

Erosive Effect of Soft Drink and Fresh Fruit Juice on Restorative Materials

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ABSTRACT

Aims: To evaluate and compare the effect of a soft drink and a fresh fruit juice on microleakage as well as surface texture of flowable composite (Filtek™ Flow 3M Dental products) and resin-modified glass ionomer cement (GIC) (Vitremer™ 3M Dental products).

Materials and methods: Seventy noncarious human premolars extracted for orthodontic treatment purpose were collected and stored in saline for microleakage study. The experimental groups comprised of 60 teeth, while the remaining 10 formed the control group. Class V cavities were prepared and restored with RMGIC on the buccal surface and Filtek Flow on the lingual surface for evaluating microleakage. The experimental samples were then divided into two groups (group I: Cola drink and group II: Fresh orange fruit juice) of 30 teeth. Each of this group was further divided into three subgroups (low, medium and high immersion) containing 10 teeth. The control group (group III: Water) contained 10 teeth.

Using a brass mold, 56 pellets were prepared with Filtek™ Flow and Vitremer™ tri-cure restorative material each for studying surface texture. Again these were divided into experimental group of 48 pellets each and control group of eight pellets each. The experimental samples were then divided into two groups (group I: Cola drink and group II: Fresh orange fruit juice) of 24 pellets of each. Each of this group was further divided into three subgroups (low, medium and high immersion) containing eight pellets each. The control group (group III: Water) contained 16 pellet (eight pellets of each material).

Both the teeth and pellets were subjected to a common immersion regime according to Maupome et al. Microleakage was evaluated by using Rhodamine B dye and surface texture was evaluated prior to immersion and final surface roughness (Ra) after subjecting the pellets to immersion regime.

Statistical analyses used were Chi-square test/Fisher exact test, Wilcoxon's signed rank test and Mann-Whitney test and ANOVA test.

Results and conclusion: The teeth and the pellets showed statistically significant microleakage and surface roughness respectively as the immersion regime increased. Thus, the study conclusively proves that the 'sipping habit' associated with commonly available low pH beverages, are detrimental to the longevity of restorations.

Keywords: Erosion, Soft drink, Fresh fruit juice, Microleakage, Surface texture.

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INTRODUCTION

Dental erosion can be defined as an irreversible loss of dental hard tissue due to a chemical process without the involvement of microorganisms. This process may be caused by either extrinsic or intrinsic agents.¹ Intrinsic causes are recurrent vomiting as a part of eating disorders, anorexia or bulimia nervosa or due to regurgitation of gastric contents.² Extrinsic causes include acidic substances, beverages, food, medication and environmental exposure to acidic agents.³

The dietary behavior and knowledge about dental erosion is very low in spite of experiencing the signs and symptoms of the same.⁴

Over the last decade, prevalence of dental erosion seems to have increased presumably due to an increase in the consumption of soft drinks and fruit juices.⁵ It has been recognized as an important cause of tooth structure loss not only in adults, but also in children.⁶ There is increasing concern over the high prevalence of dental erosion in children, and the prevalence seems to be increasing. In Australia, the prevalence of erosion in the deciduous dentition was recently found to be as high as 8%. Several studies indicate a relation between dental erosion and a high consumption of cola-type, other acid containing soft drinks, and lemon tea and fruit juices.^{7,8} *In vitro*, exposure of human enamel to citric acid solutions results in a considerable reduction in enamel hardness.⁷

The average daily requirement of water in man is 2 to 3 liters, of which, in developed countries, more than half comes from soft drinks and fruit juices.⁹ The commercial sale of acidic beverages has increased by 56% over the last 10 years and now it is estimated that they will keep rising at about 2 to 3% a year. Excessive contact of the tooth structure with acidic beverages over a prolonged duration of time leads to proportionate loss of dental hard tissues due to their low pH and high titratable acidity leading to noncarious cervical tooth loss (NCTL) thus, posing a challenge to any dentist for restoring these teeth.

It can be assumed that restorative materials are also subjected to low pH values in the oral cavity by erosive attacks, leading to a degradation of their surface integrity thereby leading to microleakage as well as change in the surface texture. The purpose of this study was to evaluate

and compare the effect of a soft drink and a fresh fruit juice on microleakage as well as surface texture of flowable composite (Filtek™ Flow 3M Dental products) and Resin-modified glass ionomer cement (RMGIC) (Vitremmer™ 3M Dental products).

