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Original Article

Dentistry Section

To Analyse the Erosive Potential of Commercially Available Drinks on Dental Enamel and Various Tooth Coloured Restorative Materials – An In-vitro Study

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ABSTRACT

Introduction: With the enormous change in life style pattern of a common man through the past few decades, there has been proportional variation in the amount and frequency of consumption of drinks. An increased consumption of these drinks will concurrently increase enamel surface roughness by demineralization, resulting in hypersensitivity and elevated caries risk.

Aim: The present study was designed to evaluate the erosive potential of commercially available drinks on tooth enamel and various tooth coloured restorative materials.

Materials and Methods: Extracted human teeth were taken and divided into four groups i.e. tooth enamel, glass ionomer cement, composite and compomer. Four commercially available drinks were chosen these were Coca -Cola, Nimbooz, Frooti and Yakult. The pH of each drink was measured. Each group was immersed in various experimental drinks for a period of 14 days. The erosive potential of each drink was measured by calculating the change in average surface roughness of these groups after the immersion protocol in various drinks. The data analysis was done by One Way Anova, Post-Hoc Bonferroni, and paired t –test.

Results: Group II-GIC showed highest values for mean of change in average surface roughness and the values were statistically significant ($p<0.001$) with tooth enamel, composite and compomer ($p=0.002$). Coca-cola showed the highest erosive potential and Yakult showed the lowest, there was no statistical significant difference between the results shown by Yakult and Frooti.

Conclusion: Characteristics which may promote erosion of enamel and tooth coloured restorative materials were surface texture of the material and pH of the drinks.

Keywords: Dental erosion, Immersion period, Surfcom , Surface roughness

INTRODUCTION

Dental erosion is defined as loss of dental hard tissue due to a chemical process which is irreversible and without the involvement of microorganisms. Cause of erosion can be endogenous or exogenous [1]. Acidic drinks and food are major exogenous source for erosion. According to data the sale of soft drinks had grown 76% from the year 1998 – 2002 in India, and were expected to grow at least 10% per year through 2012 [2]. With these soft drinks substituting water, their erosive effects on dental hard tissues pose a special challenge to any dentist for their restoration [3].

The purpose of this in vitro study was to evaluate the erosive potential of commercially available drinks (Coca-cola, Frooti, Nimbooz and Yakult) and their effect on surface degradation of tooth enamel and various tooth coloured restorations like conventional glass ionomer cement, composite and compomer using surface profilometry with diamond stylus.

MATERIALS AND METHODS

The present double blinded in vitro study was carried out for one and a half year in Department of Pedodontics and Preventive Dentistry at National Dental College, Dera Bassi with the help of the Mechanical Department of Punjab Engineering College, Chandigarh. Ethical clearance for the study was obtained from institutional ethical committee for the use of human extracted teeth. Human premolar and molar teeth extracted for orthodontic purpose or compromised periodontal condition were collected from the Department of Oral and Maxillofacial Surgery of National Dental College, Dera Bassi (Punjab), to examine the erosive effect of drinks. A total of 80 teeth free from caries, crack or without hypo calcification were selected for the study. Hypoplastic and carious teeth were excluded.

Preparation of samples: The teeth were thoroughly cleaned and stored in normal saline at room temperature till further use. The crowns were separated from the roots using a diamond disc in a low-speed straight hand piece, the crown portion of the teeth was then sectioned longitudinally into buccal and lingual halves through the centre of the crown [Table/Fig-1], thus making 160 halves of the 80 teeth. These halves of the enamel sections were then embedded in acrylic resin blocks of dimensions 20mm (w) x 20mm (l) x 15mm (h) with the outer enamel surface exposed. These blocks were specifically constructed to hold the specimen precisely during surfometry.

160 samples were divided into following four groups [Table/Fig-2]. Tooth Enamel was taken as control group. Each group was further subdivided into four subgroups of 10 teeth each depending on the testing media (Experimental drinks) (n=10) whose erosive potential was to be evaluated [Table/Fig-3].

