	Barakat	24/4/2018
	Negative Control	Still Water	Volvic	22/1/2019
			Mai Dubai	28/12/2018
Study Drinks	Carbonated	Energy Drink	Red Bull	23/1/2019
			Monster	19/2/2019
		Soda Water	Perrier	8/1/2019
	Non-Carbonated	Fruits drinks	Vimto fruit cordial	18/4/2018
			Kassatly Chtaura Jallab	1/2/2019
			Kassatly Chtaura Almond-amande	1/2/2019
			Kassatly Chtaura Apricot- kamardine	1/2/2019
			Sunquick Lemon Juice	14/6/2019
			Rooh Afza Fruit juice	5/2019
			Tang - Orange	19/7/2019
			Pran Litchi Drink	21/8/2018
		Other/Herbal	Ramzy Carob	1/1/2020
			Lipton - Lemon and Ginger	26/9/2019
			Ramzy Licorice	1/1/2021
			Safa - Hibiscus	21/5/2019
			Golden Zaatar - Thyme	3/2/2020
			Lipton - Chamomile	12/2019

3.4.Study Instruments

Table 3: List of instruments used in the study.

Type	Brand
1- Ph and temperature meter	WTW – inoLab pH meter – pH7110
2- Fluoride meter	Hanna- Fluoride Low Range Portable Photometer HI96729
3- Calcium meter	Hanna Calcium and Magnesium Portable Photometer HI 96752
4- Phosphate meter	Hanna Low Range Phosphate Colorimeter – Checker® HC HI713
5- Magnetic stirrer, heater	Stuart Heat stir – UC152
6- Beakers, pipette	Tefal beaker, Gilson pipettes (1ml, 0.1ml)

3.4.1. Training and Calibration:

- Hanna instruments ltd. (Ajman Free zone, UAE) provided training for usage.
- All Hanna instruments are factory calibrated.
- Other instruments were calibrated before usage.

3.5. Method of Measuring

1- All concentrated samples where diluted with Mai-Dubai water according to the manufacturer's recommendations.

2- The pH of carbonated drinks was measured immediately after opening.

3- Herbal Drinks that needed boiling to prepare them, pH were measured at 2 points:

   a. Measured at almost 100° C.

   b. Measured after cooling down to room temperature.

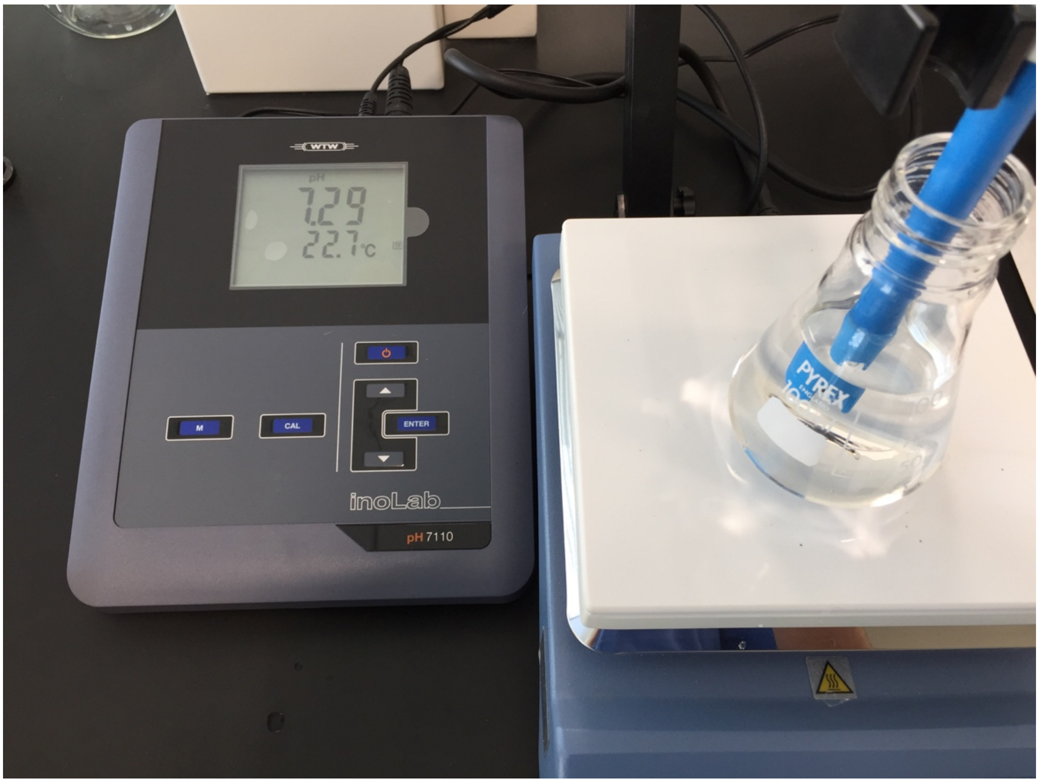
3.6. Steps of Measuring

The following steps where conducted in the laboratory and all variable were measured according to manufacturer recommendation.

