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Surface Hardness Assessment of Tooth Substrates and Different Esthetic Restorative Materials After Immersion in Different Acidic Media

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Abstract

Objectives: The aim of the current study was to measure and evaluate the surface hardness of tooth substrates (enamel and dentin) and different tooth colored restorative materials (resin composites, GIC and their drivatives) after immersion for certain time in different acidic food and drinks.

Methods: Different acidic food and drinks used in this study include: Cola soft drink, yogurt, orange juice, sports drink, and some sore food like Tom-yum soup. Immersion of specimens in previously mentioned acidic food\drinks were for 15 seconds then immersed in artificial saliva for 10 cycles to simulate what happened in oral cavity. These procedures repeated daily for 14 days. Surface hardness for specimens were measured by Vickers hardness device before and after immersion. Data were collected, tabulated and analyzed using one-way ANOVA followed by a least significant different test.

Results: In comparison between tooth substrates (enamel & dentin), the surface hardness values of enamel were decreased than of dentin after immersion in cola soft drinks. Same results were observed after immersion in orange juice and sports drink but with less effect than cola soft drinks. Significant decrease in surface hardness values were detected for micro-filled composite and resin modified glass ionomer cement after immersion in cola soft drinks ($p>0.05$). On the other hand, there were no statistical significant effect on surface hardness values of all specimens after immersion in yogurt and Tom-yum soup.

Conclusion: Some public acidic food and drinks have an erosive harmful effect on surface hardness of tooth substrate (enamel and dentin) in addition to their bad effect on mechanical properties of some tooth colored restorative materials.

Keywords: Surface hardness, Tooth substrates, Tooth colored restoratives

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Introduction

Regarding Restorative dentistry, although there was shifting from the concept "Drill and fill" to the more conservative one "preventive and immune", most literatures still directed and focused on how to prevent tooth loss by prevent and control carious lesion. Another form of tooth loss is non-carious lesion e.g. erosion. Though erosion is another form of tooth surface destruction, it did not take the same concern. Different types of chemical process can lead to mineral loss of tooth substrate. The acidic dissolution from outside origin (i.e. not from bacterial plaque origin) was the most common cause of dental erosion(1,2). Presence of proper amount of saliva can neutralize or dilute the acidic effect on tooth substrates(2,3). One of the main sources of acids from outside origin is consumption of acidic beverages that initiate the dental erosive activity with subsequent mineral loss of tooth substrates(3,4). Fruit juices, sour, spicy food and carbonated soft drinks have a relation with progress of dental erosion(5-7). As media in modern societies give a big concern to the nature of healthy food and drinks for children, youth and adults, knowledge about the components and ingredients of the popular food-stuff and drinks and their relation with initiation and progression of dental erosion became an important issue in these modern societies(7,8). Carbonated cola (soft drinks) and power/energy drinks that have a widely consumption rate by youth of days and athletes considered the main sources of strong chemicals that are of outside origin to initiate and progress dental erosion. The acidity nature presented in some healthy food like citrus fruits or drinks like fruit juices, in addition to some kinds of yogurt may initiate and progress the erosive activity. Also certain restaurants provide their customers with sour dishes may have acidic nature incorporated in their content[9]. Frequent consumption of sour lemon grass soup and Thai hot soup a well-known 'Tom-yum' may lead to reduce enamel surface hardness. Patients may suffer from dentin hypersensitivity in progressive dental erosion that reach dentin. In some advanced cases, pulp exposure or even tooth cracks and fracture may be the last stage[7-12]. Dental erosion that resulted from increasing the acidity of oral conditions not only affects deciduous and permanent tooth substrates but also the performance of some esthetic restorations. Biodegradation of conventional GIC and its modified forms are severely affected by acidic nature of food stuff and beverages. Surface hardness and some physical properties of resin composite and its derivatives are also influenced by acidity and erosive activity[13-15]. Presence of normal salivary flow with proper amount play an important role in the resistance of erosive activity. The less salivary flow in patient mouth, the higher erosive activity and vice versa[4, 5]. Some studies concluded that surface hardness of some esthetic restorations could increase after immersion in saliva for long time. This may be due to effect of salivary secretion in neutralization of acidic activity[16]. The aim of the current study was to measure and evaluate the surface hardness of tooth substrates (enamel and dentin) and different tooth colored restorative materials (resin composites and GIC) after immersion for certain time in different acidic food and drinks.