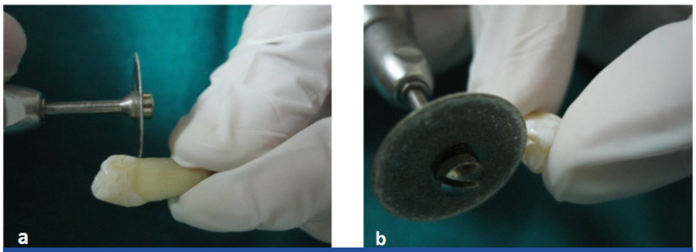
Experimental drinks

A) Aerated Carbonated Drink (Coca-cola)

B) Mango Juice (Frooti)

C) Lemon Juice (Nimbooz)

D) Fermented Milk (Yakult)



[Table/Fig-1]: Preparation of samples. (a)-Crown separated from root. (b)- Crown sectioned into buccal and lingual halves.

Group I – Tooth Enamel: Sample size-40
Group II – Glass Ionomer Cement: Sample size-40
Group III – Composite: Sample size-40
Group IV – Compomer: Sample size-40

[Table/Fig-2]: Table showing groups.

Group-I	Group-II	Group-III	Group-IV
Sub-Group I A	Sub-Group II A	Sub-Group IIIA	Sub-Group IVA
Sub-Group I B	Sub-Group II B	Sub-Group III B	Sub-Group IV B
Sub-Group I C	Sub-Group II C	Sub-Group III C	Sub-Group IV C
Sub-Group I D	Sub-Group II D	Sub-Group III D	Sub-Group IV D

[Table/Fig-3]: The various groups and subgroups.

TESTING -DRINKS	pH OF DRINKS(Mean)
Coca-Cola	1.87
Nimbooz	2.58
Frooti	3.07
Yakult	3.17

[Table/Fig-4]: Measured pH of the drinks.

[Table/Fig-5]: Profilometer Surfcom 130A.

Preparation for Various Groups

Group I - Tooth Enamel: - The enamel surfaces were smoothened by using abrasive grit papers of silicone carbide in a gradually increasing fineness from 400 grits to 1200 grits (Kemet International, Maidstone, UK). These were applied on mandrel at low speed using straight handpiece. The samples were then polished with diamond paste (Shofu) and super snap buffs (shofu).

For Group II-IV: - Cavity preparation: Standardized cavities were prepared on the buccal or lingual surfaces of the already sectioned halves of the teeth. The cavity preparation was standardized using a William's graduated periodontal probe. Cavities were then thoroughly cleaned restored with respective materials following standardized steps.

Each sample from group I – IV was polished with nail paint leaving a 3mm x 5mm window exposed to evaluate the erosive potential of drinks. All the samples were stored in normal saline. Each specimen was given a reference number.

Measurement of initial pH of the drinks- Digital pH meter was used to measure the pH of each experimental drink [Table/Fig-4].

Group		Sum of Squares	df	Mean Square	F	Sig.
Tooth -Enamel	Between Groups	2.643	3	0.881	24.292	<0.001**
	Within Groups	1.306	36	0.036		
	Total	3.949	39			
GIC	Between Groups	98.146	3	32.715	164.845	<0.001**
	Within Groups	7.145	36	0.198		
	Total	105.291	39			
Composite	Between Groups	31.574	3	10.525	119.077	<0.001**
	Within Groups	3.182	36	0.088		
	Total	34.756	39			
Compomer	Between Groups	59.679	3	19.893	292.913	<0.001**
	Within Groups	2.445	36	0.068		
	Total	62.124	39			

[Table/Fig-6]: Inter & intra group comparison of mean average surface roughness at post-immersion (μm) One Way ANOVA.
Ra values were statistically significant between the groups at 0.1% level and the Ra values were non significant within the groups.
Abbreviations- Ra- Mean Average Surface Roughness at Post-Immersion (μm)

Surfcom-130A was used in this study to measure surface roughness of each sample both before and after immersion in drinks. Surfcom-130A is a type of profilometer manufactured in Tokyo (Japan) by Carl Zeiss [Table/Fig-5].