MATERIALS AND METHODS

The experiment was conducted in two parts:

- Evaluation of the effect of cola drink (Coca Cola®) and fresh fruit juice (orange) on the microleakage of RMGIC and flowable composite.
- Evaluation of the effect of cola drink (Coca Cola®) and fresh fruit juice (orange) on the surface texture of RMGIC and flowable composite.

Seventy human premolars with no signs of caries or developmental defects extracted for orthodontic treatment purpose were used. Two restorative materials namely Vitremmer™ tri-cure and Filtek™ Flow and soft drink (Coca Cola®) and fresh fruit orange and water as control were used for the study. Standardized class V cavities (3 mm in length, 2 mm in width and 1.5 mm in depth) were prepared on the buccal and lingual surfaces of the teeth, 1 mm above the cemento-enamel junction (CEJ). The cavity preparation was standardized using a William's graduated periodontal probe.⁵

The cavities on the lingual surface were restored with Filtek™ Flow and cavities on the buccal surface were restored with Vitremmer™ tri-cure according to manufacturer's instructions. The restored teeth were stored in room temperature water for 1 week. During this period the teeth were subjected to 200 thermocycles between 5°C and 55°C water baths. Dwell time was 1 minute with 10 seconds transit between baths. Then the samples were subjected to the various immersion regimens.

Out of the 70 prepared tooth samples, 60 were equally divided into two groups of 30 each. Each group was further divided into three subgroups as mentioned below. Remaining 10 prepared samples were used as control (Fig. 1).

Groups	Low immersion (1 time)/day	Medium immersion (5 times)/day	High immersion (10 times)/day
Group I: Cola drink (Coca-Cola®)	10	10	10
Group II: Fresh fruit juice (orange)	10	10	10

Group III: Water (Control)—10 Samples

Fifty-six pellets each were prepared with Filtek™ Flow and Vitremmer™ tri-cure restorative material using a brass mold of inner diameter 3 × 3 mm thickness. The setting material was held under constant hand pressure using two glass slabs on either side. The material was then light cured for 20 seconds for Filtek™ Flow and 40 seconds for Vitremmer™ tri-cure according to manufacturer's instructions. No finishing procedure was required for the specimen, because the surfaces were cured against matrix strips.

Forty-eight pellets of each material were divided into two groups (Groups I and II) of 24 pellets each. Each group was again subdivided into three parts for use in the immersion regimes as mentioned below (Fig. 2).

Groups	Low immersion (1 time)/day	Medium immersion (5 times)/day	High immersion (10 times)/day
Group I: Cola drink (Coca-Cola®)			
IA Filtek™ flow	8	8	8
IB Vitremmer™	8	8	8
Group II: Fresh fruit juice (orange)			
II A Filtek™ flow	8	8	8
II B Vitremmer™			

The remaining 8 pellets each of Filtek™ flow and vitremmer™ formed the control group.

Group III: Water (control)

- III A—Filtek™ flow—8 pellets
- III B—Vitremmer™—8 pellets

Each specimen was placed on a flat table. The tip of the Profilometer (Taylor and Hobson England) was made to run on the surface and a baseline value was obtained.¹⁰

Common immersion regime was followed for evaluating both the microleakage and the surface texture. Ten restoration samples of each individual subgroup were placed in six airtight plastic containers and carefully labelled. Three plastic containers were filled with 25 ml cola drink (Coca Cola®) and the remaining three plastic containers were filled with 25 ml fresh fruit juice (orange) for 5 minutes. Cola drink (Coca Cola®) and fresh fruit juice (orange) was used for each immersion. Eight pellets of each material were placed in six airtight plastic containers filled with 25 ml cola drink (Coca Cola®) and in six plastic containers filled with 25 ml fresh fruit juice (orange). For low immersion regime the restorations and pellets were subjected to one immersion lasting 5 minutes per day. For medium immersion

regime they were subjected to five immersions, each lasting 5 minutes per day evenly distributed over a 12-hour period. For high immersion regime the samples were subjected to 10 immersions per day each lasting 5 minutes, evenly distributed over a 12-hour period. The whole procedure was carried out for 8 days.¹¹ Before and after each immersion both the restorations and pellets were copiously rinsed in 0.1 M phosphate buffered saline (PBS; pH 7.2). When not exposed to the immersion regime, they were stored in deionized water at room temperature.¹¹ The 10 restorations and eight pellets of each restorative material were placed in an airtight container containing water. Water was changed each day, for 8 days (Figs 1 and 2).