3.6.1. pH and temperature Measurement

50 ml of the sample drink was placed in a beaker, pH and temperature values were measured and recorded.

Figure 1: pH and temperature meter, electrode placed in 50 ml sample of Volvic water.



3.6.2. Titratable acidity

The same 50 ml of the sample drink was placed on the magnetic stirrer, with the pH electrode placed in the sample. Incremental addition of NaOH 0.1M with a pipette was done while monitoring the pH until it reached 5.5 and 7.0 and recorded at the two points.

3.6.3. Fluoride

A cuvette was filled with 10 ml distilled water, followed by addition of 2 ml of fluoride reagent(HI 93729-0). The cuvette was placed in the meter and a timer is set to 2 minutes by pressing the READ/TIMER button for 3 seconds, the zero button is pressed until the display shows (0.0). The cuvette was then removed, cleaned and flushed with distilled water. Using the same cuvette, using a pipette up to 10 ml and 2ml of fluoride reagent was added. The cuvette is placed back again in the fluoride meter and the READ/TIMER button is pressed for

3 seconds to initiate a countdown of two minutes. After the end of the countdown the meter directly displays the fluoride concentration in mg/L (ppm).

Figure 2: Fluoride meter with the cuvette inserted and showing reading for Volvic water.

3.6.4. Calcium

Using a pipette a cuvette was filled with 3 ml of the sample followed by addition of 7 ml of calcium buffer reagent (HI 93752A-0 CA) and 4 drops of Buffer reagent. The cuvette was shaken and placed in the calcium meter. The cuvette was then removed and Oxalate reagent 1 ml (HI 93752B-0 Ca) added. The cuvette was then placed back into the calcium meter and the READ/TIMER button pressed for 3 seconds, the countdown was initiated for 5 minutes. After the end of the countdown the meter directly displays the calcium concentration in mg/L (ppm).

Figure 3: Calcium meter with cuvette inserted and showing reading for Volvic water.

3.6.5. Phosphate

The cuvette was filled with 10 ml of the sample and placed in the phosphate meter and the button pressed. After which phosphate reagent (HI 713-25) was added and mixed until the powder dissolved completely. At the end of the 3 minute countdown the meter directly displayed the phosphate concentration in mg/L (ppm).

Figure 4: Phosphate meter with cuvette inserted and showing reading for Volvic water

4. RESULTS

A total of 17 drinks were tested at room temperature excluding the positive control (Barakat orange juice) and the negative controls (Volvic and Mai Dubai). Four drinks were tested as hot and at room temperature ((Lipton) Lemon and Ginger, (Safa) Hibiscus, (Golden Zatar) Thyme, (Lipton) Chamomile).

Table 4: pH of the tested drinks

No.	Drink Name	pH	Temperature
1	Red Bull Energy Drink	3.47	19.7
2	Perrier Soda Water	5.30	22.0
3	Monster Energy Drink	3.15	22.2
4	Vimto Fruit Cordial	2.94	21.3
5	Kassatly Chtaura Jallab	4.13	21.8
6	Kassatly Chtaura Almond	3.30	21.7
7	Kassatly Chtaura Kamardine-Apicot	2.74	22.7
8	Sunquick lemon Juice	2.78	22.0
9	Rooh Afza Fruit Juice	4.16	22.3
10	Tang Orange	2.84	22.0
11	Pran Litchi	3.30	22.4
12	Ramzy Carob	5.00	23.9
13	Ramzy Licorice	7.56	23.8
14	Lipton Lemon and Ginger Hot	4.75	99.5
15	Lipton Lemon and Ginger Cold	5.13	21.7
16	Safa Hibiscus Hot	2.56	99.1
17	Safa Hibiscus Cold	2.75	21.7
18	Golden Zaatar Thyme Hot	5.71	99.8
19	Golden Zaatar Thyme Cold	6.33	22.0
20	Lipton Chamomile Hot	5.78	99.8
21	Lipton Chamomile Cold	6.90	23.0
22	Barakat Orange juice	3.55	22.9
23	Volvic Water	7.29	21.0
24	Mai Dubai	7.59	20.8

Table 4 shows the pH values of drinks tested in the study. The highest pH was Mai Dubai (pH=7.59) which was the negative control followed by licorice (pH=7.56), while the lowest pH was the hot (Safa) Hibiscus (pH= 2.56). The positive control (Barakat) orange juice had a pH of 3.55. The overall mean pH of the 21 drinks excluding the 3 control drinks (drinks no. 22, 23, 24) was (4.31).

