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Research Report

Threshold value of enamel mineral solubility and dental erosion after consuming acidic soft drinks

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ABSTRACT

***Background**: Dental erosion is irreversible and can caused by acidic soft drink consumption. Dental erosion prevention had already been done, but it still has not been satisfying since the consumption of acidic soft drink is still high. There is still no explanation about the threshold value of enamel mineral solubility and the occurance of dental erosion after consuming acidic soft drink. **Purpose**: This research is aimed to find the threshold value of enamel mineral solubility and dental erosion before and after consuming acidic soft drinks. **Methods**: Subjects of the research are saliva and enamel of 12 rabbits, which have some criteria such as age > 70 days, body weight > 600 grams, and teeth considered to be healthy. The sample devided equally into 4 groups. Each of those marmooths was given a drink as much as 2.5 cc/consumption (there are 1, 2 and 3× per day) by using syringe without injection needle. Salivary minerals then were examined by using atomic absorption spectrophotometric (ASS), while dental erosion was examined using scanning electron microscop (SEM). The data were analyzed by using Paired t-test. **Results**: It is known that the threshold value of enamel mineral solubility (K, Na, Fe, Mg, Cl, P, Ca, F, C) has significant difference ($p < 0.05$) after being exposed to folic acid. Meanwhile, Fe did not have significant difference ($p = 0.090$) after being exposed to citric acid. Similarly, C did not have significant difference ($p = 0.063$) after being exposed to bicarbonate acid. Furthermore, it is also known that the threshold time value of dental erosion are on the 105^{th} day for folic acid, on the 111^{th} day for citric acid, and on the 117^{th} day for bicarbonate acid. **Conclusion**: Threshold value of enamel mineral solubility before and after consuming soft drinks containing acid is different. Based on the threshold value of dental erosion, it is known that folic acid is the most erosive acid.*

***Key words**: Soft drinks, threshold value, mineral solubility, dental erosion*

ABSTRAK

***Latar belakang**: Erosi gigi bersifat irreversible disebabkan oleh konsumsi minuman ringan yang mengandung asam. Pencegahan erosi gigi telah dilakukan tetapi hasilnya tidak memuaskan karena masih banyak orang selalu mengkonsumsi minuman ringan yang berasam. Tidak ada satupun yang menjelaskan lebih terperinci tentang perbedaan nilai ambang kelarutan email dan waktu erosi gigi setelah konsumsi minuman ringan yang berasam. **Tujuan**: Penelitian ini dilakukan untuk mengetahui perbedaan nilai ambang kelarutan mineral email dan erosi gigi sebelum dan setelah mengkonsumsi minuman ringan yang mengandung asam. **Metode**: Subjek dari penelitian ini adalah saliva dan enamel dari 12 ekor kelinci dengan criteria usia lebih dari 70 hari, berat lebih dari 600 gram, dan gigi dalam keadaan sehat. Sampel dibagi menjadi 4 kelompok. Masing-masing kelinci diberikan 2,5 ml minuman sekali konsumsi (1, 2, dan 3 kali sehari) menggunakan spite tanpa jarum. Mineral saliva dianalisa menggunakan Atomic Absorption Spectrophotometric (ASS), sedangkan erosi gigi diperiksa dengan menggunakan Scanning Electron Microscop (SEM). Data analisa dengan Paired-t test. **Hasil**: Semua mineral email (K, Na, Fe, Mg, Cl, P, Ca, F, C) nilai ambang kelarutannya berbeda secara bermakna sebelum dan setelah terpapar oleh asam folat ($p < 0,05$). Sebelum dan setelah terpapar oleh asam sitrat nilai ambang kelarutan mineral Fe tidak bermakna ($p = 0,090$), sebelum dan setelah terpapar oleh asam bikarbonat nilai ambang kelarutan mineral C tidak bermakna ($p = 0,063$). Nilai ambang waktu erosi gigi didapatkan pada hari ke 105 untuk asam folat, hari ke 111 untuk asam sitrat dan hari ke 117 untuk asam bikarbonat. **Kesimpulan**: Nilai ambang kelarutan mineral email sebelum dan setelah konsumsi minuman ringan mengandung asam berbeda. Berdasarkan nilai ambang erosi gigi, dapat diketahui bahwa asam folat merupakan asam yang paling erosif.*

***Kata kunci**: Minuman ringan, nilai ambang, kelarutan mineral, erosi gigi*

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INTRODUCTION

There are 17% teens, more than 35% athletes in America, 20–30% athletes in Australia, and 57% children aged 14 years in Birminghan UK who have the prevalence of dental erosion due to the consumption of acidic soft drinks.[1] Another researcher also reported that consuming alcoholic beverages can cause regurgitation of stomach acid into the oral cavity so that pH in the mouth is decreasing and causes the solubility process of enamel and dentine minerals.[7,10] The socio-economic conditions can also affect the occurrence of dental erosion. Children with good socioeconomic condition usually are diligent to brush their teeth, but with wrong method, so they still can get dental abrasion. Dental erosion will appear if the dental abrasion is not treated immediately and soft drinks containing acid are still consumed dental erosion.[2–6]

Factors triggering the solubility of dental enamel minerals and dental erosion have actually been known, but none of researchers gives more details about the different threshold value of the dental enamel mineral solubility and the threshold time value of the dental erosion after consuming acidic soft drinks. The prevention of dental erosion has actually been done, but still not satisfied enough since acidic soft drinks are still consumed.

