치의과학석사 학위논문

Physicochemical properties of beverages and their demineralization effects on tooth enamel

액체 간식품의 이화학적 특성과 법랑질 탈회

2017년 8월

서울대학교 대학원

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이 논문을 치의과학석사 학위논문으로 제출함

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허연진의 치의과학석사 학위논문을 인준함

2017년 6월

위 원 장 ______________________ (인)

부위원장 ______________________ (인)

위 원 ______________________ (인)

Abstract

Physicochemical properties of beverages and their demineralization effects on tooth enamel

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Objectives

The purpose of this study was to analyze *in situ* demineralization of tooth enamel induced by beverages and their physicochemical properties.

Methods

This study involved an *in situ* experiment that determines the effects of beverages on the demineralization of tooth enamel and an *in vitro* experiment that measures the physicochemical properties of beverages. 13 test beverages are the most frequently consumed in Korea, and 10% sucrose for control was served. This study was performed according to the randomized complete block design with subsampling. Five volunteers wearing intra-oral appliance with two enamel slabs were subjected to biofilm formation period for 2 days and demineralization period for 5 days in each cycle. Enamel demineralization was determined by surface microhardness. For 14 test beverages, total and reducing sugar, pH, viscosity, fluoride and calcium content were measured. General Linear Model (GLM) and Ducan's multiple range test was used to compare the tooth demineralization. Cluster analysis was performed to classify the beverages into two groups according to the tooth demineralization.

Results

Chocolate-flavored milk showed the highest and grape juice showed the lowest change of surface microhardness. In the low demineralization group, F^- showed higher and pH, total sugar, and Ca contents were lower tendency than in the high demineralization group, but the difference was not significant.

Conclusions

In situ demineralization of tooth enamel could provide the valid rank of beverages' demineralization potential. However, we could find no significant differences in the physicochemical properties of clusters based on *in situ* demineralization.

Keywords : beverages, cariogenic potential, dental caries, physicochemical property

Student Number : 2010-22029

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1. Introduction

Dental caries is a highly prevalent chronic disease and its consequences cause a lot of social burdens.[1] It has been described as a disease related to the diet although, as a multifactorial disease, oral bacteria, host, and time are also major factors.[1,2] Significant correlations between diet and dental caries have been demonstrated in several studies.[3]

After tooth eruption, the effects of diet on the dentition are topical rather than systemic. Dietary factors and eating patterns that may exacerbate or minimize caries development included[1], the frequency of eating[1,4], the physical form of the carbohydrate (liquid vs. solid), retentiveness of food on the tooth surface[5], and the presence of minerals in a food[4].

Some experimental methodologies have been used to evaluate the cariogenic potential of foods. These include caries formation in animals, acid production in dental plaque, and demineralization of enamel[2,5-9]. Animal studies have been conducted using a programmed feeding machine[10]. The rat caries model incorporates many aspects of the caries process *in vivo* and is, therefore, considered to be a valuable and appropriate model for the evaluation of the cariogenic potential of dietary substances[10]. The caries potential of the test food is compared against that of sucrose which is considered to have a caries potential index (CPI) of 1.0. If the food has a CPI score 0.4 or lower, it can be classified into the low cariogenic potential category.[2,10] However, its use appears to be declining, possibly because of the costs of the equipment needed and also because of a trend away from the use of animals in research[2]. Also, such experiments are virtually considered unethical because many animals are sacrificed for the study of the cariogenic potential of foods.

Acid production in plaque material after the ingestion of a fermentable substrate has been measured by the application of various techniques (plaque sampling, touch electrode, and an indwelling electrode with telemetry). Results achieved using the indwelling electrode technique described by Graf and Mühlemann[11] among these seem to be the most widely accepted even though the method measures only the effect of the foodstuff on the pH of plaque, which is a most important factor in the pathogenesis of dental caries. Since that time the plaque pH method using an indwelling electrode has been extensively used in Switzerland to assess the acidogenic potential of confectionery for the 'tooth friendly' scheme[12]. Plaque may reach saturation with calcium, phosphates or apatite. Unfortunately, plaque pH methods are difficult to measure the factors which involve calcium and phosphate concentrations, the buffering power, and the fluoride concentration.[13]

· An intraoral cariogenicity test has been developed by Koulourides and co - worker[6], to assess the demineralization ability of food in the oral environment. Bovine or human dental enamel slabs are embedded in the prosthesis and placed in the mouth where a tooth is missing. After ingesting a test food, changes in surface microhardness or enamel porosity are determined[14]. The main advantage of this method is that foods and beverages can be tested under clinically relevant conditions and that very sensitive laboratory method can be applied to measure changes in mineral status (demineralization/remineralization)[12,15].

