The Assessment of Erosive Potential of Some Acid Beverages on Indirect - Restorative Materials

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The aim of the study was to assess the pH of some acid beverages and their erosive potential on the indirect restoration materials by evaluation the surface microhardness. The study group included 20 samples of three ceramics mass (IPS In Line, Hera Ceram, Reflex Dimension) and three composite resins (Ceramage, SR Adoro, Luna-Wing) immersed in three acid beverages (Red Bul, wine, Coca Cola), for 5 min, 3 times daily, 14 days. In the control group, the samples were maintained in artificial saliva. After the end of erosive cycles and before the determination of surface microhardness, all the samples were maintained in artificial saliva for 18 h. The surface microhardness was determined using microhardness tester CV-400DM (Tecnimetal S.A. Spania), and pH was measured using a pH-meter Checker (HANNA Instrument – Romania). The immersion of indirect restorative materials (composite resins and ceramics) in acid beverages determines significant decreased of their surface hardness. The highest hardness changes were determined by Coca-Cola, followed by wine and Red Bull.

Keywords: surface hardness, composite resins, ceramic, erosion, acid beverages

The loss of dental tissues represents an issue of high interest in the actual dental practice. The non carious dental lesions are associated with irreversible loss of tissues by chemical, mechanical and corrosion processes.

Nowadays the dental erosion is frequently observed due to the change of nutritional habits. In this context, the dental erosions constitute a challenge regarding the diagnostic, the identification of etiological factors, as well as the use of the proper treatment and preventive measures.

Lussi A. et al. [1, 2] considered that the interaction between chemical, biological and behavioural factors plays a major role in the apparition of dental erosions. Some factors are implicated in corrosion onset: chemical aggression due to the titratable acidity of the foods and beverages, mineral content, chelation properties of calcium ions and clearance rate, microbiological activity of the acquired biofilm and dental surface structure, behavioural situations related to the nutritional habits, physical effort related to dehydration and the decrease of saliva secretion, excessive oral hygiene, unhealthy lifestyle (alcoholism, drugs consume), etiological system related to the supply of acids from foods and beverages with pH below 5-5,7 (fruits juices, acid beverages, wines) [3-7].

In most cases there is a multifactorial etiology of erosion, including internal and external factors [8-11]. The data from the literature demonstrated the negative effect of these factors on the materials used in carious and non carious lesions [3, 14-16].

Because of the steady increase of dental erosion prevalence, the preventive and therapeutical management of dental erosions becomes extremely important to maintain dental health on long term [1, 12-15].

The modern therapeutic strategies highlight the importance of the preventive and minimally invasive treatments [16]. The most recommended materials are the composite resins associated with adhesive systems [17-22]. Direct restorations are preferred to indirect restorations techniques. However, indirect restoration techniques are requested in particular situations, as numerous teeth affected by extensive dental tissues loss. The indirect restoration techniques include the use of ceramic mass and composite resins for veneers, inlays, onlays or crowns [23]. All these indirect restorations are estheticaly excellent, but impose high costs for the patients.

The chemical stability is a major factor related to the long term resistance of a restorative material in the oral environment [24]. Under the action of various factors, the indirect restorative materials can be affected by processes as dissolution, erosion or corrosion that reduce the long-term durability or even lead to the release of toxic compounds in the oral environment.

It is requested an accurate assessment of the restoration material properties, considering that a high solubility and low resistance to erosion will limit the longevity and therapeutic success. The *p*H variations in the oral cavity during a day can vary between 4.0 and 8.5 [24-30]. The consumption of wine, acid juices, acid fruits, acid pills, toothpaste, oral hygiene products with acid *p*H or specific professional environment can extend these limits from pH 2 to *p*H 12.

Numerous methods were used to assess the loss of hard dental tissue and the areas of demineralised enamel [31] as well as the action on direct or indirect restoration materials [32-35]. The microhardness tests and nanoindentations tests are useful to determine the changes of hard dental tissues submitted to erosive attacks [36]. The microhardness measurements allow the determination of dissolution degree in early stages in relation to hardness decrease. They can also allow the differentiation of erosive potential of different substances, even after short exposures. The long- term exposures to various acid agents are associated with similar

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demineralization depths of dental layers. The big advantage of the microhardness tests is related to low costs and the possibility to combine them with other testing methods. Despite the studies that analyse the behavior of these materials to intraoral acid attacks, the results are controversial and inconclusive [27, 39-42].