Baseline surface roughness i.e., Ra (Average surface roughness) was measured for each of the 160 samples. To record the reading, tip of stylus of Surfcom-130A was made to run transversely on the exposed surface of specimen. Three consecutive readings were made and their arithmetic mean was taken as baseline Ra. Ten specimens of each individual sub group (Group I-Group IV) were placed in four separate air tight plastic containers carefully labelled with each drink. Each plastic container was filled with 600ml of respective drink. The containers with specimen and drinks were stored at 37°C for a total period of 14 days. Testing period was taken as 14 days as studied by Von Fraunhofer for dissolution of enamel in beverage solutions [4]. The drinks were changed daily for 14 days. At the end of testing period, the average surface roughness (Ra) of each sample was evaluated again.

STATISTICAL ANALYSIS

The values for baseline average surface roughness and post immersion average surface roughness were tabulated and the change in average surface roughness of all the 160 samples was statistically analyzed using One Way Anova, Bonferroni Post Hoc test and t-test at 0.05% level of significance.

RESULTS

From the results of One Way ANOVA [Table/Fig-6], the mean average surface roughness at post-immersion for all the four groups were statistically significant between the groups at 0.1% level and the values were non-significant within the groups. When paired t-test was applied the post-immersion values for all the four groups (i.e., tooth enamel, GIC, composite, compomer) showed statistically significant difference as compared to the respective baseline values [Table/Fig-7].

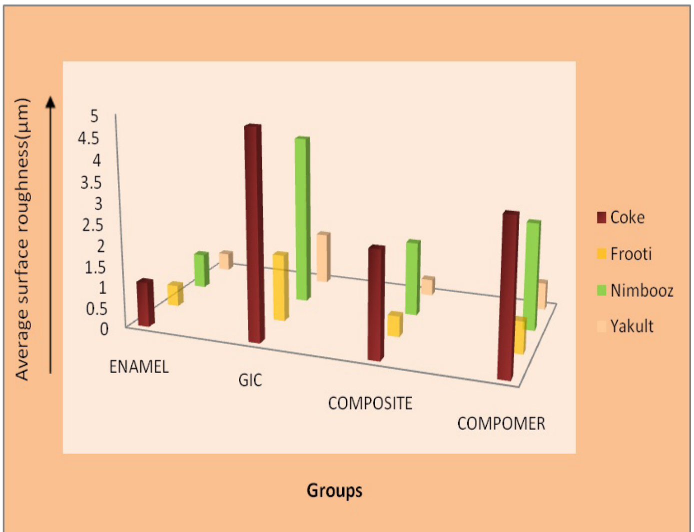
When the comparison was done between various groups [Table/Fig-8], group I–tooth enamel showed statistically significant difference (p<0.001) with GIC and compomer. No statistically significant difference was found between tooth enamel and composite.

Group	n		Mean	S.D.	S.E.	Paired Differences			T	Sig. (2-tailed)
						Mean of Difference between B-PI	S.D.	S.E.		
Tooth –Enamel	40	Baseline	0.357	0.068	0.0107	-0.356	0.300	0.048	-7.502	<0.001**
	40	Post Immersion	0.713	0.318	0.0503					
GIC	40	Baseline	0.499	0.062	0.0098	-2.467	1.640	0.259	-9.510	<0.001**
	40	Post Immersion	2.965	1.64	0.260					
Composite	40	Baseline	0.299	0.045	0.0071	-0.997	0.946	0.150	-6.665	<0.001**
	40	Post Immersion	1.296	0.944	0.149					
Compomer	40	Baseline	0.361	0.035	0.006	-1.520	1.259	0.199	-7.637	<0.001**
	40	Post Immersion	1.881	1.262	0.1996					

[Table/Fig-7]: Inter-group comparison of baseline and post-immersion mean average surface roughness of various groups.