At the end of the test period the apices of the teeth were sealed with sticky wax, and all tooth surfaces except a

1 mm wide zone around the margins of the restoration (buccally and lingually) was painted with nail varnish. To minimize dehydration of the restorations, the teeth were replaced in deionized water as soon as the nail varnish dried. The teeth were then immersed in 1% Rhodamine B solution (pH 7.2) for 24 hours at 37°C, rinsed, dried and invested in clear resin.¹¹ Each tooth was sectioned buccolingually through the center of the restoration with help of a low-speed water cooled diamond disk. The specimens thus, obtained were examined under stereomicroscope to evaluate the microleakage. Dye penetration was graded based on the extent of penetration along the occlusal wall of the restoration using criteria similar to the one used by Michal Staininec and Mark Holtz in 1988.¹²

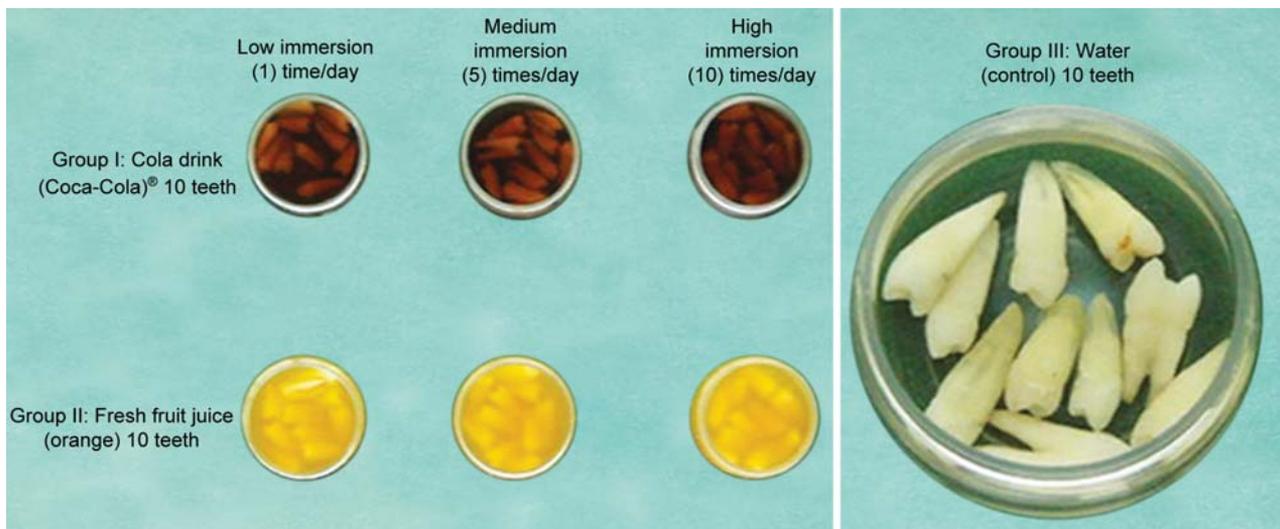


Fig. 1: Immersion regime employed to evaluate the microleakage of the specimen

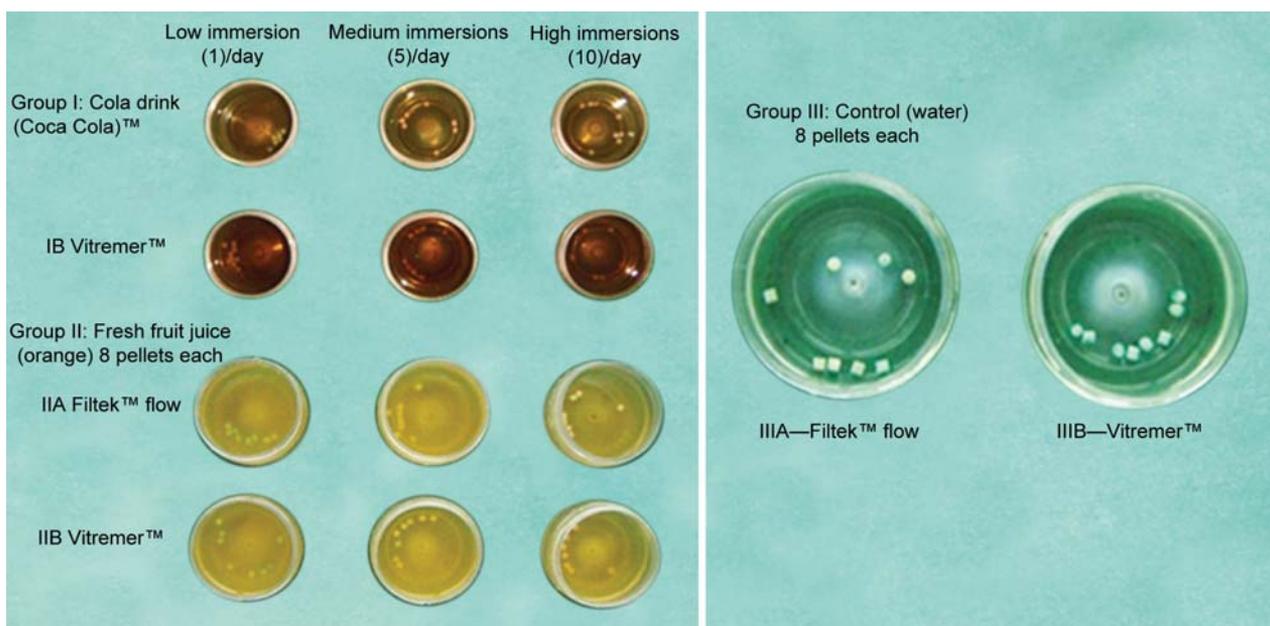


Fig. 2: Immersion regime employed to evaluate the surface texture of the specimens

Scores¹²

Score 0	No dye penetration (Fig. 3)
Score 1	Dye penetration along occlusal wall but less than half way to axial wall (Fig. 4)
Score 2	Dye penetration along occlusal wall but more than half way to axial wall (Fig. 5)