Figure 5: pH of the tested drinks

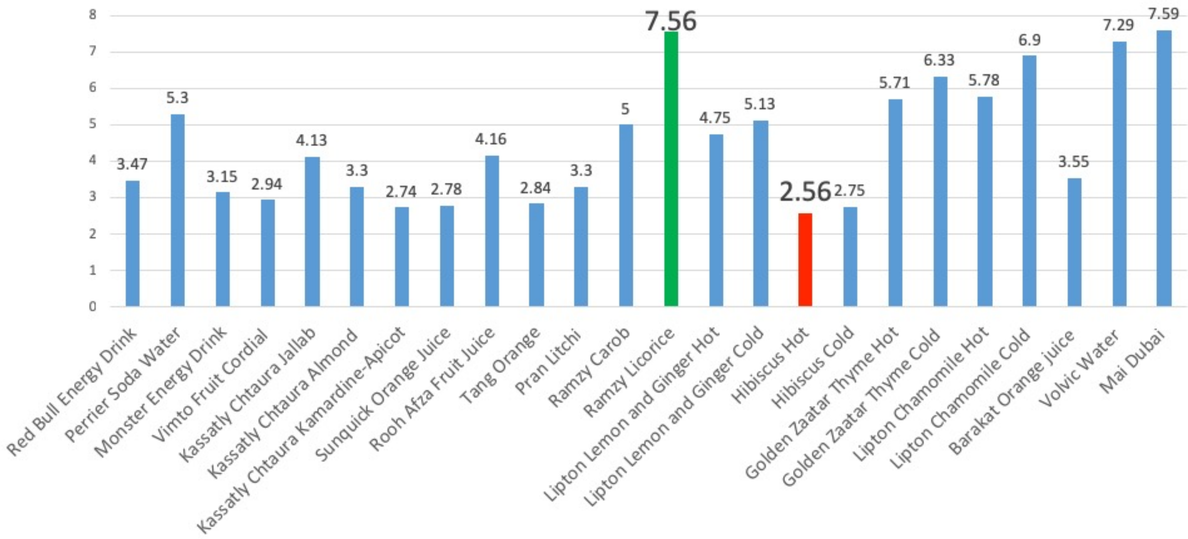


Table 5: Mean And Std. Deviation of grouped samples pH (ranked from the lowest to high mean pH)

Group Drinks	N	Mean	Std. Deviation	Minimum	Maximum
Fruit juices	8	3.36	0.56	2.74	4.16
Carbonated	3	3.97	1.16	3.15	5.30
Hot Tea Drinks	4	4.70	1.50	2.56	5.78
Powdered fruit juices	3	5.13	2.36	2.84	7.56
Cold Tea Drinks	4	5.28	1.84	2.75	6.90

Figure 5: pH of the tested drinks

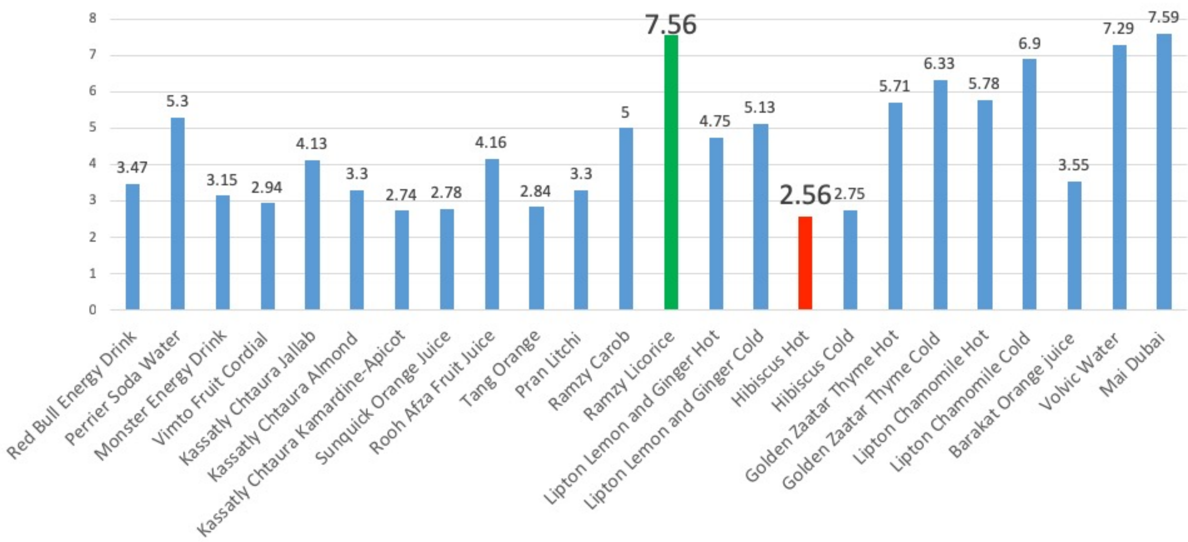


Table 5 shows samples grouped according to drink type. The lowest mean pH at 3.36 was for fruit juices which was significantly lower than the negative control (one-way ANOVA, Scheffe post hoc test, $F=3.514$, $p<0.05$).While teas in their cold form had the highest mean pH (5.28).