International conference on methods for assessing cariogenic potential of foods was held in San Antonio (USA) in 1985 and in London (UK) in 1999[15,16]. Dental scientists in the conferences provided consensus opinions on the three above mentioned methods that these methods for measuring the cariogenic potential of foods are difficult to apply universally, limited to reproduce the intake process of foods, and have relatively large variations depending on the skill of measurement. It was also addressed that the actual cariogenicity of foods can only be established by experimentally determining in humans.

Therefore, the present study was carried out to analyze *in situ* demineralization of tooth enamel induced by beverages for assessing their potential of tooth demineralization. And we tried to find the difference of the physicochemical properties between clusters of beverages based on *in situ* demineralization.

2. Materials and Methods

2.1 *In situ* demineralization study

2.1.1 Test drinks

The 13 test beverages in Table 1 were selected because they represented typical drinks consumed in Korea[17]. 10% sucrose solution was used as a control.

Table 1. Test beverages.

	Beverage types	Beverage name	Manufacturer
1	Soft drink	Chilsung cider	Lotte chilsung
2	Orange juice (with sugar)	Jeju citrus juice	Haetae
3	Grape juice (with sugar)	Grape juice	Delmonte
4	Coffee (with sugar)	Let's be	Lotte chilsung
5	Sports drink	Pocarisweat	Donga otsuka
6	Tea	17 tea	Lotte chilsung
7	Lemon black tea	Ceylon tea	Lotte
8	Soybean milk	Vegemil A	Chung's food
9	Milk	Milk	Seoul milk
10	Chocolate - flavored milk (with sugar)	Chocolate milk	Mail
11	Strawberry - flavored milk (with sugar)	Strawberry milk	Mail
12	Coffee - flavored milk (with sugar)	Mochaccino milk	Mail
13	Yogurt (with sugar)	Yogurt IO	Namyang

All test beverages were made in Korea.

2.1.2 Study design and subjects

The study was performed according to the randomized complete block design with subsampling, and with an approval of the Institutional Review Board of the School of Dentistry of Seoul National University (S-D20090008). Five healthy adults from 24 to 29 yrs old with no active dental caries and healthy gingival conditions were recruited for this study. None of the selected subjects had an ongoing dental treatment, tooth mobility, and eating disorder. The informed written consents were given by all the subjects. The characteristics of subjects are summarized in Table 2.

Table 2. Characteristics of the subjects

No.	Sex	Age (yr)	Salivary flow rate (ml/min)	Salivary buffer capacity*	Dentocult SM† (CFU/ml)	Dentocult LB‡ (CFU/ml)
1	F	29	2.00	1	2	1
2	F	26	1.10	1	2	1
3	M	29	1.40	1	1	2
4	F	25	1.75	1	3	1
5	F	24	1.80	2	2	1

*Salivary buffer capacity: (1) high (2) medium (3) low.
†Dentocult SM:(1)$<10^3$ (2)$<10^4$ (3)10^4 -10^5 (4)$>10^5$.
‡Dentocult LB:(1)10^3 (2)10^4 (3)10^5 (4)10^6.

2.1.3 Preparation of specimens

Enamel cylinders (3 mm in diameter) were prepared from the labial surface of bovine incisors. Each specimen was placed in plastic mold, embedded in resin (Vertex Self-Curing, Vertex-dental B.V. Netherlands), and then ground and polished using sandpaper up to a grid 2,000 under running water to produce flat enamel surfaces. Afterwards, all specimens were sterilized with gamma irradiation (25 kGy)[7]. They were mounted on a mandibular removable acrylic appliance with sticky wax. The appliance had a hole with the diameter of 5 mm and the depth of 3 mm to house enamel slab on lingual surface. The hole was positioned about 1 mm lower than the surface of the appliance.