Materials and methods

Teeth specimens: twenty five extracted caries free human premolars were used in this study. Teeth were extracted for orthodontic reasons. After extraction, each tooth was cleaned from any periodontal shreds by scaling with sharp scalars, and then polished with a rotary hair brush and a slurry mix of pumice and water. Teeth were examined under light microscope to avoid the use of teeth with morphological defects or cracks. Teeth were cut in bucco-lingual direction with a slow speed diamond saw (Isomet 1000, Buehler, Lake Bluff, USA) to produce fifty specimens. Enamel side is prepared using grit silicon carbide paper of different size (600, 1000, 1200), followed by polishing with alumina slurry (0.05 microns). For achieving a flat dentine surface, the other side was ground and polished using the same previous manner. All teeth specimens were kept in jars contained distilled water in an incubator at 37 Co until time of experiment.

Esthetic restorative materials: Five types of esthetic restorative materials were used in this study. Filteke Z250 (Universal composite), Filteke A110 (Microfilled composite), Ketak fill (Conventional glass ionomer), Photac fill (Resin-modified glass ionomer) and Dyract AP (Polyacid modified resin composite/ Compomer). A2 shade was selected for standardization of all restorations. Each restorative material produced fifty specimens to be used in the experiment. Restorative materials used in the study were listed in table [1].

Materials	Products	Manufacturer	Lot number
Universal composite	Filteke Z250 A2	3M ESPE, St. Paul,USA	1kw
Microfilled composite	Filteke A110 A2E	3M ESPE, St. Paul,USA	1BW
Conventional glass ionomer	Ketak fill A2	3M ESPE, St. Paul,USA	5101
Resin-modified glass ionomer	Photak fill A2	3M ESPE, St. Paul,USA	108241
Polyacid modified resin composite	Dyract AP A2	Dentsply Detrey, Wey-bridge, UK	0107000297

Table 1: Tooth-colored filling materials used in the study

For making a specimen of Composite resin (Universal and Microfilled), Resin-modified glass ionomer and Polyacid modified resin composite, an increment was introduced out of the syringe into the central hole of the split copper ring directly utilizing a gold plated composite instrument , until the hole was overfilled, then gross excess was removed with a plastic instrument. For composite material as example, a celluloid matrix was applied over the composite to produce a smooth surface followed by a transparent slide, over which two weights of 150 gm. Each was placed, one at each end to ensure standardized pressure during polymerization. A light curing unit was utilized to polymerize the composite resin by contacting the glass slide by the curing unit tip for 40 seconds as recommended by manufacturer. After light polymerization, the weights, the glass slide and the celluloid matrix were removed and any excess composite was removed out of the split copper mold with their attached composite discs. The specimens were stored in distilled water in an incubator to be tested for surface hardness. Universal composite and polyacid-modified composite were light cured for 40 s and microfilled composite for 20 s following manufacturer's instructions, using a dental curing unit (Profil Lux Hlogen light cure unit, Voco/Germany). Resin-modified glass ionomer specimens were light cured for 20 s, and conventional glass ionomer specimens were left in the mold for 6 min to harden. All specimens of teeth and esthetic restoratives undergone micro-hardness measurements before and after immersion in food stuff and drinks and comparison between the two values were analyzed. Measurements of micro-hardness were performed using a Vickers indentor device that has been attached to a micro-hardness tester. After recording the micro-hardness values for all teeth specimens and esthetic restoratives before any immersion in food or drinks, data was collected and kept until recording the post-immersion micro-hardness values to be compared later. After the first measurement of micro-hardness, all specimens were undergone immersion in different acidic popular food stuff and drinks listed in table[2].