Figure 6: Mean pH of grouped samples

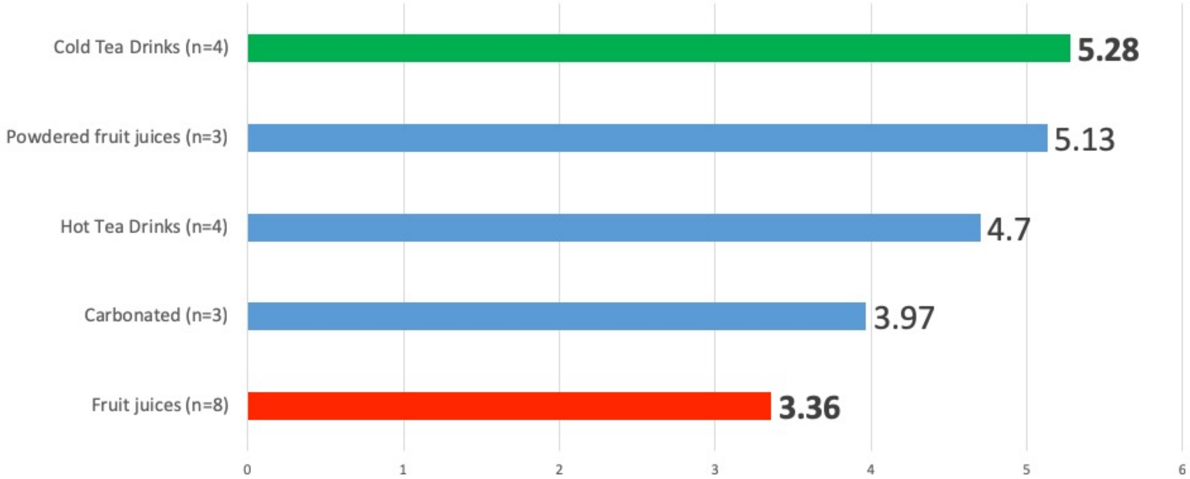


Table 6: Titratable acidity at pH 5.5 and 7.0

No.	Drink Name	T.A at pH 5.5	T.A at pH 7.0
	Carbonated Drinks		
1	Red Bull Energy Drink	36	55
2	Perrier Soda Water	1	27
3	Monster Energy Drink	35	61
	Fruit Juices		
4	Vimto Fruit Cordial	15	18.8
5	Kassatly Chtaura Jallab	3.2	4.7
6	Kassatly Chtaura Almond	2.8	3.4
7	Kassatly Chtaura Kamardine-Apicot	23.4	31.8
8	Sunquick lemon Juice	34	45
9	Rooh Afza Fruit Juice	0.5	1.3
10	Pran Litchi	12.7	17.4
11	Orange Juice Barakat	54	76
	Powdered Fruit Juices		
12	Tang Orange	21	59
13	Ramzy Carob	1.3	3.1
14	Ramzy Licorice	N/A	N/A
	Teas (Hot and Cold)		
15	Lipton Lemon and Ginger Lipton Hot	N/A	N/A
16	Lipton Lemon and Ginger Lipton Cold	0.2	0.6
17	Safa Hibiscus Hot	N/A	N/A
18	Safa Hibiscus Cold	11	12
19	Golden Zaatar Thyme Hot	N/A	N/A
20	Golden Zaatar Thyme Cold	0	0.1
21	Lipton Chamomile Hot	N/A	N/A
22	Lipton Chamomile Cold	0	0

Negative controls			
23	Volvic Water	N/A	N/A
24	Mai Dubai Water	N/A	N/A

Table 6 shows the titratable acidity using 0.1M of NaOH at pH 5.5 and 7.0 added to 50 ml of acidic drinks. The highest value of titratable acidity at pH 5.5 was the positive control (Barakat) orange Juice (54 ml of 0.1M NaOH) followed by (Red Bull) carbonated energy drink (36 ml of 0.1M NaOH), while the lowest was cold Lemon and Ginger (0.2 ml of 0.1M NaOH). At pH 7.0, the highest value for titratable acidity was positive control (Barakat) orange Juice (76 ml/0.1M NaOH) followed by Monster and (Tang) Orange Juice (61 and 59 ml of 0.1M NaOH) respectively.

Titratable acidity to pH 7.0 and drink pH had a moderate negative correlation which was highly significant (Pearson Correlation coefficient -0.6, $p<0.01$). The titratable acidity to pH 5.5, however, was weakly negatively correlated to the pH of the drinks but this was not significant (Pearson Correlation coefficient – 0.2, $p> 0.05$).