2.1.4 Clinical phase

During a one-week lead-in period for standardization and every one week washout period between experimental cycles, the subjects were compelled to brush their teeth with a fluoridated dentifrice (1,000 ppm F, dental clinic 2080, Aekyung, Korea) and toothbrush (Skydent no.24 S, skydent, Korea) supplied by the researchers. The subjects wore the intra-oral appliances contained enamel specimen on either side of the mandibular molar region for 7 days, from 9 am to 6 pm, except while having lunch, with two days of biofilm formation and five days of demineralization in each cycle. During demineralization period, the subjects were asked to keep the 15 ml beverages in their mouth for 15s once an hour, totally 8 times per day. The appliances were kept fully hydrated by covering with a moist paper (Science Wipers, KIMTECH, yuhan - kimberly, Korea) in a plastic container while the subjects were not wearing them. During the experiment period, subjects had a gargle with fluoride solution (0.05% NaF) just after taking off the appliance every day to prevent dental caries. The occurrence of early caries was also monitored according to International Caries Detection and Assessment System (ICDAS)[10].

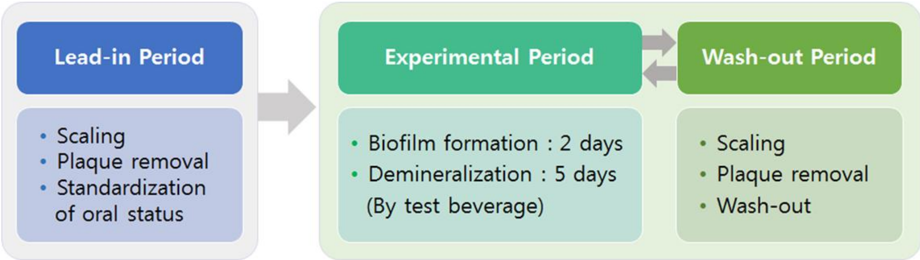

Fig. 1. Overall flow of the experiments.

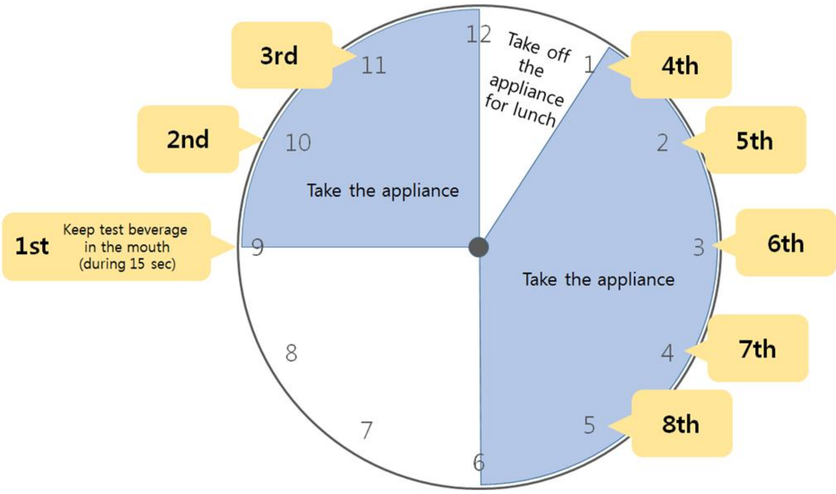

Fig. 2. Clinical phase of the experiments.

2.1.5 Evaluation of enamel demineralization

Enamel demineralization was evaluated by surface microhardness just before and after each experimental period. The surface microhardness of the enamel specimen was measured three times using a microhardness tester (HMV-2, Shimadzu, Tokyo, Japan) with a Knoop diamond loaded with 9.8 N for 10 sec.

2.2 Analysis of physicochemical properties of beverages

For the 14 kinds of beverage, total sugar, reducing sugar, pH, viscosity, fluoride content, calcium content were measured. Total and reducing sugar content were measured using Phenol-sulfuric method[18] and Somogyi-Nelson method,[19] respectively. The pH measurement was carried out using pH meter (Seven Easy, Mettler Toledo, Switzerland). Viscosity was measured with 20 ml of the beverages under 37℃ condition by vibrating viscometer (SV-10, AND, Tokyo, Japan) and calcium values were measured by inductively coupled plasma spectrometer (ICP, IRIS XDL Duo, Thermo, Beverly, MA, USA), after preprocessing of samples. Fluoride contents were measured for beverages by fluoride ion-selective electrode (Orion 9609BN, Thermo, Beverly, MA, USA). All experiments were repeated 3 times.