The aim of this study was to assess the *p*H of some acid beverages and their erosive potential on the indirect restoration materials by evaluation the surface microhardness.

Experimental part

For this study three commercial acid beverages were selected: Cotnari Francusa wine (S.C. Compania S.A., Iasi Romania), Red Bull (S.C. Red Bull Romania S.R.L.), Coca-Cola (Coca- Cola HBC Romania SRL). The assessment of beverages *p*H was performed by pH-meter Checker (HANNA Instruments Romania), performing an immersion of his peak in 30 mL liquid, the results being indicated by a display.

The restoration materials were as follows: three ceramic mass (IPS In Line, Hera Ceram, Reflex Dimension) and three composite resins (Ceramage, SR Adoro, Luna-Wing). Details about the category and composition are indicated in table 1.

From each material were manufactured, using a cast, 20 cylindrical samples with 10 mm diameter and 2mm depth. The indications of the producers were followed regarding the thermal regime of handling. All the materials were submitted to the same polishing procedures, using silicon carbide paper (3M ESPE, St.Paul, MN, USA) fixed in the device Phoenix 4000 (Buehler GmbH, Dusseldorf, Germany) under water cooling. All the samples were cleaned using ultrasound and distilled water for 10 min and dried under air spray. All the samples were analysed with an optical stereo microscope SMZ 1500 m (Nikon Instech, Kanagawa, Japan) under 40X magnification to highlight defects like pits and fissures. These defects were not observed to any of the analysed samples. The samples were randomly divided into three study groups and a control group. In the three study groups the samples were immersed in wine (study group I), Red Bull (study group II), Coca-Cola (study group III) accordingly to the next protocol: immersion for 5 min , 3 times daily, for 14 days. During the immersion times, the same quantity of beverage (30mL) was used for each sample. Between the erosive cycles, the samples were immersed in artificial saliva AFNOR (30 mL/sample). In the control group, the samples were maintained permanently in artificial saliva. The composition of the artificial saliva is indicated by table 2.

Material	Material type	Material composition	Trade name	Manufacturier
ceramic	Leucite-containing veneering ceramic	SiO_2:40-65%, $Al_2O_{3,B2O3}$, BaO, CaO, CeO_2, K_2O, MgO, P_2O_5, TiO_2, ZrO_2	IPS In Line	Ivoclar Vivadent, Schaan, Liechtenstein
	Microfineleucite-containing veneering ceramic	ZrO_2+ H_2O + Y_2O_3 > 99 % Stabilised leucite structure (SLS) microfine leucite crystals	Hera Ceram	Heraeus-Kulzer GmbH, Germany
	Nanoleucite-containing veneering ceramic	Aluminosilicate glass-based systems SiO_2: 40-65% Fillers: nano-leucite	Reflex Dimension	Wieland Dental Tehnik GmbH & Co, Pforzheim , Germany
compozite	Compozit micro ceramic	Zirconium silicate micro ceramic a PFS (Progressive Fine Structure) filling of more than 73% organic polymer matrix	CERAMAGE	Shofu Dental Corp. Kyoto , Japan .
	Microfilled, light-/heat-curing veneering composite	Prepolymerbased on nanofillers and the new UDMA Urethane dimethacrylate (UDMA) (17–19 wt.%); copolymer and silicon dioxide (82–83 wt.%), stabilizers, catalysts and pigments (<1wt.%). The total content of inorganic fillers is 64–65 wt.%/46–47 vol.%. Particle size 10-100 nm	SR Adoro	Ivoclar Vivadent,
	Nanocomposite	Indirect nanocomposite resin, one of the highest-density filler products using a mix of different-sized inorganic fillers metacrylate monomer, organic fillers, inorganic fillers, pigments, silane coupling agent	Luna-Wing	Yamamoto Precious Metal Co, Ltd Tokyo.