Figure 7: Titratable Acidity at pH 5.5 and 7.0

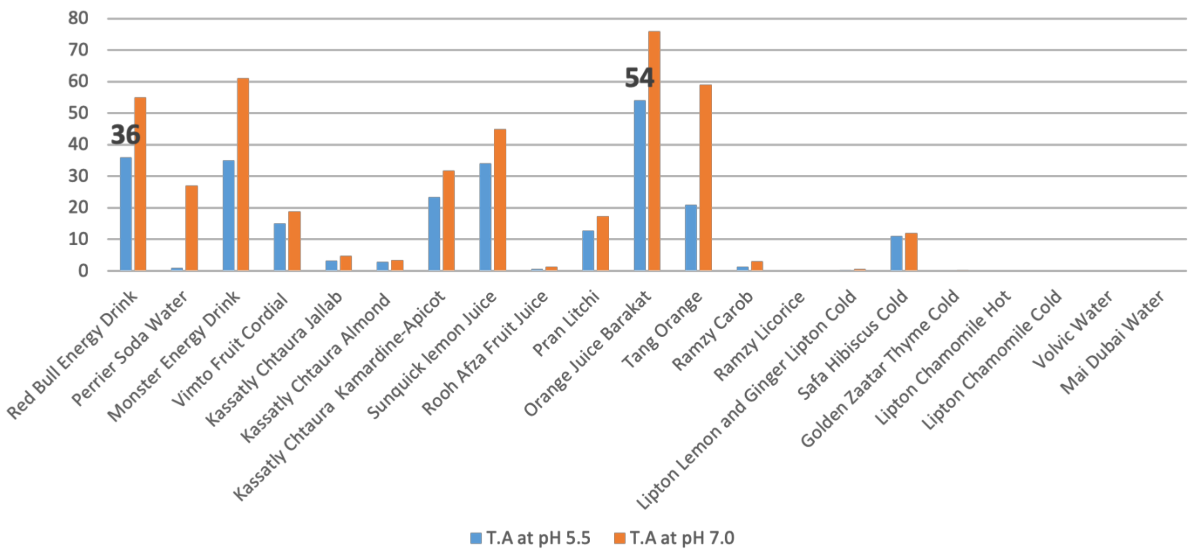


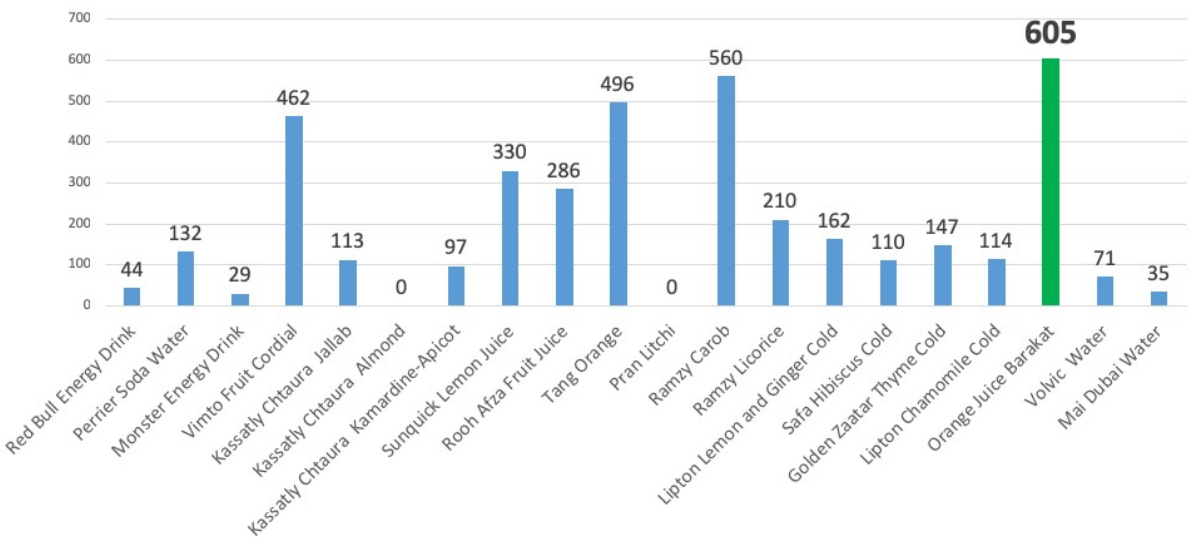
Table 7: Mineral Contents in of tested drinks

No.	Drink Name	Fluoride (ppm)	Calcium (ppm)	Phosphate (ppm)
1	Red Bull Energy Drink	0.98	44	0
2	Perrier Soda Water	0.04	132	0.25
3	Monster Energy Drink	1.09	29	0.03
4	Vimto Fruit Cordial	2.86	462	6.71