Food/drink	Products	Manufacturer	Description
Cola soft drink	Coke	Coca-Cola \ Saudi Arabia	Carbonated water, 10% sugar, flavors
Orange juice	Almarai	Almarai Co. \ Saudi Arabia	100% tangerine juice
Sports drink	Sponser	T.C.Pharmaceutical Ltd., Bangkok, Thailand	Carbonated drink with minerals
Drinking yogurt	Almarai	Almarai Co. \ Saudi Arabia	53% yogurt, 16% mixed juice, 8% sugar
Tom-yum soup (Thai hot soup)	Kanton	Kanton restaurant \ Saudi Arabia	2 cubes in 1 L boiling water. Each cube contained 5% citric acid, 1.5% lime juice, salt, spices, paprika, palm oil
Artificial saliva	Artificial saliva Composition: 2.2 g/L gastric mucin, 0.381 g/L sodium chloride, 0.231 g/L calcium chloride, 0.738 g/L potassium phosphate, 1.114 g/L potassium chloride, 0.02% sodium azide, trace of sodium hydroxide to pH 7.0		

Table 2: Acidic food and drinks and the composition of artificial saliva used in the present study.

This was done manually by immersion teeth and different esthetic restorative materials for 15 seconds in different acidic mentioned food &drinks then immersed again in artificial saliva for 10 cycles to simulate what happened in oral cavity. This process done daily for 14 days. The pre and post-immersion measurements of surface hardness done by Vickers device were compared using paired t-test. The differences in hardness after immersion were compared using one-way ANOVA followed by a least significant different (LSD) test.

Results

Vicker hardness values of different teeth and restorative surfaces pre and post immersion in acidic food or drink are shown in table[3]. Results revealed that there was different types of response of tested substrates. First, Surfaces their hardness values showed minimal effect with no statistical significant difference before and after immersion in all acidic food\drink used in this study (p<0.05).example was universal composite (Filteke Z250), conventional glass ionomer (Ketak fill), and polyacid-modified resin composite (Dyract AP). Second, Surfaces their hardness values showed statistical significant difference after immersion in only Cola soft drink (p<0.05).example was dentine, microfilled composite (Filteke A110), and resin-modified glass ionomer (Photak fill). Third, Surfaces their hardness values showed statistical significant difference after immersion in Cola soft drink, orange juice, and sports drink (p<0.05).example was enamel surface.

Surface	Pre-immersion hardness values	Acidic food or drinks	Post-immersion hardness values	p-values
Enamele	271.9 (14.4)	Cola	172.1 (12.3)	0.000*
	265.4 (18.4)	Drinking yogurt	262.3 (16.7)	0.695
	266.1 (15.9)	Orange juice	249.8 (21.7)	0.030*
	265.9 (25.1)	Sports drink	238.2 (19.3)	0.004*
	260.3 (28.2)	Tom-yum soup	259.8 (27.9)	0.635
Dentin	46.3 (1.7)	Cola	43.0 (2.0)	0.000*
	51.0 (5.1)	Drinking yogurt	51.0 (5.3)	0.937
	50.2 (2.0)	Orange juice	49.4 (2.3)	0.281
	52.7 (4.4)	Sports drink	52.3 (5.0)	0.229
	51.3 (2.7)	Tom-yum soup	51.1 (2.7)	0.053

Table 3: Mean (SD) Vicker hardness values of different teeth and restorative surfaces pre and post immersion in acidic food or drink

Universal composite Filteke Z250 A2	76.1 (1.2)	Cola	74.7 (2.7)	0.112
	72.6 (5.3)	Drinking yogurt	72.1 (4.4)	0.204
	73.9 (2.7)	Orange juice	73.1 (3.7)	0.149
	76.2 (2.5)	Sports drink	75.5 (2.3)	0.227
	75.3 (2.7)	Tom-yum soup	74.8 (2.0)	0.130
Micro-filled Composite Filteke A110 A2E	35.4 (2.7)	Cola	33.2 (2.8)	0.001*
	36.1 (1.7)	Drinking yogurt	35.9 (1.7)	0.536
	36.3 (2.1)	Orange juice	35.6 (2.4)	0.061
	36.0 (1.4)	Sports drink	35.8 (1.3)	0.068
	33.6 (1.4)	Tom-yum soup	33.5 (1.3)	0.172
Conventional glass Ionomer Ketak fill A2	59.1 (1.6)	Cola	59.2 (1.3)	0.673
	59.8 (1.8)	Drinking yogurt	60.2 (1.5)	0.393
	59.1 (1.6)	Orange juice	58.4 (1.5)	0.116
	58.6 (1.7)	Sports drink	58.3 (1.6)	0.090
	59.2 (1.6)	Tom-yum soup	59.0 (1.7)	0.557
Resin-modified glass	39.2 (2.4)	Cola	37.2 (2.3)	0.000*
	38.4 (1.7)	Drinking yogurt	38.3 (1.8)	0.508
	39.2 (1.6)	Orange juice	39.3 (1.4)	0.825
Ionomer Photak fill A2	38.7 (1.5)	Sports drink	38.4 (1.6)	0.089
	38.6 (1.8)	Tom-yum soup	38.4 (1.6)	0.263
Polyacid-modified resin composite Dyract AP A2	45.3 (2.6)	Cola	44.0 (2.5)	0.124
	40.4 (1.7)	Drinking yogurt	39.8 (1.2)	0.279
	42.1 (1.4)	Orange juice	41.9 (1.7)	0.445
	42.4 (1.3)	Sports drink	42.2 (1.5)	0.083
	42.1 (1.8)	Tom-yum soup	42.0 (1.8)	0.454