Table 1
THE TESTED MATERIALS

Table 2
ARTIFICIAL SALIVA COMPOSITION

SOLUTION	COMPOSITION (g/L)		pH
AFNOR	NaCl;	0.700	6.7-8
	KCl;	1.200	
	Na_2HPO_4	0.26	
	H_2O	1.500	
	$NaHCO_3$	0.330	
	KSCN;	1.330	
	Uree		

Table 3
*p*H VALUES FOR ACID BEVERAGES

Drink category	Commercial brand	pH
White wine	Cotnari Francuşa	2.20
Sport drink	Red Bull	3.35
Acid beverage	Coca Cola	2.44

Table 4
MICROHARDNESS VALUES OF THE TESTED MATERIALS AFTER IMMERSION IN ACID BEVERAGES

Acid beverages	Composite resins			Ceramic mass		
	Ceramage	Adoro	Luna	Reflex	Hera	Inline
saliva	86.6	82.4	93.2	759.2	561.4	400.6
saliva	85	80.1	94.8	782.3	552.5	389
Saliva	88.3	83.6	91.9	776.7	547.5	404.8
Saliva	87.2	83.6	93.4	780.2	559.3	401.7
saliva	87.6	82.8	92.9	779.2	561.2	402.8
RedBull	85.7	58.3	92.8	583.9	516.8	350
RedBull	84.6	63.9	93	616.5	533	357.6
RedBull	83.1	60.9	92.5	550.6	528.6	371.9
RedBull	84	62.2	92.2	612.2	531.2	361
RedBull	85.2	59.8	92.8	591.4	527.3	358.2
Wine	84	77.6	95.1	412.7	351.1	276.8
Wine	85.8	81.6	93.7	394.7	374.6	284.8
Wine	85.2	79.9	88.8	396	341.2	299.3
Wine	84.9	80.2	94.7	412.6	360.8	296.2
Wine	85.4	79.6	93.4	398.4	371.2	297
Coca Cola	61.2	55.8	96.3	300.5	262.3	228.4
Coca Cola	60.4	56.9	85.4	307.1	254.1	232.9
Coca Cola	62.3	54.5	92.6	293.8	273.1	233.8
Coca Cola	62.2	56.4	94.8	306.2	271.1	232.2
Coca Cola	61.8	55.3	88.4	299.4	269.5	233

After the end of the erosive cycles and before to determine the samples microhardness, all the samples were maintained in artificial saliva for 18 h. The samples surface microhardness was measured using microhardness tester CV-400DM (Tecnimetal S.A. Spania). The microhardness tester contains a microscope and a load control system (10gf-400gf). In our study, we used a 50gf load. The device CV-400DM has many advantages: easy *measure* monitor system, high-quality digital microscope, fully automated load control, easy to use operating system, two optical paths, built-in high-speed thermal printer, dual indenter (Vickers/Knoop), 2 kg optional load. For each sample, it was recorded the mean value Vickers hardness number (VHN) as a final result of 12 measurements.

Results and discussions

The *p*H values of the tested beverages are indicated by table 3. The lowest *p*H value was recorded for wine (*p*H 2.20), followed by *p*H 2.44 (Coca-Cola) and *p*H 3.30 (Red Bull).

VHN values for the tested materials after immersion in acid beverages are indicated by table 4.

Following the analysis of the microhardness results, a decrease of the surface microhardness was recorded after 14 days of submission to the acid cycles, comparing with the control group (figs. 1, 2 and 3). The highest decrease of microhardness (from 82.03 VHN to 55.73 VHN) was recorded for the composite resin Adoro. For Ceramage, the decrease was from 86.63 VHN to 61.43 VHN. The lowest decrease (from 93.30 to 91.43) was recorded for the composite resin Luna. All these decreases were recorded for the immersion in Coca-Cola.

Regarding the microhardness mean values for ceramic mass, the highest decrease was recorded from 772.73 to 300.47 for Reflex, followed by a decrease from 553.80 to 263.17 for Hera and from 398.13 to 231.70 for Inline. All these decreases were recorded for the immersion in Coca-Cola.

The highest decrease of microhardness for all the tested materials was recorded for the immersion Coca-Cola, followed by the immersions in wine and Red Bul.

The microhardness values were compared using statistic test Mann-Whitney ($p < 0.05$). The differences were statistically significant when the microhardness