5	Kassatly Chtaura Jallab	7.26	113	13.64
6	Kassatly Chtaura Almond	6.6	0	0.33
7	Kassatly Chtaura Kamardine-Apicot	1.1	97	0.42
8	Sunquick Lemon Juice	6.38	330	0
9	Rooh Afza Fruit Juice	3.3	286	0
10	Tang Orange	3.52	496	1.65
11	Pran Litchi	15.95	0	0
12	Ramzy Carob	13.09	560	6.71
13	Ramzy Licorice	4.95	210	8.36
14	Lipton Lemon and Ginger Hot	N/A	N/A	N/A
15	Lipton Lemon and Ginger Cold	0.61	162	0.9
16	Safa Hibiscus Hot	N/A	N/A	N/A
17	Safa Hibiscus Cold	11.22	110	14.63
18	Golden Zaatar Thyme Hot	N/A	N/A	N/A
19	Golden Zaatar Thyme Cold	12.98	147	1.41
20	Lipton Chamomile Hot	N/A	N/A	N/A
21	Lipton Chamomile Cold	4.84	114	22
22	Orange Juice Barakat	6.71	605	0
23	Volvic Water	0.05	71	0.45
24	Mai Dubai Water	0.52	35	0

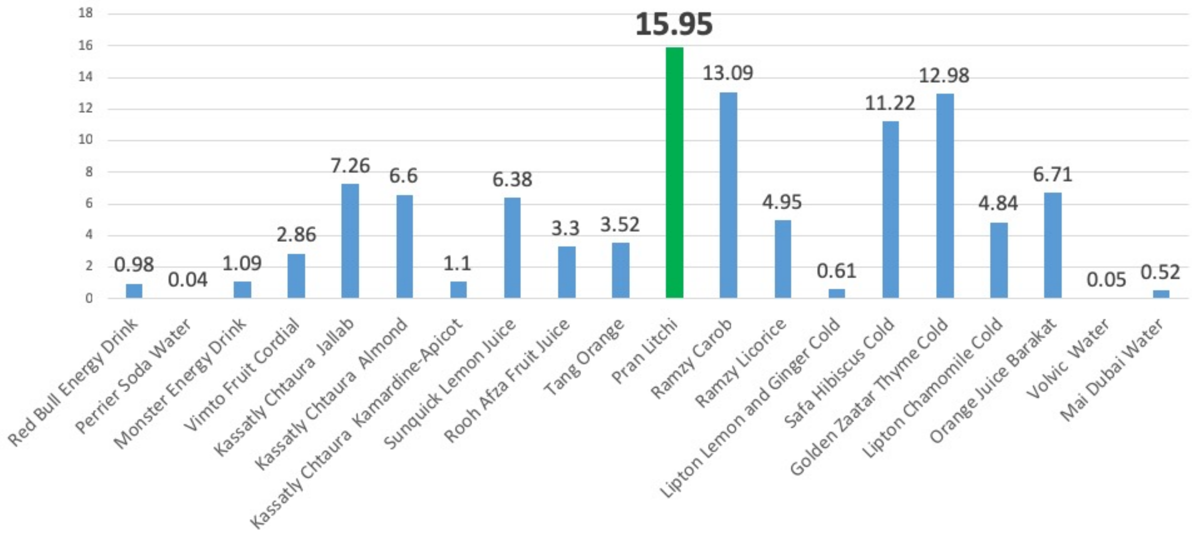
Table 7 shows the fluoride, calcium and phosphate content within the tested drinks expressed in ppm. The overall mean fluoride concentration excluding the 3 control drinks (drinks no. 22, 23, 24) and (drinks no. 14, 16, 18, 20) was 5.69 ppm. Litchi drink had the highest concentration of fluoride 15.95 ppm.

Figure 8: Fluoride Concentration (ppm)



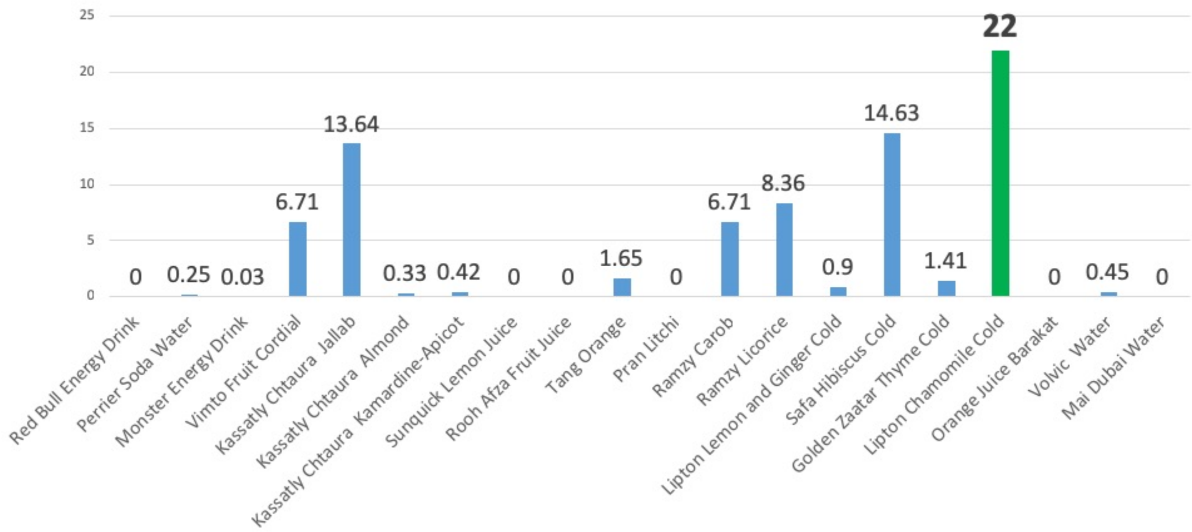
The overall mean calcium concentration excluding the 3 control drinks (drinks no. 22, 23, 24) and (drinks no. 14, 16, 18, 20) was 198.62 ppm. Calcium concentration was found to be highest in (Barakat) orange juice (605 ppm) which was the positive control, followed by Carob which was 560 ppm.

