Study Regarding the Effect of Acid Beverages and Oral Rinsing Solutions on Dental Hard Tissues

SIMONA STOLERIU[1], GIANINA IOVAN[1], ANDREI GEORGESCU[1], ANDREI VICTOR SANDU[2], MIHAELA ROŞCA[1], SORIN ANDRIAN[1]*

[1] „Gr.T.Popa" University of Medicine and Pharmacy, Faculty of Dental Medicine, 16 Universitatii Str., 700115, Iaşi, Romania

[2] „Gh.Asachi" Technical University, Materials Science and Engineering Faculty, 53A D. Mangeron Blvd., 700050, Iaşi, Romania

The aims of the study were: (i) to evaluate the pH and titrable acidity of three acid beverages (Nestea lemon, Coca-Cola and red wine) and of two oral rinsing solutions (Listerine and Corsodyl); (ii) to determinate the calcium and phosphate ions concentration in enamel and dentine before and after the solution action; (iii) to evaluate the corrosive effect of solutions on dental hard tissues. The pH values and the titrable acidity of solutions were established using an electronic pH-metre. The teeth sections were SEM analized to evaluate the morphological changes after acid solutions action. The calcium and phosphate ions concentrations in enamel and dentine were evaluated using EDX spectra. Coca-Cola had the highest level of titrable acidity (0.580 mL/mL) and the lowest pH value (2.85), followed by red wine: 0.330 mL/mL,pH = 3.9, Nestea lemon: 0.300 mL/mL, pH = 3.8, Listerine: 0.110 mL/mL, pH = 4.35 and Corsodyl: 0.040 mL/mL, pH = 5,6. Significant decrease of calcium and phosphate ions concentrations were obtained for samples placed in solutions when compared to control group (paired samples t test). SEM images clearly shown the corrosive effect of Coca-Cola, red wine, Nestea and Listerine, with enamel surface irregularities, markedly open of the dentine tubules and minor surface changes for Corsodyl. This study provides that all these common acid beverages and rinsing solution soften and dissolve dental hard tissues.

Key words: *corrosive effect, dentine, enamel, acidic beverages, oral rinsing solutions*

The continuing challenge of physical appearance and the continued pressure exercised by marketing different products led to an increase in consumption of acid, light or energy diet drinks or food. Although it is believed that they have not adverse effects on dental tissues, however, chronic consumption is instrumental in the development of erosions or carious lesions [1]. Saliva acts as an acid-neutralization solution [2, 3], the oral pH dropping after consuming acid drinks below five within two or three minutes after intake [3]. The critical pH level, the starting point of hydroxyapatite dissolution, is considered to be in the range of 5.2-5.5 and, because teeth are considered to be composed of a calcium-ion-poor carbonate-apatite, they are very vulnerable to demineralization in acid medium [4].

Repeated exposure to acidic beverages reduces intraoral *p*H below the critical *p*H level, when the chemical dissolution of the carbonate-apatite in enamel occurs. If *p*H remains below 5.5, it enables acid action to lead to the decalcification of hard dental tissues. In case of an corrosive attack caused by acidic beverages, some extremely important factors, besides *p*H and the salivary buffering capacity, are the calcium, phosphorus and (to a lesser degree) fluoride ions [4]. Chronic consumption, the way of intake, the duration of consumption, the type and quantity of the drink influence their mode of action and the development of corrosive or carious lesions [1].

More often producers keep the composition of industrial drinks secret and very few data related to their acidity are indicated on the package.

There are many methods to assess the effects of acidic beverages upon dental tissues, including determining the hardness of hard dental tissues, surface profilometry, iodine permeability test, chemical analysis of dissolved minerals, microradiography, scanning electron microscopy, atomic force microscopy, element analysis of solid samples, ultrasonic measurements [5].

The aims of the study were: determining the *p*H and the titratable acidity of three acidic beverages and two antimicrobial mouthwashes; measuring the calcium and phosphorus ions concentration in enamel and dentine before and after the prolonged action of the five solutions; SEM-EDX evaluation of the five solutions corrosive effect on dental hard tissues.

Experimental part

Determining pH and titratable acidity

The *p*H and the titratable acidity were determined automatically using an Electronic pH-meter Device (HANNA *p*H 210). Titratable acidity was assessed using a 0.1 M NaOH solution, necessary in order to increase the pH level of the test solution to 7. 60 mL of each solution were used, taken directly from each container and placed in polystyrene test tubes. All determinations were made at ambient temperature (23°C). Each measurement was repeated ten times, adopting the mean value recorded. The device was calibrated after each determination.