2.3 Statistical analysis

General Linear Model (GLM) with beverages for fixed factors, subjects for random factors, and demineralized amounts of specimens for the outcome variable, were used to compare the potential of tooth demineralization of beverages. Duncan's multiple range test was then performed for post hoc comparison of the data. Based on squared euclidian distance of microhardness of beverages, cluster analysis was also performed to divide them into two groups. The differences in physicochemical properties between groups were analyzed using Mann - Whitney U test.

3. Results

3.1 The rank of beverages according to the microhardness change of tooth enamel

Microhardness change of all specimens by *in situ* demineralization model is shown in Table 3. The surface microhardness was decreased in all beverages compared with baseline. The change of surface microhardness showed the highest in chocolate-flavored milk and the lowest in grape juice.

Table 3. The rank of beverages according to the microhardness change of tooth enamel (mean ± standard deviation)

Rank	Beverages	△ VHN*
1	Chocolate - flavored milk	-94.63 ± 28.73^{a}
2	10% sucrose	$-74.00 \pm 20.64^{a,b}$
3	Yogurt	$-65.05 \pm 31.10^{a,b,c}$
4	Coffee	$-64.53 \pm 38.06^{a,b,c}$
5	Soy bean milk	$-54.92 \pm 15.51^{b,c,d}$
6	Lemon black tea	$-53.29 \pm 27.36^{b,c,d}$
7	Soft drink	$-51.11 \pm 46.41^{b,c,d}$
8	Tea	$-46.30 \pm 38.33^{b,c,d}$
9	Coffee - flavored milk	$-44.44 \pm 16.31^{b,c}$
10	Milk	$-43.48 \pm 36.75^{b,c,d}$
11	Orange juice	$-36.04 \pm 10.83^{c,d}$
12	Sports drink	-32.41 ± 12.44^{c}
13	Strawberry - flavored milk	-32.38 ± 21.75^{c}
14	Grape juice	-28.58 ± 8.99^{d}

[a,b,c,d]The different characters show statistically significant deference between groups by general linear model and Duncan's multiple range test.
△VHN (Vickers Hardness Number) = VHN_{after} - VHN_{before}.

3.2 Physicochemical properties of beverages

Table 4 shows the result of physicochemical properties of beverages. Fluoride ion concentration (F^-) showed the highest in lemon black tea (0.223 ppm) and the lowest in 10% sucrose solution (0.012 ppm) although most test beverages were measured for less than 0.1 ppm. Data from the pH showed that yogurt, lemon black tea, soft drink, orange and grape juice, and sports drink were as low as about pH 3 when compared to others, and soy bean milk was especially the highest (pH 7.23). Total sugar was measured the highest in yogurt and the lowest in tea. In most test beverages, reducing sugar showed similarly 1.85 mg/ml, but tea showed nearly half of the others. The high viscosity was shown in both chocolate-flavored milk and soybean milk, and the lowest in tea. Calcium concentration was measured the highest in milk (903.63 mg/L) and relatively high level in chocolate-flavored milk (807.97 mg/L), but tea was showed much less than 10% sucrose (27.15 mg/L).

Table 4. Physicochemical properties of beverages

Rank	Beverages	Total sugar (mg/ml)	Reducing sugar (mg/ml)	Viscosity (cP)	pH	F^- (ppm)	Ca^- (mg/l)
1	Chocolate - flavored milk	65.90	1.85	2.60	6.81	0.023	807.97
2	10% sucrose	100.83	1.75	0.96	6.39	0.012	27.15
3	Yogurt	367.00	1.84	1.57	3.60	0.055	525.37
4	Coffee	157.65	1.85	1.11	6.69	0.026	203.63
5	Soy bean milk	97.72	1.84	2.40	7.23	0.062	600.03
6	Lemon black tea	152.89	1.85	0.98	3.09	0.223	4.52
7	Soft drink	267.47	1.84	1.17	2.97	0.035	8.97
8	Tea	2.35	0.75	0.93	6.07	0.045	0.68
9	Coffee - flavored milk	68.69	1.84	1.45	6.87	0.035	468.43
10	Milk	56.25	1.84	1.69	6.68	0.027	903.63
11	Orange juice	239.23	1.84	1.63	3.27	0.017	32.67
12	Sports drink	90.79	1.85	1.01	3.52	0.013	15.61
13	Strawberry - flavored milk	96.54	1.85	1.68	6.56	0.026	634.83
14	Grape juice	322.85	1.84	1.36	3.48	0.080	111.05