Figure 9: Calcium concentration (ppm)



The overall mean phosphate concentration excluding the 3 control drinks (drinks no. 22, 23, 24) and (drinks no. 14, 16, 18, 20) was 4.53 ppm. (Safa) Hibiscus tea had the highest phosphate concentration among the tested drinks (14.63 ppm).

Figure 10: Phosphate concentration (ppm)



Measurement of the titratable acidity and mineral content at boiling was not applicable (N/A). If the initial pH was higher than 5.5 of 7, the titratable acidity was not measured

5. DISCUSSION

The main aim of the study was to determine the erosive potential of 17 drinks consumed in Dubai by measuring the pH and the Titratable acidity 0.1M of NaOH. In addition the mineral content of fluoride, calcium and phosphate was measured. All samples where measured at room temperature, except for tea drinks that where measured at 2 points: boiling and room temperature.

Dental erosion occurs due to the chemical properties of the drinks that includes pH, titratable acidity and the mineral content of the solution.[9,15]

It can be noted that the highest pH was the Negative control (Mai Dubai) at pH 7.59 and within the sample of drinks Licorice had a pH of 7.56, indicating that it has a low erosive potential. The critical pH for enamel demineralization is 5.5.[6,24] Only Thyme and Chamomile tea drinks were below the neutral pH and above the critical pH in both states at room temperature and at boiling temperature. Most drinks were below the critical pH 5.5, with the lowest pH at 2.56 for hot hibiscus indicating that it has high erosive potential. This result supports a study in Sudanese school children that concluded that Hibiscus was an erosive drink.[8] Red bull had a pH of 3.47, which is similar to the findings of Reddy et al (2016)[46] who reported Red Bull had a pH of 3.43.

When samples were grouped according to their type, fruit drinks had the lowest mean pH of 3.36 compared to carbonated and powdered drinks, which was significantly lower than the negative controls (one-way ANOVA). Fruit drinks had a range of pH from 2.74 to 4.16 the highest, indicating high erosive potential as described by Ganss (1999) and Salas (2015).[4,16] Reconstituted powdered fruit juices had a higher mean pH of (5.13) than fruit juices 3.36.

Tea drinks group in their room temperature state had the highest mean pH of 5.28 compared to other groups, which was slightly less than the critical pH 5.5. The rate of chemical reactions usually increases with temperature, and the acid dissolution constant is temperature dependent, thus erosive potential increases with temperatures. There was correlation between enamel softening, enamel erosion, and temperature, with softening and erosion increasing with temperature.[47] A difference in mean pH was found between the tea drinks when measured at boiling 4.70 and room temperature 5.28.

Titratable acidity is the amount of alkali needed to neutralize an acid within a given aqueous solution. Within our tested drinks, any drink with pH above 7 was not tested (licorice pH=7.56) in addition to that negative controls (Mai Dubai and Volvic water). In our tested samples the titratable acidity was measured at 2 points: The critical pH for enamel demineralization 5.5 and the neutral pH 7.0, in order to relate the amount of acid within the solution by neutralizing it with 0.1M NaOH in a 50 ml volume of the drink. The total acid available (titratable acid) of dietary substances is considered more important than their pH, because it will determine the actual Hydrogen ions available to interact with the tooth surface.[56]

Orange juice titratable acidity was the highest at pH 5.5 and 7.0, having values of 54 ml and 76 ml respectively, this indicates it has high acidic content and erosive potential. Red Bull (36 ml at pH 5.5, 55 ml at pH=7.0), Monster (35ml at pH=5.5, 61ml at pH=7.0) and Sunquick (34ml at pH=5.5, 45ml at pH= 7.0) had moderate acid content within the tested drinks with moderate erosive potential. The results are similar to Benjakul et al where Red Bull had a titratable acidity of 5.5ml at pH 7.0.[23]

Titratable acidity to pH 7.0 had a moderate negative correlation with drink pH which was highly significant. The titratable acidity to pH 5.5, however, was weakly negatively correlated to the pH of the drinks but this was not significant.