Mouth pH is above 5.5, through the process of salivary buffers it can cause supersaturation of Ca^{+2} and $PO4^{-3}$ ions. In this situation, the dental hard tissues will pull minerals from saliva, called remineralization. On the other hand, if mouth pH below the critical point ($\leq$ 5.5), it can cause subsaturation of Ca^{+2} and $PO4^{-3}$ ions, the releasing of minerals into dental saliva, called demineralization. If this situation occurs repeatedly, it then can cause dental erosion.[2–4]

Clinical symptoms of dental erosion are shiny enamel and dentin, as well as pain in incisal, palatal, labial, around cemento enamel junction of maxillary and mandibulary anterior and premolar tooth areas. The pain occurs with the short duration when the teeth are exposed to temperature, osmotics, chemical substances, both during brushing teeth and during consuming soft drinks.[5–10] The purpose of this research was to find the threshold value of enamel mineral solubility and dental erosion before and after consuming acidic soft drinks.

MATERIALS AND METHODS

This research is a quasi experimental research using pre-test and post-test designs at the Laboratory Gramik, Medical Faculy of Airlangga University and BPTP, Maros regency in South Sulawesi. Research subjects; saliva and dental enamel of 12 rabbits (*Cavia aperea*) divided into 4 groups (3 rabbits for bicarbonate acid, 3 rabbits for citric acid, 3 rabbits for folic acid, and 3 rabbits for mineral water) with age $\geq$ 70 days, weight $\geq$ 600 grams, and healty teeth. Each of those rabbits then was given a drink as much as 2.5 cc per consumption (there are 1, 2 and 3× per day) by using a syringe without injection needles.

The dental mineral in their saliva was examined before and after consuming soft drinks and mineral water by using atomic absorption spectrophotometric (ASS). Re-examination then was conducted with the first 5-minute intervals until the 35th minute after drinking, both in the treatment group and in the control group. The research was stopped after the raising of clinical symptoms of dental erosion. Next, those marmmoths were slaughted and their teeth which got dental erosion or not were extracted. Then, further examination was conducted. The dental crowns were separated from the dental roots by cutting the cervical area with high speed diomond burs, and then made dental enamel histopathological preparation with a size 4x6 mm for examining dental erosion under scanning electron microscop (SEM).

The data was analyzed by using Paired t-test, in order to know the difference of the threshold value of enamel mineral solubility and dental erosion caused by acidic soft drinks.

RESULTS

Based on the examination of SEM with 750× magnfication, it is known that the dental enamel of the samples got erosion, in which their dental enamel surface became rough or full of big and small pores, while enamel surface that did not get erosion still smooth.

Based on SEM result most of the dental enamel surface of the samples became rough marked by large and small pores indicating the occurence of dental erosion caused by soft drinks containing citric acid (Figure 1). Similarly, figure 2 shows some pores as big as those in figure 1. Besides that, it also shows lines of cracks on the enamel surface of those marmmoths caused by the consumption of soft drinks containing bicarbonate acid.

Most of the dental enamel surface of the samples became rough marked by pores caused by the consumption of soft drinks containing folic acid (Figure 3). Figure 4 shows that most of the dental enamel surface of the samples became smooth indicating that there was no occurance of dental erosion caused by the consumption of mineral water.

Most of the the enamel minerals found in the saliva have significant difference of the solubility threshold values before and after consuming soft drinks containing citric acid, $p < 0.05$, except Fe ($p = 0.05$) (Table 1).

In the other hand, most of the the enamel minerals found in the saliva have significant difference of the solubility threshold values before and after consuming soft drinks containing bicarbonate acid, $p < 0.05$, except C ($p > 0.05$) (Table 2).