(I) Group	(J) group	Mean Difference (I-J)	S.E.	Sig.
Tooth -Enamel	GIC	-2.11(*)	0.256	<0.001**
	Composite	-0.641	0.256	0.081
	Compomer	-1.164(*)	0.256	<0.001**
GIC	Tooth -Enamel	2.110(*)	0.256	<0.001**
	Composite	1.470(*)	0.256	<0.001**
	Compomer	0.947(*)	0.256	0.002**
Composite	Tooth -Enamel	0.641	0.256	0.081
	GIC	-1.470(*)	0.256	<0.001**
	Compomer	-0.523	0.256	0.258
Compomer	Tooth -Enamel	1.164(*)	0.256	<0.001**
	GIC	-0.947(*)	0.256	0.002**
	Composite	0.523	0.256	0.258

[Table/Fig-8]: Post Hoc Test (Bonferroni) inter-group comparison of change in surface roughness (µm).
*The mean difference is significant at the 0.05 level



[Table/Fig-10]: Comparison of mean average surface roughness of all subgroups in four groups after erosive challenge (µm).

RANK	SUBGROUPS	MEAN (Change in mean average surface roughness) (µm)	SD
1	Subgroup II (A)- GIC + COCA-COLA	4.41	0.53
2	Subgroup II (C)- GIC + NIMBOOZ	3.58	0.58
3	Subgroup IV (A)- COMPOMER + COCA-COLA	3.18	0.41
4	Subgroup III (A)- COMPOSITE + COCA-COLA	2.22	0.43
5	Subgroup IV (C)- COMPOMER + NIMBOOZ	2.20	0.26
6	Subgroup III (C)- COMPOSITE + NIMBOOZ	1.48	0.41
7	Subgroup II (B)- GIC + FROOTI	1.10	0.27
8	Subgroup II (D)- GIC + YAKULT	0.77	0.30
9	Subgroup I (A)- TOOTH –ENAMEL + COCA-COLA	0.71	0.22
10	Subgroup I (C)- TOOTH –ENAMEL + NIMBOOZ	0.47	0.23
11	Subgroup IV (B)- COMPOMER + FROOTI	0.39	0.04
12	Subgroup IV (D)- COMPOMER + YAKULT	0.31	0.06
13	Subgroup III (B)-COMPOSITE + FROOTI	0.19	0.08
14	Subgroup I (B)- TOOTH – ENAMEL + FROOTI	0.18	0.08
15	Subgroup III (D)- COMPOSITE + YAKULT	0.10	0.02
16	Subgroup I (D)- TOOTH – ENAMEL + YAKULT	0.07	0.05

[Table/Fig-9]: Ranking of subgroups.

For group II-GIC showed highest values for mean of change in average surface roughness among all four groups and the values were statistically significant (p<0.001), group III-composite showed statistically significant difference (p<0.001) with GIC. GroupIV- compomer showed statistically significant difference with tooth enamel (p<0.001) and GIC (p=0.002). The values were non-significant with composite.

[Table/Fig-9] Shows ranking of combinations of experimental drinks, restorative materials and the control tooth enamel. According to table, we can conclude that GIC in coca-cola showed highest change in average surface roughness whereas tooth enamel in Yakult showed the lowest change in average surface roughness.

The graph [Table/Fig-10] showed that group II GIC showed the highest change in average surface roughness for all the subgroups and the change in average surface roughness was highest for coca cola, while the change in average surface roughness was lowest for group I tooth enamel. From the graph we can interpret that Yakult and Frooti were non erosive in all groups.

DISCUSSION

Dental erosion is a multi-factorial disease which is highly influenced by habits and lifestyles. The pH of most beverages are below 3.5 and literature have reported that enamel dissolution occur below 4.24 pH value [5]. Results revealed that Coca-Cola is most acidic drink with pH of 1.87, followed by Nimbooz- 2.58, Frooti - 3.07 and the lowest pH was shown by Yakult (3.18) [Table/Fig-4]. The pH of all drinks investigated ranged from 1.87- 3.18, which was well below the critical pH at which enamel dissolution occurs. Measuring pH of the drink is the most accurate method to quantify the acid content of a beverage. The pH or actual acidity is the negative logarithm of hydrogen ion concentration and is measured on a scale of 0-14. A reading below 7 indicates an acid content. Generally the beverages with lower pH has more erosive effect; however, additional factors such as type, concentration, amount of acid, calcium chelating properties, exposure time and temperature, buffering capacity of saliva can also contribute to enamel dissolution in the oral cavity [6].