3.3 The physicochemical properties of the beverages between low and high demineralization groups

The physicochemical properties of the beverages between low and high demineralization groups dichotomized by the results of cluster analysis based on the change of the VHN of the specimens are shown in Table 5. F^- showed higher and total sugar, pH, and Ca^{++} showed a lower tendency in the low demineralization group than in the high demineralization group, but the difference was not significant. The results of effect size (ES) showed the highest in pH (ES=0.49).

Table 5. The physicochemical properties of the beverages between low and high demineralization groups

	low demineralization (n=10)	high demineralization (n=4)	ES	p†
△VHN*	-42.30±9.45	-74.55±14.07	-3.41	0.005
F^-	0.056±0.06	0.029±0.02	-0.44	0.228
pH	4.974±1.83	5.873±1.53	0.49	0.322
Total sugar	139.478±103.73	172.845±134.85	0.32	0.480
Reducing sugar	1.734±0.35	1.823±0.05	0.26	0.757
Viscosity	1.330±0.63	1.560±0.74	0.37	0.888
Ca^{++}	278.024±339.90	391.030±346.13	0.33	0.396

Mean ± standard deviation.
low - demineralization: sports drink, strawberry - flavored milk, orange juice, grape juice, milk, coffee - flavored milk, tea, lemon black tea, soy bean milk, soft drink.
high - demineralization: coffee, yogurt, chocolate - flavored milk, 10% sucrose.
*Δ VHN (Vickers Hardness Number) = VHN_{after} − VHN_{before}.
ES (effect size) = (high group mean − lowgroupmean) / low group standard deviation.
†by Mann − Whitney U test.

4. Discussion

Dental caries is a multifactorial disease. The cariogenicity of foods consumed is just one of many factors which determine whether clinical caries develops or not[20].

In this study, *in situ* tooth demineralization test was carried out to measure the relative demineralization potentials of beverages among 13 kinds of drinks consumed the most frequently based on Korean food distribution statistics[7]. This study could be helpful for the prevention of dental caries by diet control and the development of beverages good for dental health.

In the present study, enamel demineralization was determined by Micro Vickers Hardness (MVH) though there are many ways to measure it[21].

The surface microhardness test has been widely used to study the demineralization / remineralization process[22]. It has been identified that there was a linear relationship between change in penetration depth and mineral loss for a broad range of demineralizing conditions by several experiments. In this study, the surface microhardness of the specimens in all beverages showed a decrease, and the test beverages were ranked according to the microhardness change based on the results. There was a wide range of response, from a high degree to a low degree of demineralization.

The work by Edgar et al.[23] using the plaque pH procedure had also shown a wide range of foods. The beverages used in the study showed as following in ascending order of acidogenicity; milk, chocolate milk, carbonated beverages, and orange juice. These findings are different from the result of the present study that the demineralization potential of the chocolate-flavored milk was the highest and orange juice was low. Such a difference suggest that the demineralization potential of beverages could be various according to the ways simulating *in vivo* drinking process. Curzon et al.[12] also reported that the ranking of foods for cariogenicity showed a big difference between the evaluation methods.

Dental caries is a common plaque-dependent bacterial infection that is strongly affected by diet,[24] and the cariogenicity of foods is related to their physicochemical properties. As for the relationship between properties of food and dental caries, bacterial acid production markedly increases in the plaque as soon as sugar and sugar products are included in the diet of the host[1,25].

These acids demineralize dental enamel[24]. Kashket et al.[26] reported that foods that have been perceived as sticky or clingy have been considered to be more cariogenic than foods that do not stick to the teeth, and Holloway and Sissons et al.[27,28] reported that a food with low pH was correlated with caries increment as a value of pH 5.5 at which enamel begins to dissolve. Many another researchers reported that some minerals in the food, especially calcium and fluoride have markedly protective effects on the teeth.[29-31]

Therefore, the physicochemical properties of the test beverages were measured in this study. We tried to find the significant difference of the physicochemical properties of the beverages between low and high cariogenic potential groups divided by *in situ* demineralization, but failed.