Determining calcium and phosphorus ions concentration in hard dental tissues

In this study were used 18 molars that had been extracted for orthodontic or periodontal reasons and that did not present carious, non-cariogenic or dystrophic lesions. The teeth were kept in distilled water, at a temperature of 4°C, until the study began. The teeth were sectioned in the mesiodistal direction using active edge Diamond Abrasive Discs (Gebr. Brasseler GmbH & Co, Germany), continuously cooled by water in order to avoid overheating and then they were randomly divided into six groups. Six tooth halves that were kept in distilled water constituted the control group. Each of the other five groups included six tooth halves that were introduced in three acidic beverages: Nestea Lemon, Coca Cola and wine (Merlot, Recaş, Romania) and in other two oral antiseptic

* email: sorinandrian@yahoo.com

	Coca Cola	Nestea lemon	Red Wine	Listerine	Corsodyl
Titratable acidity(mL/mL)	0,580	0,330	0,300	0,110	0,040

Table 1
TITRATABLE ACIDITY OF TEST SOLUTIONS

Tested Systems	Mean values(%wt)			
	Calcium		Phosphorus	
	Enamel	Dentine	Enamel	Dentine
Distilled water	46.7	34.5	28.7	21.8
Nestea	36.9	1.8	15.4	0.3
Coca Cola	22.0	1.5	9.0	0.2
Corsodyl	44.6	28.3	23.2	14.8
Listerine	45.0	8.1	20.0	3.3
Red Wine	29.7	1.4	5.2	0.7

Table 2
MEAN VALUES OF CALCIUM AND PHOSPHORUS CONCENTRATIONS IN ENAMEL AND DENTINE

solutions: Listerine and Corsodyl. The samples were kept in the mouthwashes for 14 min (Corsodyl and Listerine) and in the acidic beverages Nestea Lemon, wine and Coca Cola for 30 min. Calcium and phosphorus ions concentration in enamel and dentine was determined by detector – EDX, type Quantax QX2 (Germany) – after immersing the samples. It has an active area of 10 mm^2 and it can analyze all items heavier than carbon, smooth or rough samples, thin coatings or particles, with resolution below 1.33 eV (MnK, 1,000 cps). Quantax QX2 uses a third generation detector, Xflash, which does not require liquid nitrogen cooling and is about ten times faster than the traditional Si(Li) detectors.

SEM evaluation of acid solutions corrosive effect

The tooth sections were morphologically analyzed using a Scanning Electron Microscope (SEM), type Vega II LSH (Czech Republic). The microscope, entirely operated by computer and containing an electron gun with tungsten filament that can achieve a 3 nm resolution at 30 kV, with a magnifying power between 30 and 1,000,000X in the resolution mode, acceleration tension between 200 V and 30 kV, a scanning speed between 200 ns and 10 ms per pixel. The working pressure is lower than $1X10^{-2}$ Pa. For the samples used in this study the appearance of enamel and dentine was analyzed after their immersion in corrosive solutions.

Results and discusions

The *p*H of test solutions was 2.85 for Coca Cola, 3.8 for Nestea Lemon, 3.9 for wine, 4.35 for Listerine and 5,6 for Corsodyl. The titatrable acidity (mL/mL) of these solutions is shown in table 1. The highest value was recorded for Coca Cola, followed, in descending order, by wine, Nestea Lemon, Listerine and Corsodyl.

The calcium concentration in enamel varied in the control group between 45.91-47.19% wt. As for the five test solutions it varied between 35.92-37.68% wt for Nestea

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Distilled water - Nestea	9.81333	.92815	.37892	8.83930	10.78737	25.898	5	**.000**
Pair 2	Distilled water - Coca Cola	24.62333	.68398	.27923	23.90554	25.34112	88.182	5	**.000**
Pair 3	Distilled water - Corsodyl	2.11667	.54724	.22341	1.54238	2.69096	9.474	5	**.000**
Pair 4	Distilled water – Listerine	1.64833	.56474	.23056	1.05567	2.24100	7.149	5	**.001**
Pair 5	Distilled water- red wine	17.01167	.72292	.29513	16.25301	17.77033	57.641	5	**.000**
Pair 6	Coca Cola – Corsodyl	-22.50667	.36335	.14834	-22.88798	-22.12535	-151.725	5	**.000**
Pair 7	Coca Cola - Listerine	-22.97400	.37756	.15414	-23.37122	-22.57878	-149.055	5	**.000**
Pair 8	Coca Cola – red wine	-7.61167	.55470	.22646	-8.19379	-7.02954	-33.612	5	**.000**
Pair 9	Corsodyl - Listerine	-.46833	.55105	.22497	-1.04663	.10996	-2.082	5	**.000**
Pair 10	Corsodyl – red wine	14.89500	.64158	.26193	14.22170	15.56830	56.867	5	**.000**