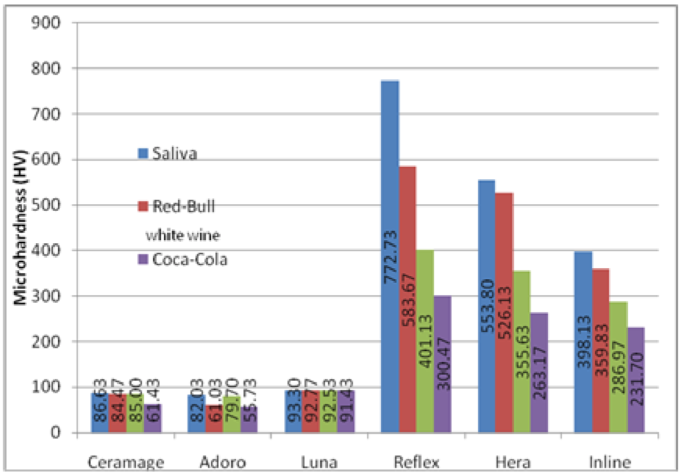

Fig. 1. Comparative variation of microhardness values for all study groups

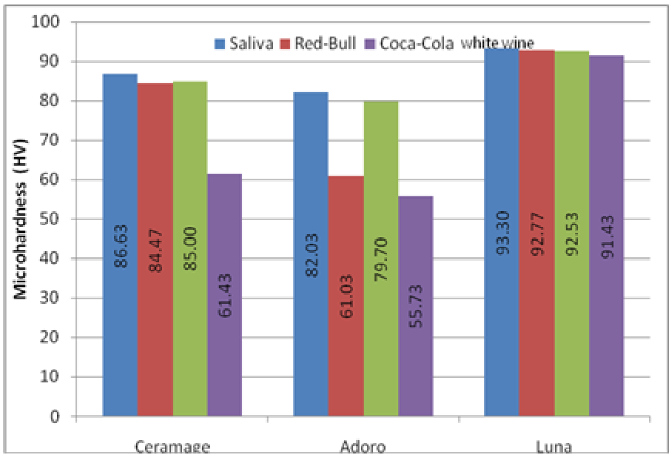

Fig. 2. Comparative variation of microhardness values for composite materials

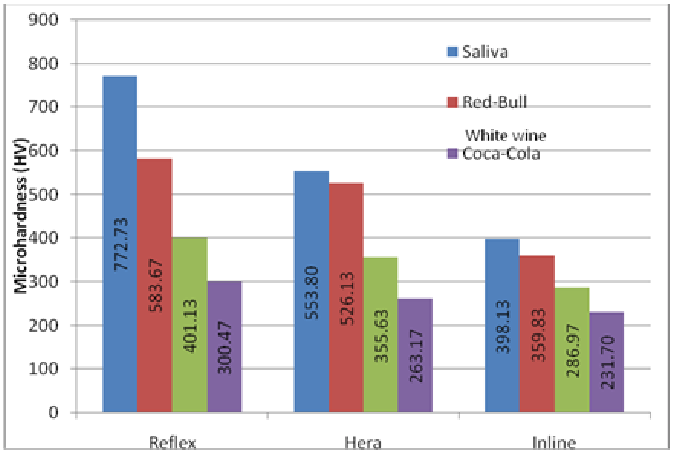

Fig. 3. Comparative variation of microhardness values for ceramic mass

values of the composite resins Ceramage and Adoro were compared after the immersion in acid beverages with the control group. The differences were statistically significant when the microhardness values of each composite resin were compared for each tested acid beverages (table 5). The only case without a significant statistical difference was recorded for the composite resin Ceramage after the immersion in wine and Red Bull (table 5). For the composite resin Luna the immersion in different acid beverages was not associated with significant changes of microhardness after the comparison with the control group. Also for the composite resin Luna it was not recorded a significant statistical difference between the microhardness values after the immersion in various tested acid beverages.

Significant statistical differences were recorded when the microhardness values of ceramic mass after the immersion in acid beverages were compared with the control group. Also, significant statistical differences were recorded between the microhardness values obtained after the immersion in different tested acid beverages (table 6.)

To understand the mechanisms implied in the acid attack on ceramics, we must know the composition of the ceramic mass. The ceramic is an inorganic material that contains metallic (Al, Ca, Mg, K) and non-metallic (Si, O, B and F) elements that form oxides, nitric oxides, or silicates, as well as complex mixtures of these minerals [43]. The modern ceramics has two different phases: an amorphous matrix, formed by a network of silicates, containing the crystalline phase that determines the material properties (mechanical, physical, chemical, optical). The ratio between these two phases determines the resistance of the material. A higher percent of amorphous phase gives a higher resistance and better translucent aspect.