Score 3	Dye penetration along occlusal wall, up to and along axial wall (Fig. 6)

Scoring was done by a single investigator, tabulated and statistically analyzed.

At the end of the test period, the pellets were reevaluated in a similar way as done for the baseline surface texture evaluation. The new values were tabulated as final surface texture values for each pellet and were statistically analyzed.¹⁰

RESULTS

Microleakage Study

Group I {cola drink (Coca Cola[®])} showed highest microleakage tendency with p-value highly significant

($p < 0.001$) followed by group II {fresh fruit juice (orange)} with significant p-value ($p < 0.01$) and no changes with group III {water (control)} in both restorative materials [Filtek[™] Flow and Vitremer[™]] used. It is also evident that the number of immersion is directly proportional to the microleakage pattern {Table 1 (Filtek[™] Flow) and Table 2 (Vitremer[™])}.

Surface Texture Study

Group I {cola drink (Coca-Cola[®])} showed an increased tendency of surface roughness with p-value highly significant ($p < 0.001$) followed by group II {fresh fruit juice (orange)} with significant p-value ($p < 0.01$) and no changes with group III {water (control)} in both [Filtek[™] Flow and Vitremer[™]] restorative materials used. It is also marked that the number of immersion is directly proportional to surface roughness pattern of the specimens {Table 3 (Filtek[™] Flow) and Table 4 (Vitremer[™])}.