Profilometer is chosen as the method to assess the surface roughness of eroded specimens as it has sufficient senstivity to investigate early tooth tissue loss produced by limited exposure to acid [7]. Surface profilometer (Surfcom -130 A) measures the irreversible loss of dental hard tissue determined by a contact stylus (diamond) with diameter of 5µm. The contact stylus is loaded with a force of a 0.87 milli Newtons. It gives the measurements in the form of Ra i.e., average surface roughness which is the arithmetic average height of roughness component irregularities from mean line measured within the sampling length and is expressed in microns (µm). Smaller Ra values indicate smoother surface [8-10]. Result of baseline average surface roughness for all the samples revealed highest value for GIC (Chemflex) followed by compomer (Dyract), tooth enamel and lowest for composite (Ceram –X)

GIC > Compomer > Tooth Enamel > Composite.

This suggests that the composition of the materials has been responsible for these differences. According to Gladys compomer (Dyract) appears to be more like a composite than a glass–ionomer cement as far as polishing is concerned [11]. Better polish obtainable with dyract is probably because of its smaller particles and the absence of air bubbles.

Immersion protocol of 14 days taken in the study was based on daily consumption of 25 ounces of soft drinks with residence time of 20 seconds in mouth before salivary clearance, thus making an annual soft drink exposure to enamel approximately 90,000 seconds (25 hours) per year. Thus testing period of 14 days (350 hours) is comparable to 14 years of soft drink consumption [4].

When comparison was done between various groups, GIC showed the highest change in mean average surface roughness followed by compomer, composite and the control tooth enamel. These results could be explained by the surface texture of the test materials, as GIC showed the highest baseline average surface roughness when compared with other materials. Attin T et al., stated that dissolution of GIC in low pH drinks could be result from dissolution of the siliceous hydrogel layer [12]. Ibhrahim et al., showed the highest change in surface roughness of conventional GIC, may be due to the materials composition with large mean particle sizes [13].

The compomer (Dyract) demonstrated significantly less change in mean average surface roughness than GIC (Chemflex) after immersion protocol in experimental drinks. The difference of mean average surface roughness was not statistically significant from that of composite (Ceram X). This can be explained as acidic attack on compomer resulted in loss of structural ions from the glass phase of compomer [14].

K.Rajavardhan et al., concluded that both compomer and giomer showed significant change in surface roughness and the change is more for compomer after exposure to cola drinks and fruit juices [15].

Our study reveal composite (Ceram-X) showed statistically significant difference in mean average surface roughness ($p<0.001$) with GIC. The values were non significant with tooth enamel and compomer.

On exposure to drinks containing citric acid, lactic acid, heptanes the resin matrix softens [16]. More the filler content of material lesser will be the water adsorption thus leading to less surface degradation [17]. Lowest change in surface roughness of Ceram X may be due to more filler content [18] and due to the presence of silane coupling agent, which bond the filler chemically to resin matrix, which may account for their hydrolytic stability [14].

In our study group I tooth enamel (control) showed statistically significant difference in change in surface roughness ($p<0.001$) with GIC and compomer. No statistically significant difference was found between tooth enamel and composite.

Researches had reported that low pH beverages containing citric acid, lactic acid, phosphoric acid have shown to increases potential for dissolution of hydroxyapatite due to formation of calcium citrate and chelating action of citric acid that withdraws Ca ions from the beverages resulting in an increased dissolution tendency due to loss of common ion effect [19-21].