Related to composition, there is two categories of ceramic mass: vitreous ceramics (high content of silicate), vitreous ceramics with leucite crystals, crystalline ceramics (Al) with glass matrix, polycrystalline ceramics

Table 5
RESULTS OF MANN-WHITNEY TEST. MICROHARDNESS COMPARISON OF THE TESTED COMPOSITE RESINS

		Saliva	Red bull	White wine	Coca Cola
Ceramage	saliva	-	0.028	0.047	0.009
	Red bull	0.028	-	0.344	0.008
	White wine	0.047	0.344	-	0.009
	Coca Cola	0.009	0.008	0.009	-
Adoro	saliva	-	0.009	0.028	0.009
	Red bull	0.009	-	0.009	0.009
	White wine	0.028	0.009	-	0.009
	Coca Cola	0.009	0.009	0.009	-
Luna	saliva	-	0.173	0.402	0.675
	Red bull	0.173	-	0.116	0.917
	White wine	0.402	0.116	-	0.602
	Coca Cola	0.675	0.917	0.602	-

Table 6
RESULTS OF MANN-WHITNEY TEST. MICROHARDNESS COMPARISON OF THE TESTED CERAMIC MASS

		Saliva	Red bull	White wine	Coca Cola
Reflex	saliva	-	0.009	0.009	0.009
	Red bull	0.009	-	0.009	0.009
	White wine	0.009	0.009	-	0.009
	Coca Cola	0.009	0.009	0.009	-
Hera	saliva	-	0.009	0.009	0.009
	Red bull	0.009	-	0.009	0.009
	White wine	0.009	0.009	-	0.009
	Coca Cola	0.009	0.009	0.009	-
In Line	saliva	-	0.009	0.009	0.009
	Red bull	0.009	-	0.009	0.009
	White win	0.009	0.009	-	0.009
	Coca Cola	0.009	0.009	0.009	-

(Al, zirconia) [44, 45]. The various types of dental ceramics have different microstructure properties: the Al ceramics contains a high percent (40-50%) of aluminium oxide, the feldspathic ceramics contains 19% leucite crystals ($K_2O \cdot Al_2O_3 \cdot 4SiO_2$), the vitreous leucite ceramics contains 40-50% leucite crystals [46, 47].

The immersion in Coca-Cola induced the highest decreases of microhardness, due to the presence of acids with high erosive potential (carbonic acid, citric acid, phosphoric acid). The immersion of samples in wine determined an important decrease of the microhardness for all tested samples. The immersion in wine was also associated with a significant decrease of the microhardness for the tested samples. The wines contain organic acids (tartaric acid, malic acid, lactic acid, citric acid) [48, 49]. The champagne contains also carbonic acid [50]. This complex of acids can present an erosive-corrosive potential both on the hard dental tissues and the restoration materials.

The composite resins suffer a softening of the surface layer under the acids action, due to the changes of the organic component [25]. Wongkhantee S. et al. observed that organic acids induce the dissolution of BIS-GMA [51].

Following our analysis of the indirect composite resins immersed in acid beverages, we observed a significant decrease of microhardness for the microfill composite resins (Ceramage, Adoro) and a less significant decrease of microhardness for the nanofiller composite resin (Luna). For the nanofiller composite resins, with very low diameter particles, the acid attack produces a smoother and more homogenous surface. After the immersion in acid beverages, the surface presents some smooth areas of exposed organic matrix, due to the dissolution of nanoparticles, while the microfill composite resins present more unregulated matrix areas.

Regarding the mechanism of the aggressive action on ceramic mass, this is due to the selective release of alkaline ions and the dissolution of the ceramics silicate network. All these processes are controlled by the diffusion of the hydrogen ions from aqueous solution in ceramics and by the release of alkaline ions from the ceramic surface in the aqueous solution to maintain the *electrical neutrality* [27].

Our study proves, in accordance with the literature data [37, 38, 48-51], that the action of the three acid beverages influences both the microhardness of the composite resins and the dental ceramics. Because this study was performed in vitro, for more accurate results, future research is requested to simulate the intraoral conditions (temperature variations, intraoral *p*H changes, acquired pellicle).

For an optimal and effective therapeutical decision of the erosive lesions, the dentists must attend to the features of the factors implied in the development of these lesions, especially when is associated a nutritional disorder.

Conclusions

The exposure of indirect restorative materials (composite resins and ceramics) to the tested acid beverages determines significant changes of their hardness. The highest changes were determined by Coca-Cola, followed by wine and Red Bull. The micro ceramic composite presented the lowest decrease of surface hardness after the immersion in acid beverages.

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