It is speculated that this result was drawn because test beverages include lots of components not only for their caries - causing potential, but also for their anti - cariogenic potential. For example, some components such as fluorine and calcium in the beverages interact with the carbohydrates and influence their metabolism in the mouth. Some will inhibit the caries process, others may encourage it[20].

Burt and Pai[32] reported that relationships among sugars and dental caries appear much weaker in the modern age of fluoride intake than it used to be, so the effect of sugar products on the dental caries is possibly limited. Also, the presence of minerals and ions such as fluoride and calcium in plaque and saliva promotes remineralization of incipient lesions[1].

As noted above, beverages can have the physicochemical properties related to a high cariogenic potential but yet not induce much demineralization under specific conditions of use which are not conducive to caries. In other words, the absolute cariogenic potential of a food will be influenced not only by its components and physical characteristics but also by the other factors of the beverages, especially biologic factors which were not be considered in this *in vitro* study.

The present study had several limitations. The enamel demineralization was measured by only surface microhardness. Multidimensional measurement of demineralization would provide more validity on outcome assessment. In addition, sample size was relatively small, which could not be representative. In order to overcome this limitation, we used the crossover design. the further studies should include more subjects and minimize this limitation. One of the most important limitations of this study is its *in vitro* design. Although dental caries is developed by the interaction between cariogenic bacteria and diet, we analyzed only the physicochemical properties of the beverages. The further study will be needed to develop the *in vitro* model for the interaction between cariogenic bacteria and diet.

Since equilibrium of the environment factors in the oral cavity is important in the process of demineralization and remineralization, further studies on cariogenic potential are required to consider equilibrium based on the physicochemical properties. Because they could show different cariogenic potential when they have different component, even though they are the same products.

Nevertheless, the meaningful rank of demineralization potential among the beverages was provided based on *in situ* demineralization in this study. Most studies did not consider as many beverages as the present study by *in situ* method. This study derived practical and systematic inference concerning the demineralization potential of the beverages by *in situ* demineralization and physicochemical analysis.

5. Conclusions

Based on the data obtained in this study, it may be concluded that *in situ* demineralization of tooth enamel could provide the valid rank of beverages' demineralization potential. However, we could not find any significant differences of the physicochemical properties of beverages between clusters based on *in situ* demineralization.

References

1. Harris NO, Garcia-Godoy. Primary Preventive Dentistry: sixth edition. New Jersey: Pearson Education;2004:10-72, 430-431.

2. Mundorff SA, Featherstone JDB, Bibby BG. Cariogenic potential of foods Ⅰ. Caries in the rat model. Caries Res 1990;24:344-355.

3. Marshall TA, Broffitt B, Eichenberger-Gilmore J, Warren JJ, Cunningham MA, Levy SM. The roles of meal, snack, and diary total food and beverage exposures on caries experience in young children. J Public Health Dent 2005;65:166-173.

4. Gustaffson BE, Quensel CE, Lanke LS, Lundqvist C, Grahnen H, Bonow BE, et al. The Vipeholm dental caries study: the effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for five years. Acta Odontol Scand 1954;11:232-264.

5. Lingstrom P, Birkhed D, Ruben J, Arends J. Effect of frequent consumption of starch food items onenamel and dentin demineralization and on plaque pH in situ. J Dent Res 1994;73:652-660.

6. Koulourides T, Bodden R, Keller S. Cariogenicity of nine sugars tested with an intraoral device in man. Caries Res

1976;10:427-441.

7. Zero DT, Rahbcck I, Fu J, Proskin HM, Fcathcrstone JDB. Comparison of the iodide permeability test, the surface microhardness test and mineral dissolution of bovine enamel following acid challenge. Caries Res 1990;24:181-188.

8. Rugg-Gunn W, Edgar M, Jenkins GN. The effect of altering the position of a sugary food in a meal upon plaque pH in human subjects. J Dent Res 1981;60:867-872.

9. Mundorff-Shrestha SA, Featherstone JDB, Eisenberg AD. Cariogenic potential of foods II. Relationship of food composition, plaque microbial counts, and salivary parameters to caries in the rat model. Caries Res 1994;28:106-115.