Table 1. The different threshold value of enamel mineral solubility in the saliva before and after consuming soft drinks containing citric acid

Mineral	Mean ± SD		p
	Before	After	
K	157.00 ± 59.76	777.72 ± 707.26	0.001
Na	820.00 ± 460.42	1144.68 ± 740.63	0.001
Fe	40.01 ± 32.60	36.13 ± 28.21	0.090
Mg	2.83 ± 1.22	10.18 ± 6.14	0.001
Cl	36.66 ±14.61	48.72 ± 24.24	0.001
P	20.07 ± 7.44	71.05 ± 48.19	0.001
Ca	74.82 ± 10.03	191.49 ± 114.79	0.001
F	163.16 ± 58.35	453.36 ± 245.13	0.001
C	205.66 ± 126.82	501.27 ± 169.67	0.001

SD: Standard Deviation, p: probability

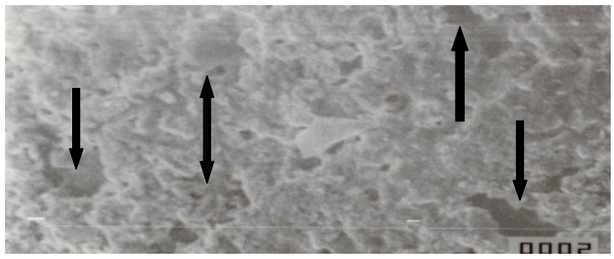

Figure 1. The dental erosion occured (arrows) is caused of citric acid marked by the presence of pores.

Table 2. The different threshold value of enamel mineral solubility in the saliva before and after consuming soft drinks containing bicarbonate acid

Mineral	Mean ± SD		p
	Before	After	
K	205,667 ± 67,236	718,682 ± 563,733	0.013
Na	228,667 ± 45,386	542,409 ± 265,097	0.001
Fe	5,167 ± 2,041	10,909 ± 3,294	0.001
Mg	3,833 ± 1,169	11,500 ± 6,739	0.001
Cl	66,667 ± 35,601	146,182 ± 83,211	0.001
P	248,003 ± 87,504	485,364 ± 202,732	0.001
Ca	131,502 ± 38,501	320,591 ± 177,430	0.001
F	211,005 ± 52,014	493,591 ± 200,100	0.001
C	781,833 ± 287,482	615,818 ± 216,896	0.063

SD: Standard Deviation, p: probability

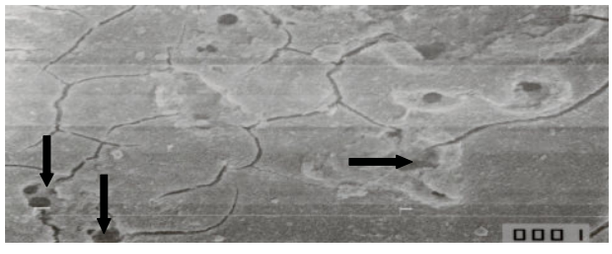

Figure 2. The dental erosion (arrow) occured is caused of bicarbonate acid marked by the presence of pores.

Table 3. The different threshold value of enamel mineral solubility in the saliva before and after consuming soft drinks containing folic acid

Mineral	Before	After	p
	Mean ± SD	Mean ± SD	
K	241.23 ± 163.00	763.13 ± 522.48	0,013
Na	450.66 ± 257.58	700.77 ± 411.98	0.001
Fe	14.83 ± 4.23	22.03 ± 17.59	0.001
Mg	6.66 ± 4.17	20.682 ± 14.90	0.001
Cl	105.66 ± 72.15	345.40 ± 53.34	0.001
P	210.00 ± 49.32	283.81 ± 203.03	0.007
Ca	197.66 ± 15.27	463.45 ± 274.47	0.001
F	177.16 ± 72.10	482.81 ± 200.35	0.001
C	395.83 ± 174.64	722.63 ± 255.33	0.001

SD: Standard Deviation, p: probability

All of the enamel minerals found in the saliva can be indicated to have significant difference of the solubility threshold values before and after consuming soft drinks containing folic acid, ($p < 0.05$) (Table 3).

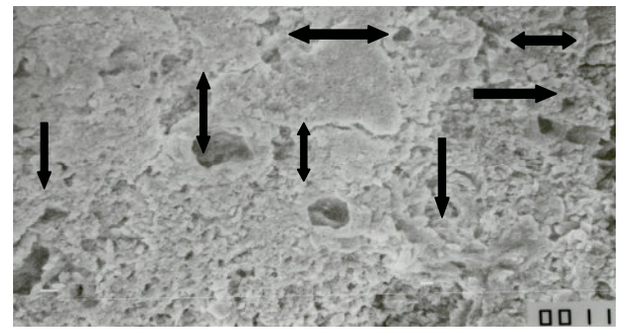

Figure 3. The dental erosion (arrow) occured is caused of folic acid marked by the presence of pores.

It indicated that soft drinks containing folic acid is the kind of soft drinks that can cause dental erosion more than those containing citric acid and bicarbonate acid, either on the frequency of consumption of 1 time, 2 times, or 3 times per day (Table 4).