DISCUSSION

Dental erosion as defined earlier is an irreversible loss of dental hard tissue by a chemical process without the



Fig. 3: Score 0: No dye penetration



Fig. 5: Score 2: Dye penetration along occlusal wall but more than 1/2 way to axial wall



Fig. 4: Immersion regime employed to evaluate the surface texture of the specimens



Fig. 6: Score 3: Dye penetration along occlusal wall, up to and along axial wall

Table 1: Descriptive statistics on the microleakage pattern of Filtek™ flow following immersion for varying periods of time in cola drink (Coca-Cola®), fresh fruit juice (orange) and water (control)

Groups	Microleakage scores	Low immersion		Medium immersion		High immersion		Difference between immersion regime		
		No.	Mean median	No.	Mean median	No.	Mean median	Low vs medium	Low vs high	Medium vs high
Group I: Cola drink (Coca-Cola®)	0	4	—	—	—	—	—	p < 0.001 HS	p < 0.001 HS	p < 0.001 HS
	1	6	0.6	—	2.0	—	2.8			
	2	—	1.0	10	2.0	2	3.0			
	3	—	—	—	—	8	—			
Group II: Fresh fruit juice (orange)	0	10	—	7	—	1	—	p > 0.05 NS	p < 0.001 HS	p < 0.01 S
	1	—	0.0	3	0.3	9	0.9			
	2	—	0.0	—	0.0	—	1.0			
	3	—	—	—	—	—	—			
No immersion regime was followed										
Group III: Water (control)	0	10	—	—	—	—	—			
	1	—	0.0	—	—	—	—			
	2	—	0.0	—	—	—	—			
	3	—	—	—	—	—	—			
Differences between groups	Group I-II	p < 0.01 S		p < 0.001 HS		p < 0.001 HS				
	Group I-III	p < 0.01 S		p < 0.001 HS		p < 0.001 HS				
	Group II-III	p > 0.05 NS		p > 0.05 NS		p < 0.001 HS				

Chi-square test/Fisher's exact test; p < 0.05, p < 0.01: Significant (S); p < 0.001: Highly significant (HS); p > 0.05: Not significant (NS)

Table 2: Descriptive statistics on the microleakage pattern of Vitremer™ following immersion for varying periods of time in cola drink (Coca-Cola®), fresh fruit juice (orange) and water (control)

Groups	Microleakage scores	Low immersion		Medium immersion		High immersion		Difference between immersion regime		
		No.	Mean median	No.	Mean median	No.	Mean median	Low vs medium	Low vs high	Medium vs high
Group I: Cola drink (Coca-Cola®)	0	7	—	—	—	—	—	p < 0.01 S	p < 0.01 S	p < 0.01 S
	1	3	0.3	9	1.1	—	2.2			
	2	—	0.0	1	1.0	8	2.0			
	3	—	—	—	—	2	—			
Group II: Fresh fruit juice (orange)	0	9	—	8	—	9	—	p > 0.05 NS	p > 0.05 NS	p > 0.05 NS
	1	1	0.1	2	0.2	1	0.1			
	2	—	0.0	—	0.0	—	0.0			
	3	—	—	—	—	—	—			
No immersion regime was followed:										
Group III: Water (control)	0	10	—	—	—	—	—			
	1	—	0.0	—	—	—	—			
	2	—	0.0	—	—	—	—			
	3	—	—	—	—	—	—			
Differences between groups	Group I-II	p > 0.05 NS		p < 0.01 S		p < 0.01 S				
	Group I-III	p > 0.05 NS		p < 0.01 S		p < 0.01 S				
	Group II-III	p > 0.05 NS		p > 0.05 NS		p > 0.05 NS				

Chi-square test/Fisher's exact test; p < 0.05, p < 0.01: Significant (S); p < 0.001: Highly significant (HS); p > 0.05: Not significant (NS)

involvement of microorganisms and is due to either extrinsic or intrinsic sources. Enamel being the hardest tissue has not been spared off.¹³ Dietary erosion may result from food or drinks containing a variety of acidic ingredients. Frequent consumption of these easily and widely available beverages showed erosion of the enamel in both *in vitro* and *in vivo* studies.¹⁴⁻²¹

Phosphoric acid is a common constituent of most of the soft drinks.^{13,22,23} The acid content of the cola soft drink,

which is added to give a peculiar tangy taste and has a preservative property, is known to play a well-established role in the erosive process.