10. Bowen WH, Amsbough SM, Monell-Torrens S, Brunelle J, Kuzmiak-Jones H, Cole MF. A method to assess cariogenic potential of foodstuffs. J Am Dent Assoc 1980;100:677-681.

11. Graf H, Mühlemann HR. Telemetry of plaque pH from inter-dental area. Helv Odontol Acta 1966;10:94-101.

12. Curzon MEJ, Pollard MA. Integration of methods for determining the acido / cariogenic potential of foods: A comparison of several different methods. Caries Res 1996;30:126-131.

13. Discussion of Dr. Edmondson's Paper by Prof. Jenkins. Caries

Res 1990;24 (Suppl.1):72-74.

14. Ribeiro CC, Tabchoury CP, Del Bel Cury AA, Tenuta LM, Cury JA. Effect of starch on the cariogenic potential of sucrose. Br J Nutr 2005;94:44-50.

15. Curzon ME, Hefferren JJ. Modern methods for assessing the cariogenic and erosive potential of foods. Br Dent J 2001;191:41-46.

16. Hefferren JJ. Proceeding of the Scientific Conference on methods for assessment of the cariogenic potential of foods. San Antonio, Texas Nov. 17-21, 1985. J Dent Res 1986;65 (Spec Iss):1473-1544.

17. An editorial department (2009) Food distribution yearbook 2009. Seoul, South Korea.

18. Gruenwedel DW, Whitaker JR. Food Analysis:Principle and Techniques. New York:Marcel Dekker Inc;2007.

19. Nielsen SS. Introduction to Food Analysis. Gaithersburg:Aspen Publisher;2004.

20. Edmondson EMS. Food composition and food cariogenicity factors affecting the cariogenic potential of foods. Caries Res 1990;24(suppl 1):60-71.

21. Arends J, ten Bosch JJ. Demineralization and remineralization

evaluation techniques. J Dent Res 1992;71:924-8.

22. Featherstone JDB, ten Cate TM, ShariatiM, Arends J. Comparison of artificial caries-like lesions by quantitative microradiography and microhardness profiles. Caries Res 1983;17:385-391.

23. Edgar WM, Bibby BG, Mundorff S, Rowley J. Acid production in plaque after eating snacks: Modifying factors in foods. J Am Dent Assoc 1975;90:418-425.

24. Navia JM. Carbohydrates and dental health. Am J Clin Nutr 1994;59:719S-727S.

25. Newbrun E: Substrate: Diet and caries; in Cariology, ed 3. Chicago, Ouintessence Publishing, 1989, pp 99-134.

26. Kashket, S. Lack of correlation between food retention on the human dentition and consumer perception of food stickiness. J Dent Res 1991;70:1314.

27. Hollway, P.J. Epidemiology : Summary of discussion, Cariology Today. Zurich:Int. Congr.;1983:328.

28. Sisson, C.H., Wong, L., Shu, M. Factor affecting the resting pH of *in vitro* human microcosm dental plaque and *Streptococcus mutans* biofilms. Arch Oral Biol 1998;43:93.

29. DePaola PF, Brudevold F, Aasenden R, Moreno EC, Englander

H, Bakhos Y, et al. A pilot study of the relationship between caries experience and surface enamel fluoride in man. Arch Oral Biol 1975;20:859-864.

30. Weiss ME, Bibby BG. Effects of milk on enamel solubility. Arch Oral Biol 1966;11:49-57.

31. Haldi J, Wynn W, Bentley KD, Law ML. Dental caries in the albino rat in relation to the chemical composition of the teeth and of the diet. Ⅳ Variations in the Ca/P ratio of the diet induced by changing the calcium content. J Nutr 1959;67:645-653.

32. Burt BA, Pai S. Sugar consumption and caries risk: a systematic review. J Dent Educ 2001;65:1017-1023.

국문초록

액체 간식품의 이화학적 특성과 법랑질 탈회

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치아우식증은 치아 발거 원인 비중이 가장 높은 질환으로 치주질환과 함께 구강건강을 위협하는 대표적인 양대 구강상병 중의 하나이다. 치아우식증은 숙주, 병원체, 환경(식이 등) 그리고 시간요인들이 복합적으로 작용하여 발생되는 다인성 질환으로, 특히 식이와 치아우식증은 서로 밀접한 관련성이 있는 것으로 보고되었다. 식이요인이 치아에 미치는 영향은 전신적인 효과보다 국소적인 효과가 더 크며, 식품의 물리화학적인 특성은 치아우식의 발생을 가속화 시키거나 최소화 시키는데 영향을 줄 수 있다.