Table 3
RESULTS OF t-TEST USED TO COMPARE CALCIUM CONCENTRATIONS IN ENAMEL

Lemon, between 21.76-22.44% wt for Coca Cola, between 44.18-45.12% wt for Corsodyl, between 44.69-45.34% wt for Listerine and between 29.12-30.25% wt for wine. In dentine the calcium concentration ranged between 33.67-35.16% wt for the control group, between 1.59-1.88% wt for Nestea, between 1.41-1.61% wt for Coca Cola, between 28.1-28.81% wt for Corsodyl, between 7.49-8.56% wt for Listerine and 1.31-1.5% wt for wine.

In the case of phosphorus ions, their concentration in enamel varied in the control group between 28.42-28.81% wt, between 22.89-23.78% wt for Corsodyl, between 19.54-20.43% wt for wine, between 14.92-15.87% wt for Nestea, between 1.41-1.61% wt for Coca Cola. In dentine the phosphorus ion concentration ranged between 21.09-22.23% wt for the control group, between 14.64-15.1% wt for Corsodyl, between 2.97-3.51% wt for Listerine, between 0.27-0.35% wt for Nestea, between 0.64-0,75% wt for wine, between 0.16-0.23% wt for Coca Cola.

The mean values of calcium and phosphorus concentrations in the control samples and in the samples immersed in the five corrosive solutions are shown in table 2.

There was a declining tendency in the values of calcium and phosphorus concentrations in enamel and dentine after immersing the samples in the five solutions. The lowest concentrations were recorded for the samples immersed in Coca Cola, followed, in ascending order of concentration values, by those immersed in Nestea, wine, Listerine and Corsodyl.

The values obtained after immersion in the five test solutions were statistically analyzed compared to the control samples using Paired Samples t-test, with a materiality threshold of 0.05 and a confidence interval of 95%. Statistically significant values were obtained in all the studied groups when calcium and phosphorus concentrations in enamel were compared (tables 3 and 4). In dentine there were no significant values recorded after comparing the calcium concentrations of the samples immersed in wine and Coca Cola ($p = 0.064 > 0.05$) (table 5).

Appearance of enamel and dentine after immersion in distilled water is shown in figures 1 and 2. Smear layer is observed on the enamel surface and a uniform dentine surface.

Appearance of enamel and dentine after immersion in Listerine is shown in figures 3 and 4. There are areas of enamel demineralization and a widening of the dentinal tubules.

There are areas of pronounced enamel demineralization and a widening of the dentinal tubules in the samples after immersion in Nestea lemon, as well as the presence of spherical, regular deposits on the enamel and dentinal surface.

The aspect of the enamel and dentine after immersion in wine is shown in figures 5 and 6. There are areas of pronounced enamel demineralization and a widening of the dentinal tubules, as well as the presence of polyhedral, irregular deposits on the enamel and dentinal surface.

Table 4

RESULTS OF t-TEST USED TO COMPARE PHOSPHORUS CONCENTRATIONS IN ENAMEL

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Distilled water - Nestea	9.81333	.92815	.37892	8.83930	10.78737	25.898	5	**.000**
Pair 2	Distilled water - Coca Cola	24.62333	.68398	.27923	23.90554	25.34112	88.182	5	**.000**
Pair 3	Distilled water - Corsodyl	2.11667	.54724	.22341	1.54238	2.69096	9.474	5	**.000**
Pair 4	Distilled water – Listerine	1.64833	.56474	.23056	1.05567	2.24100	7.149	5	**.001**
Pair 5	Distilled water- red wine	17.01167	.72292	.29513	16.25301	17.77033	57.641	5	**.000**