Restoring a noncarious lesion presents a special clinical challenge, as it requires a restorative material, which can adhere to two different types of tooth tissue, i.e. both enamel and dentin. RMGIC and flowable composites bond equally well to enamel and dentin, therefore are the materials of choice in restoring cervical lesions.^{24,25}

Table 3: Descriptive statistics on mean surface texture values of Filtek™ flow following immersion for varying periods of time in cola drink (Coca Cola®), fresh fruit juice (orange) and water (control)

Groups	Particulars	Low immersion			Medium immersion			High immersion			ANOVA F	Comparison at different concentrations		
		Before	After	Difference	Before	After	Difference	Before	After	Difference		Low vs medium	Low vs high	Medium vs high
Group I: Cola drink (Coca-Cola®)	Mean	0.125	0.237	0.113	0.123	0.0563	0.440	0.126	0.846	0.720	486.9	p < 0.001 HS	p < 0.001 HS	p < 0.001 HS
	SD	0.001	0.033	0.034	0.004	0.029	0.031	0.002	0.056	0.049	p < 0.001 HS			
	Ratio p-value*		1.896	<0.05 S		4.57	<0.05 S		6.71	<0.05 S				
Group II: Fresh fruit juice (orange)	Mean	0.124	0.140	0.016	0.127	0.271	0.144	0.126	0.543	0.417	3356.0	p < 0.001 HS	p < 0.001 HS	p < 0.001 HS
	SD	0.010	0.014	0.005	0.004	0.016	0.016	0.003	0.005	0.003	p < 0.001 HS			
	Ratio p-value*		1.12	<0.05 S		2.13	<0.05 S		4.3	<0.05 S				
No immersion regime was followed														
Group III: Water (control)	Mean	0.124	0.126	0.002										
	SD	0.003	0.002	0.004										
	Ratio p-value*		1.0	p > 0.05 NS										
Differences between groups**	ANOVA F		74.1	p < 0.001 HS		958.4	p < 0.001 HS		1270.4	p < 0.001 HS				
	Group I-II		p < 0.001 HS			p < 0.001 HS			p < 0.001 HS					
	Group I-III		p < 0.001 HS			p < 0.001 HS			p < 0.001 HS					
	Group II-III		p < 0.01 S			p < 0.001 HS			p < 0.001 HS					

Intragroup comparison: *—Wilcoxon's signed test; intergroup comparison: **—One-way ANOVA, Mann-Whitney test; p < 0.001 highly significant (HS), p < 0.05, p < 0.01 significant (S) and p > 0.05 not significant (NS)

Table 4: Descriptive statistics on mean surface texture values of Vitremer™ following immersion for varying periods of time in cola drink (Coca-Cola®), fresh fruit juice (orange) and water (control)

Groups	Particulars	Low immersion			Medium immersion			High immersion			Comparison at different concentrations			
		Before	After	Difference	Before	After	Difference	Before	After	Difference	ANOVA F	Low vs medium	Low vs high	Medium vs high
Group I:	Mean	0.424	0.447	0.023	0.426	0.646	0.219	0.433	0.882	0.449	486.9	p < 0.001 HS	p < 0.001 HS	p < 0.001 HS
Cola drink	SD	0.002	0.026	0.026	0.002	0.019	0.018	0.020	0.011	0.021	p < 0.001 HS			
(Coca-Cola®) Ratio				1.05			1.51			2.06				
	P-value*			p > 0.05 NS			<0.05 S			<0.05 S				
Group II:	Mean	0.422	0.423	0.001	0.422	0.551	0.129	0.422	0.702	0.280	3356.0	p < 0.001 HS	p < 0.001 HS	p < 0.001 HS
Fresh fruit juice	SD	0.001	0.002	0.002	0.002	0.012	0.011	0.001	0.072	0.072	p < 0.001 HS	p < 0.001 HS	p < 0.001 HS	
(orange)	Ratio			1.0			1.3			1.6				
	p-value*			p > 0.05 NS			<0.05 S			<0.05 S				
No immersion regime was followed														
Group III:	Mean	0.124	0.126	0.002										
Water (control)	SD	0.003	0.002	0.004										
	Ratio			1.0										
	p-value*			p > 0.05 NS										
	ANOVA F			74.1			958.4			1270.4				
Differences between groups**	Group I-II			p < 0.001 HS			p < 0.001 HS			p < 0.001 HS				
	Group I-III			p < 0.001 HS			p < 0.001 HS			p < 0.001 HS				
	Group II-III			p < 0.01 S			p < 0.001 HS			p < 0.001 HS				