Table 3: Mean (SD) Vicker hardness values of different teeth and restorative surfaces pre and post immersion in acidic food or drink

Results revealed that the erosive effect of some types of acidic popular foods or drinks are more prominent than others. Carbonated canned Cola had more dissolution activity on enamel and dentin, and more reduction in hardness and mechanical properties of microfilled composite, and resin-modified glass ionomer (($p<0.05$). The drinking yogurt and Tom-yum soup had minimal erosive effect on tooth substrates (enamel and dentin) than sports and power drinks. Changes of pre and post immersion Vicker hardness values regarding all specimens used in this study before and after immersion in Orange juice, drinking yogurt and Tom-yum soup were minimal with no statistical significant difference ($p>0.05$). Mean hardness changes (DVHN) of each substrate in acidic food and drinks was showed in table[4].

Acidic food\ drink	Enamel	Dentin	Universal composite	Micro-filled composite	Conventional glass Ionomer	Resin-modified glass Ionomer	Polyacid-modified resin composite
Cola	99.77	3.27	1.37a	2.16	0.11	2.02	1.27
Sports drink	27.71b	0.47b	0.68	0.18	0.23	0.36	0.29
Orange juice	16.35b,c	0.81b	0.84a	0.71b	0.64a	-0.05b	0.23a
Drinking yogurt	3.14c	0.02b	0.51a	0.22b	-0.36a	0.14b	0.64a
Tom-yum soup	0.53c	0.24b	0.45a	0.17b	0.17a	0.17b	0.15a

Table 4: Mean difference in surface hardness (D VHN) of substrates before and after immersion in acidic food or drink.

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The pH and neutralizable acidity for the food and drinks are shown in Table (5). Orange juice and drinking yogurt were more difficult to neutralize than Cola, sports drink, and Tom-yum soup. Cola had the lowest pH and Tom-yum soup had the highest pH value.

Type of acidic food or drink	Value of pH	Neutralisable acidity of food and drink (ml of 0.1 M NaOH)
Cola soft drink	2.74 (0.01)	7.86 (0.06)
Orange juice	3.75 (0.01)	15.05 (0.20)
Sports drink	3.78 (0.01)	3.96 (0.13)
Drinking yogurt	3.83 (0.01)	12.46 (0.18)
Tom-yum soup	4.20 (0.00)	4.49 (0.22)

Table 5: Mean (SD) pH (n=7) and neutralisable acidity (n=3) of food and drinks.