The samples in the study was also tested for fluoride at room temperature, 75% of the drinks had fluoride levels above 1 ppm. The concentration of fluoride present would reduce the erosive potential of the tested samples. Experimental studies have shown that the addition of 1 ppm of fluoride reduced erosiveness in tested drinks even at lower pH.[26,28]The When fluoride is present in oral fluids, fluorapatite is formed during the remineralization process. Fluoride ions (F^-) replace hydroxyl groups (OH^-) to form the apatite crystal lattice. In fact, the presence of fluoride increases the rate of remineralization. Fluorapatite is less soluble than hydroxyapatite, even under acidic conditions. When hydroxyapatite dissolves under acidic conditions, if fluoride is present fluorapatite will form. And because fluorapatite is less soluble than hydroxyapatite, it is also more resistant to subsequent demineralization when acid challenged.[57] Australian Water Quality Guidelines recommend levels up to 1 mg/L (1 ppm) to protect against dental caries. [58]

The rate of hydroxyapatite dissolution could be slowed if the solution contains calcium and phosphate ions. 35% of the tested drinks had a calcium concentration lower than 100 ppm, while 45% a calcium had concentration ranging from 100-300 ppm and 20% had above 300 ppm.

While Phosphate in the samples ranged from 0-22 ppm, with 60% of the samples had phosphate concentrations of less than 1 ppm and many had no phosphate in it at all.

When the pH on the tooth surface becomes acidic, phosphate in oral fluids combines with hydrogen ions (H+) to form hydrogen phosphate species, phosphate is then "pulled" from tooth enamel to restore phosphate levels in the saliva, and the hydroxyapatite dissolves. As pH returns to normal, the calcium and phosphate in saliva can remineralise the enamel.[57]

Either 1.0 mmol (equivalent to 40.1 ppm) calcium or a combination of 0.5 mmol (20.05 ppm) calcium plus 0.5 mmol phosphate plus 0.031 mmol fluoride (0.6 ppm) was added to the beverages. Modification of the test beverages with low concentrations of Calcium, Phosphate and Fluoride was able to reduce the erosive potential of the drinks.[28] Supplementation of orange juice with Calcium 42.9 mmol (1719.4 ppm) and Phosphate 31.2 mmol did not erode enamel after immersion for 7 days. showing that even lower concentrations of Calcium, Phosphate together with Fluoride were able to reduce enamel dissolution and demineralization.[32]

5.1.Study Limitations

The study had the following limitation:

- The study aimed to measure the erosiveness of the drinks indirectly by measuring the pH and titratable acidity in a lab environment but erosion of enamel slabs in situ or in vitro is able to detect the direct effect of acid.
- Titratable acidity and pH are crude determinants of erosive potential, but are indicative.
- Knoop hardness test and profilometry on enamel slabs can be more indicative.

6. CONCLUSION

Within the limitations of the study, the following can be concluded:

- 79% of the tested drinks had a pH of less than 5.5, ranging from Hibiscus pH 2.56 to licorice 7.56. The overall mean pH of the 21 drinks excluding the 3 control drinks was pH 4.31. This indicates the samples had high erosive potential.
- Titratable acidity to pH 5.5 ranged from 0.2 to 54 ml (0.1M NaOH) with overall mean 16.74 ml, while titratable acidiy to pH 7.0 ranged from 0.1 to 76 ml with overall mean 26.01. Titratable acidity to pH 7.0 and drink pH had a moderate negative correlation which was highly significant.
- The majority of drinks had moderate mineral content, possibly providing an anti-erosive effect, which will depend on the solubility constant for different enamel mineral content and impurities.
- A pH difference was found among the tea group between the hot and cold state.

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8. APPENDICES

Appendix 1: Research and Ethics committee approval

Appendix 1

جامعة محمد بن راشد للطب و العلوم الصحية
MOHAMMED BIN RASHID UNIVERSITY OF MEDICINE AND HEALTH SCIENCES

Date: 30/09/2017

Dear Dr Khalil Husain

Re: Your research protocol

Titled: Erosive potential of commonly consumed drinks in the MENA region

Thank you for submitting your research protocol to the Research and Ethics committee of the Hamdan Bin Mohammed College of Dental Medicine, MBRU.

It was considered at the meeting held on: 21st May 2017

My apologies for the late reply.

The committee had minor comments regarding the title, please replace MENA with "Middle East" as this better reflects the location of the study.

REC approval is not needed for this study as it is a laboratory based study without human participants.

The study can proceed.

The committee would like to remind you that it is a requirement of the programme that you complete a research dissertation, which comprises 15% of credits within the 3-year MSc programme.

Wishing you every success with your study.

Yours sincerely,

Alex Milosevic

Prof A Milosevic

Chair, Research and Ethics Committee, HBMCDM

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