Intragroup comparison: *—Wilcoxon's signed test; Intergroup comparison: **—One-way ANOVA, Mann-Whitney test; p < 0.001 highly significant (HS); p < 0.05, p < 0.01 significant (S) and p > 0.05 not significant (NS)

In this study, class V cavities were prepared on the buccal and the lingual surfaces of extracted human premolars 1 mm above the CEJ as it has been shown that there will be minimal microleakage above the CEJ and newer adhesives seal dentin margins better and therefore, may have more effectively prevented leakage at the dentin margins.²⁴ Thermocycling was done to simulate the temperature dynamics in the oral environment²⁶ and then subjected for immersion regime.

Consumption pattern put forward by Maupome et al in 1998, which more closely resembles a real-time sipping pattern of soft drink, was followed.¹¹ Before and after each immersion in cola drink (Coca Cola®) and fresh fruit juice (orange), the specimens and pellets were copiously rinsed in 0.1 M PBS (pH 7.2).^{11,27} This was done to buffer the effect of cola drink and fresh fruit juice after the prescribed exposure time, to return the pH to a neutral level once the exposure was over and to avoid prolonged insult to the materials while they were stored in the deionized water.

Marginal seal is the most important factor for the success of a restoration. Marginal leakage was assessed Rhodamine B dye since it has a significantly deeper dye penetration activity.²⁸

The leakage pattern of Filtek™ Flow and Vitremer™ in the cola drink group increased as the number of immersion regimes increased. Similar studies reveal that the cola drinks have an inherent acidity due to the presence of both phosphoric acid and carbonic acid, which tends to increase enamel decalcification, erosion and microleakage around the restoration.^{9,11}

On intergroup comparison of Filtek™ Flow with the cola group, fresh fruit juice (orange) group and water (control) under the low, medium and high immersion regimes, it was evident that the microleakage was obvious in the cola group as compared to the fresh fruit juice and control groups. Studies reveal that cola beverages contain phosphoric acid as the main acid which has pH of 2.57^{22,29,30} as compared to the higher pH of fresh orange juice (pH 3.98)³⁴ and neutral pH of water.

There was no significant difference in the microleakage between the low, medium and high immersion regimes of Vitremer™ in the fresh fruit juice group. The reason could be due to that though orange juice is rich in citric acid and has a pH of 3.98,³¹ the critical pH drop needed to cause enamel erosion is below 4.²²

The surface roughness patterns of Filtek™ Flow and Vitremer™ in the cola drink group and the fresh fruit juice group increased as the number of immersion regimes increased. Greater number of immersions in the beverage resulted in a more accentuated impact on the resin composites.³² The increased surface roughness of the

Filtek™ Flow could be due to the presence of the resin matrix which softens with exposure to certain food constituents like citric acid, lactic acid, heptanes and 50% ethanol-water solution.³³ Also the filler content has been correlated with the depth of polymerization, color stability, hardness, compressive strength, and stiffness, less filler content more surface degradation.

The significant surface roughness of the Vitremer™ could be reasoned with the following explanation. Glass ionomer consists of glass particles in a hydrogel matrix. In acidic solutions, H⁺ ions of citric acid diffuse into the glass ionomer component and replace metal cations in the matrix. These free cations then diffuse outward and are released from the surface. As the metal cations in the matrix decreased, more ions would be extracted from the surrounding glass particles, causing them to dissolve. Consequently the material would present a rough surface with voids and protruded, undissolved glass particles. Prolonged exposure of the glass ionomer materials to low pH drinks would result in higher surface roughness.³⁴

Control group samples were not subjected to any immersion regime. The results concluded that there was no statistically significant roughness. This could be probably due to the neutral pH of the water compared to the low pH drinks.³⁵

CONCLUSION

- Both the restorative materials showed statistically significant microleakage and surface roughness respectively as the immersion regime increased.
- Sipping habit associated with commonly available low pH beverages, are detrimental to the longevity of restorations.

However, we recommend further studies combining both qualitative and quantitative evaluations which will indicate more precisely the effects of fruit beverages on the clinical integrity of the restorative materials in the oral environment.

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