Discussion

Salivary secretion has different benefits in the oral cavity of healthy individuals. Re- mineralization of defective demineralized enamel surface, buffering capacity that compensate deficiency of minerals (calcium and phosphorus) and presence of acquired pellicle are examples for different benefits of saliva. Regarding this study, there was focusing to simulate the washing effect of saliva by cyclic immersion of specimens in artificial saliva after immersion in acidic food or drink. This was designed in a trial to achieve a controlled condition, even though the period of consuming these beverages in nature can be different than in vitro. Regarding values reported Pre-immersion of specimens in acidic foods or drinks, the vicker hardness values reported for teeth substrates (enamel and dentin) and for other esthetic restorative materials were in the same range as values reported by other investigators[16,18] but with some disagreement of the values reported by Maupome et al.(11). As this study was in vitro, hardness measurements were performed on both buccal and lingual enamel and the results revealed there was no difference in erosive effect on both buccal and lingual enamel surfaces. This was different in studies undergone clinical conditions. Due to presence of stensons duct of parotid gland at the buccal vestibules, this lead to more washing effect of saliva at buccal enamel surface and less erosive effect at this side[21,22]. The results of the present study revealed that a statistically significant difference in hardness values were reported regarding enamel surface before and after immersion in Cola soft drink followed by sports (energy) drinks and orange juice. These results are in agreement with results shown in studies of Jarvinen et.al. and Meurman et.al[4,9]. For standardization in the present study, all specimens were tested for hardness at room temperature. In real conditions, some drinks like Cola soft drinks consumed in cold state while soup consumed in hot state. Some studies stated that temperature plays a rule in the extent of erosion[23]. Meurman et al. and Lussi et al. in their studies concluded that the lower pH beverages, the greater erosive activity[9-11]. This was in agreement with the results of the present study as Cola soft drink which had the lowest pH among other foods or drinks (pH=2.74) caused statistical significant difference in hardness values of enamel, dentin and some esthetic restorative materials seen in (table 4). Results in (table 5) revealed that drinking yogurt, orange juice and sports drink had pH values between 3.75 and 3.83. Although similarity in pH values among the three drinks, enamel surface was not affected by immersion in drinking yogurt but by immersion in orange juice and sports drink. Jarvinen et al. end Larsen et al. (10,24) clarified in their studies that there were another factors could play rules in enamel surface erosion rather than pH. Erosive activity can be modified by buffering capacity, releasing of fluoride, titratable acidity and mineral composition of beverages. The drinking yogurt contained a high concentration of calcium and phosphate that compensate demineralized enamel hydroxyl apatite[8,10, 25, 26]. The extent of erosion was affected by temperature of food\drink, frequency, duration, and manner of exposure to acidic food and drinks as explained in other studies[11,23]. Results of the present study revealed that Tom-yum soup had no erosive effect on enamel surface. This may be due to short term exposure to the soup because immersion of specimens in acidic food\drinks were for 15 seconds and this was rather short for a meal. Different compositions between enamel and dentin played an important role in susceptibility to acid attack and erosive effectiveness. By volume, enamel composed of nearly 90% minerals and inorganic components that are highly susceptible to dissolve in an acidic food or drinks. On the other hand, dentin composed of nearly 50% organic materials, water and collagen fibrils that are less affected by erosive activity[11, 23]. This is in agreement with the results of the present study that revealed that sports drink and orange juice significantly reduce the values of enamel hardness, but not dentine.

Regarding surface hardness of direct esthetic restorative materials, results of the present study showed different responses of materials when immersed in acidic food or drink. While there were no significant changes were reported in hardness values of universal composite (Filteke Z250), polyacid-modified resin composite (Dyract AP), and conventional glass ionomer (Ketak fill), the other two materials; microfilled composite (Filteke A110) and resin-modified glass ionomer (Photak fill) were significantly reduced after immersion in Cola soft drink. This is in agreement with another studies[15, 25] whom explained that the higher resin content (bis- GMA based polymers) of micro-filled composite (Filteke A110) may be the reason for greater hardness reduction in comparison to universal resin composite (Filteke Z250). It was noticeable that mean micro-hardness difference of the conventional glass ionomer did not affected after immersion in drinking yogurt. This is in agreement with the study of Okada et al. (16) whom explained that the diffusion of calcium and phosphate ions to the GIC surface after prolonged immersion in saliva and other drinks rich with calcium and phosphate resulting in an increase GIC surface hardness. Further studies and new researches related to this topic are strongly needed to focus on reasons that initiate and propagate erosive activity of popular drinks and foods.

Conclusions

Based on the results obtained in this in vitro study, Cola soft drink significantly affected and reduced surface hardness of tooth substrates (enamel and dentine) and some esthetic restorative materials (micr-ofilled composite (Filteke A110) and resin modified glass ionomer (Dyract AP). Enamel surface was the most affected one and also softened by orange juice and a sports drink. Surface hardness of all tested specimens did not reduced after immersion in drinking yogurt or Tom-yum soup (Thai hot soup).

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