On comparing the experimental drinks, all the groups immersed in Coca-cola showed the highest change in mean average surface roughness compared to Nimbooz, Frooti and Yakult. Coca-cola contain acidity regulators 338 (orthophosphoric acid), coloring flavoring agents and caffeine. In addition to carbonic acid manufacturers incorporate phosphoric acid in order to impart tangy flavour to their drinks. Thus due to presence of all these acids the cola drinks have inherent acidity which lead to increase the erosion, decalcification of tooth enamel and various tooth coloured restorative materials [18].

As Coca-cola has lowest pH of all the test drinks [Table/Fig-4], so it shows highest change in surface roughness. Nimbooz showed statistically significant difference in change of mean average surface roughness with Coca-cola, but the values are highly significant with Frooti and Yakult.

Nimbooz contain concentrated lemon juices (0.8%), acidity regulators 330 (citric acid), 296 (Malic acid) and preservative (202) (Potasium sorbate) and flavouring agents. The citric acid and malic acid present in Nimbooz is the major erosive ingredient.

The erosive effect seems to be inversely related to low pH values [Table/Fig-4]; the lower the pH of the drink, the greater the hydroxyapatite dissolving capacity [22].

Yakult showed the lowest change in average surface roughness for all groups. It showed the statistically lower values compared to Nimbooz and Coca-cola. There was no statistically significant difference between the results shown by Yakult and Frooti. From the results, Yakult can be concluded as non–erosive.

Fermented milk beverages only cause superficial mineral loss of dental enamel, they do not promote erosion [23]. Frencken JE et al., concluded that calcium and phosphate contents have a protective effect on milk beverages, which has a low pH (<4) and yet has no erosive potential [14]. As observed in our study, Yakult may contribute to the dissolution of dental structures and dental materials due to its acidic pH as reported in the literature [6,24,25]. However pH of food and beverages is not only the contributory factor for demineralization, other factors should also be considered, including the stimulation of salivary flow, buffering capacity of beverages and presence of calcium, fluoride and phosphate [26,27].

Radomic Bare et al., concluded that enamel erosion was directly proportional to exposure time and all tested drinks i.e., cola, orange juice, cedevita and guarana was erosive except Yoghurt [28]. Frooti showed the lowest change in average surface roughness for all groups. Chadwick RG et al., concluded that restorative materials become rougher after they had been subjected to lower pH cycling regimen in Mirinda orange and Natural mango juice [29]. This can be attributed to the capability of acid media to soften the restorative materials.

Frooti showed the statistically lower values compared to Nimbooz, Coca-cola. There was no statistical significant difference between results shown by Yakult and Frooti.

The erosion results of this in vitro study must be interpreted with certain degree of caution as they will tend to overestimate the amount of enamel and materials lost compared to the clinical conditions. In addition, acidic drinks have also been shown to stimulate salivary secretion, which in turn facilities the buffering and flushing effects of the increased salivary flow which will help to counteract the erosive effects of these products [30]. So, further studies are recommended for both qualitative and quantitative evaluation of effects of these beverages on the clinical integrity of the tooth enamel and different tooth coloured restorative materials in the oral environment.

Setting controversies aside, the above study highlights the detrimental effects of excessive consumption of soft drinks especially the low pH drinks on existing dental enamel and restorations. Hence it is mandatory for paediatric dentists to enlighten our patients for eliminating these deleterious habits.

LIMITATIONS

In the oral cavity, any drink or foodstuff will be instantaneously mixed with saliva, with a subsequent rise in its pH. Secondly, acidic drinks have also been shown to stimulate salivary secretions, which in turn facilitates the buffering and flushing effect of increased salivary flow which will help to counteract the erosive effects of these products So, further studies are recommended for both qualitative and quantitative evaluation of effects of these beverages on the clinical integrity of the tooth enamel and different tooth coloured restorative materials in the oral environment.

CONCLUSION

Despite the limitations of in vitro studies, the change in average surface roughness was highest and statistically significant for GIC, followed by compomer, composite and tooth enamel. Coca cola showed the highest erosive potential followed by Nimbooz, Frooti and Yakult. Erosive potential was directly related to pH of the drinks.

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