이에 본 연구에서는 사람의 섭식과정을 가능한 가깝게 구현한 *in situ* 실험설계를 통하여 식품이 유발하는 법랑질 탈회정도를 측정하

고, 법랑질 탈회정도와 *in vitro* 실험에서 측정한 식품의 이화학적 특성간의 연관성을 확인해보고자 한다.

본 연구는 국민 다소비 간식품 목록을 바탕으로 하여 액체류 13종을 분석대상 간식품으로 선정하였고, 양성대조군으로는 10% 자당을 이용하였다. 연구대상 간식품은 탄산음료, 오렌지주스, 포도주스, 커피, 이온음료, 차, 홍차, 두유, 흰우유, 초코우유, 딸기우유, 커피우유, 요구르트였다. 본 임상실험 설계는 동일한 임상실험 대상자에서 간식품의 종류만 무작위로 변경되는 부표집 임의화 완전블록설계로, 현재 우식이 진행 중인 치아가 없고, 실험에 대해 충분한 정보를 제공받고 참여에 동의한 24-29세의 건강한 남녀 5명을 연구대상으로, 서울대학교 치의학대학원 의학연구윤리심의위원회의 승인 후에 진행되었다(S-D20090008). 시편제작을 위해 건전한 법랑질 표면을 가진 소의 중절치에서 직경 3 mm의 원통형 법랑질 시편을 취하여 아크릴 봉에 레진을 이용하여 표매한 후, 감마방사선 소독을 시행하였다. 실험대상자는 2일간의 치면세균막 축적기간과 5일간의 탈회 실험기간 동안, 치아시편이 매몰된 두 개의 구강 내 유지장치를 양쪽 하악 구치부 설측에 장착하였고, 한 주기에 한 가지 간식품을 적용하여 총 14주기 동안 13개의 식품과 양성대조군인 10% 자당에 대한 임상실험이 진행되었다. 임상실험 전과 후의 치아시편 탈회량을 측정하기 위하여, 비커스 미세경도계를 이용하여 9.8N 10 sec의 조건으로 시편 표면의 미세경도를 측정하였고, 총 14종류 간식품의 이화학적 특성을 분석하기 위하여, 총당과 환원당, pH, 점도, 칼슘농도 그리고 불소함량을 측정하였다. 간식품 간의 탈회량 차이를 알아보기 위하여, 간식품을 고정효과요인, 대상자를 임의효과요인으로 하고, 시편의 탈회량을 결과변수로 하여 GLM (General Linear Model)으로 검

정하였고, 간식품에 대하여 Ducan’s Mutiple Range Test로 사후 분석을 시행하였다. 또한 간식품의 미세경도 특성에 대하여 제곱 유클리디안 거리(Squared Euclidian Distance)에 근거한 계층적 군집분석(Cluster Analysis)을 시행한 결과, 다음과 같은 결론을 얻었다.

1) 구강 내 탈회모형에 의한 임상실험 결과에서 간식품에 의한 미세경도 값의 변화량은 초코우유가 가장 크게 나타났고, 포도주스가 가장 작게 나타났다.

2) 간식품에 의한 치아시편의 미세경도 값의 변화량을 이용하여 군집분석을 시행한 결과, 저탈회식품군과 고탈회식품군으로 분류할 수 있었다. 저탈회식품군은 고탈회식품군에 비해 불소이온 함량이 높고, 총 당과 환원당 함량이 적은 것으로 나타났으며, pH와 점도, 그리고 칼슘이온 함량이 낮은 것으로 나타났다. 그러나 이들 간의 유의한 차이점은 없었다.

이상의 결과, 올바른 간식품의 선택을 위한 정보로 간식품의 법랑질 탈회 정도 등도 소비자에게 제공하는 방안을 강구할 필요가 있을 것으로 사료되었다.

주요어 : 액체간식품, 치아우식유발능, 치아우식증, 이화학적특성
학 번 : 2010-22029