		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Distilled water - Nestea	13.30833	.43847	.17900	12.84819	13.76848	74.346	5	**.000**
Pair 2	Distilled water - Coca Cola	19.74833	.47508	.19395	19.24977	20.24689	101.822	5	**.000**
Pair 3	Distilled water -Corsodyl	5.45667	.32010	.13068	5.12074	5.79260	41.755	5	**.000**
Pair 4	Distilled water - Listerine	8.74667	.25382	.10362	8.48029	9.01304	84.408	5	**.000**
Pair 5	Distilled water – red wine	23.53167	.44454	.18148	23.06515	23.99818	129.663	5	**.000**

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Nestea – Coca Cola	.29500	.18855	.07697	.09713	.49287	3.832	5	**.012**
Pair 2	Nestea - Corsodyl	-26.52667	.29837	.12181	-26.83979	-26.21354	-217.770	5	**.000**
Pair 3	Nestea - Listerine	-6.27667	.44071	.17992	-6.73917	-5.81417	-34.886	5	**.000**
Pair 4	Coca Cola - Corsodyl	-26.82167	.38685	.15793	-27.22765	-26.41569	-169.830	5	**.000**
Pair 5	Coca Cola - Listerine	-6.57167	.41189	.16816	-7.00392	-6.13941	-39.081	5	**.000**
Pair 6	Distileed water - Nestea	32.72167	.58915	.24052	32.10339	33.33994	136.046	5	**.000**
Pair 7	Distileed water –Coca Cola	33.01667	.58284	.23794	32.40501	33.62832	138.758	5	**.000**
Pair 8	Distileed water - Corsodyl	6.19500	.49387	.20162	5.67671	6.71329	30.726	5	**.000**
Pair 9	Distileed water - Listerine	26.44500	.35826	.14626	26.06903	26.82097	180.810	5	**.000**
Pair 10	Distileed water – red wine	33.10333	.59335	.24223	32.48065	33.72602	136.658	5	**.000**

Table 5
RESULTS OF t-TEST USED TO COMPARE CALCIUM CONCENTRATIONS IN DENTINE


Fig. 1. Enamel aspect of a control sample (SEM, 500X)


Fig. 2. Dentine aspect of a control sample (SEM, 250X)

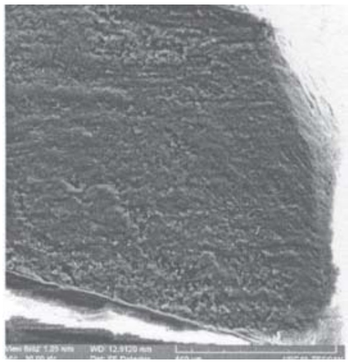
Fig. 3. Enamel aspect of a sample after immersion in Listerine (SEM, 250X)

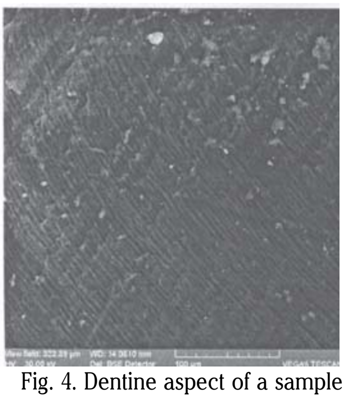
Fig. 4. Dentine aspect of a sample after immersion in Listerine (SEM, 250X)

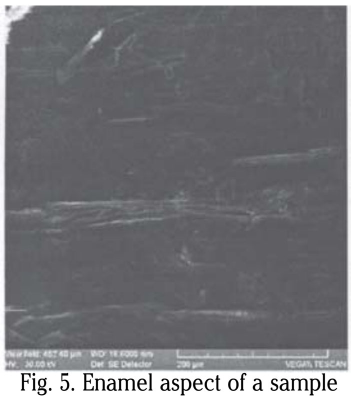
Fig. 5. Enamel aspect of a sample after immersion in wine (SEM, 250X)


Fig. 6. Dentine aspect of a sample after immersion in red wine (SEM, 250X)

The aspect of the enamel and dentine after immersion in Coca Cola is shown in figures 7 and 8. There are areas of pronounced enamel demineralization and a widening of the dentinal tubules.

Appearance of enamel and dentine after immersion in Corsodyl is shown in figures 9 and 10. There are clean surfaces, with no smear layer, but with a slight widening of the dentinal tubules.

All acidic beverages like Coca Cola required a large quantity of basic solutions in order to reach neutral *p*H. The *p*H values and the buffering capacity cannot fully explain the corrosive potential of these beverages, since there are also other relevant factors in losing enamel and dentin minerals: mineral content, phosphoric or citric acid concentration, presence of fluor ions. In our study the lowest *p*H and the highest buffering capacity values have been recorded for Coca Cola. These values have been confirmed by other studies that have sought to compare the titratable capacity of several Cola range sodas [6].