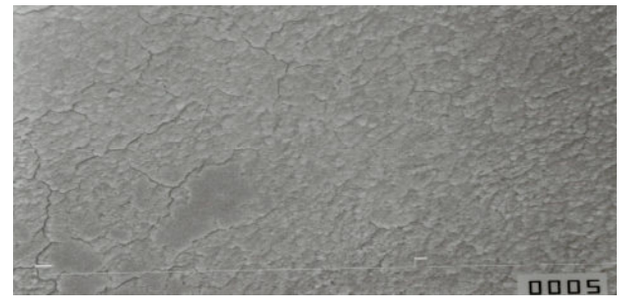

Figure 4. The smooth surface of the dental enamel (no erosion) after consuming mineral water on the examination (SEM figure with magnification 750×).

Table 4. The description of the threshold value of dental erosion based on the time and frequency of the consumption of both soft drinks containing acid and mineral water (as a control group)

Consumption	Frequency of consumption	Teeth	
		Time of erosion (Day)	Time of no erosion (Day)
Bicarbonate Acid	1×	140	-
	2×	136	-
	3×	117	-
Citric Acid	1×	135	-
	2×	126	-
	3×	111	-
Folic Acid	1×	131	-
	2×	120	-
	3×	105	-
Mineral Water	1×	-	140
	2×	-	140
	3×	-	140

DISCUSSION

Enamel consists of some minerals (K, Na, Fe, Mg, Cl, P, Ca, F, C), and is also considered to be as a hard tissue. Although considered as a hard tissue, enamel can still be dissolved by acidic chemicals. These acids are not only intrinsic (gastroesophageal reflux, vomiting), but also extrinsic (bicarbonate acid, citric acid or folic acid). Thus, if mouth is always tasted acidic, it can indicate that its dental enamel gets mineral solubility, called demineralization.

This demineralization of enamel actually occurs through a diffusion process, a process in which minerals are transfered from the dental enamel into the saliva due to the different acid concentration in the dental enamel and in the saliva. Therefore, beverages with the high concentration of acid and the low pH will be able to diffuse into enamel through the tubuli of the enamel containing water and organic matrix or proteins.

After the acid diffuses into the enamel, it is then ionized into H + and L-that can destruct calcium hydroxyapatite, and break them down into some ions, Ca^{+2}, OH^{-}, PO_4^{-3} and F^{-1}. The ions formed then diffuses into the enamel and form complex compounds, Ca $(H_2PO_4)_2$, $CaHPO_4$ and $CaCl_2$. These complex compounds with the high concentration diffuses out into the saliva. If this process always occurs, it can cause dental erosion. On the other side, if pH of mouth is high, the remineralization process will occur which can make the enamel pulls those ions from the saliva.[9–11]

There is significant difference of the threshold value of enamel mineral solubility in the saliva before and after consuming soft drinks containing citric acid, except Fe. This is not only due to the lack of Fe in dental enamel, as a result, it becomes difficult to be detected, but also due to the nature of the Fe that is reactive causing reaction under acidic or basa condition.[16] Each mineral actually has a different solubility marked by the increasing of enamel mineral level in the saliva. This process is caused by citric acid obtained from soft drinks that have low pH, below the critical point (< 5.5).[14,17]

If it is found that enamel mineral generally has the significant difference of the threshold value of solubility before and after consuming soft drinks containing bicarbonate acid, except mineral C. This result is due to the nature of mineral C that can bind itself in small chains (CC, C = C and C Ξ C). With this nature, mineral C can not be dissolved by bicarbonate acid which is weaker than and citric acid or folic acid.[16] There is no significant difference in all of the enamel mineral before and after exposured to folic acid from soft drinks. Citric acid and bicarbonate cannot dissolve all dental enamel minerals. This condition is actually caused by the differences of pH in all the three soft drinks, pH of folic acid is lower than that of citric acid and bicarbonate. This condition is actually in accordance with the opinion of earlier researchers who stated that most of soft drinks are acidic, but with different pH.[14] It is also known that most of mineral K obtained is dissolved caused by the very quickly melting point of K.[16]

Dental erosion occurs faster due to the consumption of soft drinks containing folic acid than that containg bicarbonate acid and citric acid. Thus, it is proved that folic acid from soft drinks is more erosive. Soft drinks containing folic acid are factor causing dental erosion, either on the frequency of consumption 1 time, 2 times, or 3 times per day. Therefore, to avoid the exposure of soft drinks containing acid to teeth, it is better to use a pipette during consuming the soft drinks and then to gargle with water or mineral water in order to neutralize pH of the mouth before the solubility of dental mineral occurs. It is concluded treshold value of enamel mineral solubility before and after consuming soft drinks containing acid is defferent. Based on the threshold value of dental erosion, it is known that folic acid is the most erosive acid.

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