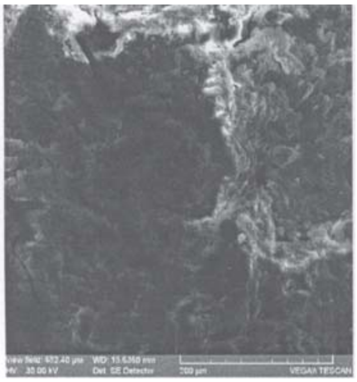

Fig. 7. Enamel aspect of a sample after immersion in Coca Cola (SEM, 250X)

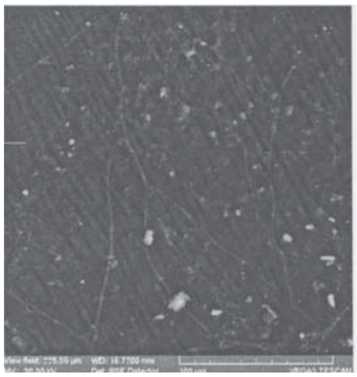

Fig. 8. Dentine aspect of a sample after immersion in Coca Cola (SEM, 250X)

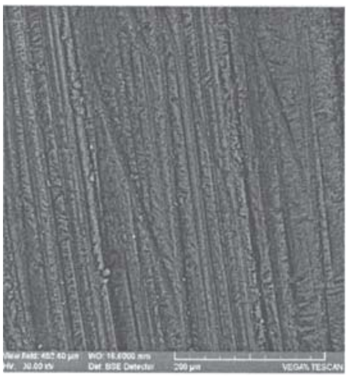

Fig. 9. Enamel aspect of a sample after immersion in Corsodyl (SEM, 500X)

Fig. 10. Dentine aspect of a sample after immersion in Corsodyl (SEM, 250X)

Table 6

RESULTS OF t TEST USED TO COMPARE PHOSPHORUS CONCENTRATIONS IN DENTIN

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Distileed water - Nestea	21.49833	.41460	.16926	21.06323	21.93343	127.013	5	**.000**
Pair 2	Distileed water – Coca Cola	21.60833	.39967	.16316	21.18890	22.02776	132.433	5	**.000**
Pair 3	Distileed water - Corsodyl	7.01333	.41433	.16915	6.57852	7.44814	41.463	5	**.000**
Pair 4	Distileed water - Listerine	18.53500	.46702	.19066	18.04489	19.02511	97.214	5	**.000**
Pair 5	Distileed water – red wine	21.10833	.39484	.16119	20.69398	21.52269	130.952	5	**.000**

Saliva is a solution with a complex buffering potential, that has a protective effect by counteracting acidity from different sources [3-5]. However, in the presence of very acidic beverages this counteracting effect can be ineffective [7]. In order to explain the corrosive potential, one must consider, besides with *p*H and the buffering capacity of the solution, the presence of additives such as chelating agents [8]. Barbour has demonstrated that a high calcium concentration will reduce the corrosive potential of various acidic beverages [9]. Adding a sufficient amount of calcium ions can saturate the original solution, thus preventing subsequent dissolution [10]. Many fruit drinks or soft drinks, such as Nestea Lemon, contain citric acid in concentrations that usually range between 15-45 mmol/L [11, 12]. It has been found that adding calcium ions to a citric acid solution that has a certain *p*H reduces the corrosive effect of the solution, the effect being stronger for higher *p*H levels [13]. The calcium ions in the solution can link to the citric acid and prevent chelation of the calcium ions in the hard dental tissues, thus preventing demineralization [10].

Some studies that analyzed the corrosive potential of different mineral waters and soft drinks are based on measuring the loss of calcium and phosphorus ions in dental tissues [14]. They found that mineral waters have a low corrosive potential, while soft drinks led to a significant loss of calcium and phosphorus ions [14], which is also the conclusion of our study. Other authors confirmed the same declining trend in the calcium concentration of hard dental tissues after a prolonged contact with acidic beverages [15]. Acidic beverages can cause a quantitative loss of the principal elements in enamel and dentine (calcium and phosphorus), as well as other elements present in smaller amounts, such as magnesium and strontium as the degree of demineralization can reach 40 μm [16].

The SEM observations in this study confirm the findings of other studies regarding the smear layer removal by the action of acid substances and the widening of dentinal tubules as a result of demineralization [6]. The possible clinical consequence of tubules opening is dentine hypersensitivity as a result of the modified dynamics of dentinal fluid and because of the impaired dental tissue integrity [17- 19].

Because there are many individual factors at the buccal level that are difficult to replicate in laboratory trials, the direct, in vivo use of the results of in vitro analyses must be handled wisely. Together with the morphology and composition of hard dental tissues, salivary buffering capacity, frequency and duration of drinks consumption, as well as certain dietary habits are considered circumstances that must be taken into consideration when assessing the corrosive effect. The long action time of acid solutions is another limitation of this study, the corrosive effect being the more marked the longer the action time of the demineralizing agent.

Conclusions

Coca Cola proved to have the lowest *p*H and the highest titratable capacity levels, followed, in ascending order of *p*H values and descending order of titratable capacity levels, by: wine, Nestea Lemon, Listerine and Corsodyl. Under the conditions in which this study was carried, all three acidic beverages and the two oral antiseptic solutions studied caused significant drops of calcium and phosphorus concentrations in enamel and dentine.

References

1. TOUYZ, L.Z.G., MEHIO, A., Journal of Aesthetic and Implant Dentistry, **8,** no 3, 2006, p. 20.
2. JOHANSSON, A.K., LINGSTROM, P., IMFELD, T., BIRKHED, D., European Journal of Oral Sciences, **112**, 6, 2004, p. 484.
3. DAWES, C., Journal of Canadian Dental Association, **69,** no.11, 2003, p. 722.
4. FEATHERSTONE, J.D., LUSSI, A., Monographs in Oral Science, **20**, 2006, p. 66.
5. ATTIN T., Monographs in Oral Science, **20**, 2006, p. 152.
6. LARSEN, M.J., NYVAD, B., Caries Research, **33**, no. 1, 1999, p. 81.
7. TAHMASSEBI, J.F., DUGGAL, M.S., MALIK-KOTRU, G., CURZON, M.E., Journal of Dentistry, **34**, no 1, 2006, p. 2.
8. MARGOLIS, H.C., ZHANG, Y.P., LEE, C.Y., KENT, R.L., MOENO, E.C., Journal of Materials Research, **78**, 1999, p. 1326.
9. BARBOUR, M. E., PARKER, D. M., ALLEN, G. C., JANDT, K. D., European Journal of Oral Sciences, **111**, 2003, p. 428.
10. FEATHERSTONE, J.B.D., LUSSI, A., Understanding the chemistry of dental erosion, in Dental erosion (editor Lussi, A.,), Ed. Karger, Basel, Switzerland, 2006, p. 66.
11. DOWKER, S.E.P., ELLIOT, J.C., DAVIS, G.R., WASSIF, H.S., Caries Research, **37**, 2003, p. 237.
12. LUSSI, A., JAEGGI, T., ZERO, D., Caries Research, **38,** Suppl. 1, 2004, p. 34.
13. HUGHES, J.A., WEST, N.X., PARKER, D.M., VAN DEN BRAAK, M.H., ADDY, M., Journal of Dentistry, **28**, no 2, 2000, p. 147.
14. PARRY, J., SHAW, L., ARNAUD, M. J., SMITH, J., Journal of Oral Rehabilitation, **28**, 2001, p. 766.
15. BARTLETT, D.W., COWARD, P.Y., Journal of Oral Rehabilitation, **28**, no 11, 2001, p. 1045.
16. WILLERSHAUSEN, B., ERNST, C.P., PISTORIUS, A., BRANDENBUSCH, M., Zahnärztliche Mitteilungen, **12**, 2002, p. 38.
17. LUSSI, A., PORTMANN, P., BURHOP, B., Clinical Oral Investigations, 1, 1997, p. 191.
18. JENSDOTTIR, T., ARNADOTTIR, I.B., THORSDOTTIR, I., BARDOW, A., GUDMUNDSSON, K., THEODORS, A., Clinical Oral Investigations, **8**, no 2, 2004, p. 91.
19. RUSU, L.-C., ARDELEAN, L., NEGRUTIU, M.-L., DGOMIRESCU, A.-O., ALBU, M.G., GHICA, M.V., TOPALA, F.I., PODOLEANU, A., SINESCU, C., Rev. Chim. (Bucharest), **62**, no. 8, 2011, p. 841

Manuscript received: 30.11.2011