Study Regarding the Erosive Potential of Water from Swimming Pools on Dental Hard Tissues

NICOLETA TOFAN*, GALINA PANCU, CLAUDIU TOPOLICEANU, ANDREI GEORGESCU, SIMONA STOLERIU, SORIN ANDRIAN
"Grigore T. Popa" University of Medicine and Pharmacy of Iasi, Faculty of Dental Medicine, 16 Universitatii Str., 700115, Iaºi, Romania

This research aimed to assess water pH from 8 swimming pools (sporting, recreation, individual) and to evaluate the erosive potential of pool chlorinated water on dental enamel as well as the protective effect of remineralisation GC Recaldent MI Paste to counteract erosion (cuantification of surface roughness by profilometry). The assessment of chlorinated water erosive potential was performed in vitro on 50 dental samples obtained by sectioning of teeth extracted from orthodontic purposes and randomly divided in five groups (four study groups, control group). The study groups (groups I, II, III, IV) were submitted to demineralisation cycles, respectively (groups II, IV) to remineralisation with GC Recaldent MI Paste. The determination of water pH was performed using pH-meter Checker (HANNA), and the wear of dental surfaces submitted to erosive cycles was determined by profilometry method using rugosimeter TAYLOR HOBSON Surtronic 25. The analysis of results shows acid pH values (under 7) for water in all 8 swimming pools, demonstrating an erosive acid potential. Accordingly to profilometry test, the erosive effect of chlorinated water from swimming pools, is direct related to exposure duration (higher for group I, corresponding to professional swimmers, lower for group III, corresponding to non-professional swimmers). Significant statistical differences were found between erosion values for groups I (professional swimmers) and group III (non-professional swimmers). In the study groups submitted to remineralization therapy (group II, IV), it was recorded a tendency to counteract the erosive effect, with significant statistical differences between groups.

Keywords: dental erosion, remineralisation, enamel, profilometry, swimmers, pH

The dental erosion represents a challenge for the dentistry of century XXI. The loss of hard dental tissues provoked by dental erosion constitutes a major problem both for teenagers and adults. Despite numerous in vitro and in vivo studies, the ethiopatogenic mechanisms are not completely understood [1-7]. The aspects regarding ethiological factors, the initiation and evolution of ethiopathogenic processes are not completely elucidated. Also the current diagnostic methods and preventive-therapeutical means are not completely satisfactory.

The erosion is influenced by factors like remineralisation and acquired pellicle formation. The salivary acquired pellicle (non-bacterial film covering hard dental tissues) has the role to slow down the diffusion of acids on enamel surface [8].

Considering critical *p*H of enamel 5.5 (for hydroxiapatite) and 4-5 (for fluorapatite), any solution that diffuses through enamel pores (accordingly to a diffusion coefficient) with a lower *p*H can produce erosion, if the attack is longer and repeated in time. The remineralisation is a slow process, prolonged on a few hours, and produced only in the demineralised area.

The dental erosion represents loss of hard dental tissue under the action of non-bacterial acids. This process can be produced by intrinsec and extrinsec factors. The extrinsec factors include consume of acid foods and beverages, low *p*H medication as well as sport practices or professions that implies acid environments. Most studies are focused on the research of diet and lifestyle. The exposure to acid environments was associated with dental erosion [9]. High rates of dental erosions were found to workers in factories that use sulphuric acid and hydrochloric acid [10]. Dental erosion is associated with professional swimmers training many hours in pools with chlorinated water [11]. One of the first researches regarding dental erosions to professional swimmers is published by E. N. Savad in 1982 [12]. Researches in the same category were published further [13-16].

The public swimming pools are chlorinated to reduce bacterial contamination and algae deposition. Accordingly to UE rules, the chlor levels in swimming pools must be maintained between 0.3-0.6mg/dm^3. The chlor can be used in swimming pools as natrium hypochlorite, with alcalin *p*H; in this form can reduce the dental erosion incidence. The stabilised chlorure is obtained by combination between chlore and cyanurate salt. In big swimming pools water is combined with chlorine gas. Chlorine gas reacts with water and form hypochlorite ($Cl_2 + H_2O = HOCl + HCl$). Hypochlorite is the antibacterial agent, but hydrochloric acid is undesirable product. Water *p*H is balanced by addition of soda (Na_2CO_3) till *p*H 7.5. The accepted *p*H level in swimming pools is between 7.2-8.0. If water is not alcalinised by the addition of enough soda, *p*H-level can rapidly decrease to 3. Also domestic swimming pools are difficult to be properly treated and cleaned. The levels of chlorine and *p*H must be monitored weekly and maintained in accepted values range.

A recent study of O. N. Baghele, that monitored 100 professional swimmers, found that 90% from athletes were affected by diverse forms of enamel erosion [17]. The daily

---

**email: iacobnicol@yahoo.com*

training means daily dose of chlorine that constantly affects the enamel. The researches prove that enamel erosion appears when water *p*H is in range 2.7-7. Also literature data suggest that water with low *p*H in swimming pools is responsible of the apparition of dental erosions. The intensive long term swimming, especially in improperly managed swimming pools must be considered a cofactor in the diagnostic of dental erosion.

În our study the research method included the assessment of water *p*H in 8 swimming pools (sporting, entertainment, domestic) and the assessment of erosive potential of chlorinated water on the dental enamel as well as the protective effect of a remineralisation product (GC Recaldent MI Paste) to counteract the dental erosion (by cuantification of surface roughness using profilometric method).

Experimental part

In the study we have carried out, out of the 8 swimming pools, whe have chosen to use the pool with the smallest *p*H = 4.90. The research was performed on a study group of 25 unaffected bicusps extracted for orthodontic purposes. The teeth were cleaned to remove debris of soft tissue, blood, plaque and calculus and stored in physiological serum. The teeth were cut at the buccal and oral level (medium third) in enamel slices using a diamond disc (Extec Corp, Enfield, USA) at slow speed. The research method included the analysis of prepared surfaces and profilometric study of the degree of acid erosion following prolonged exposure to pool chlorinated water and the analysis of remineralisation agent (GC Recaldent MI Paste) ability to counteract dental erosion. The indications and stages of literature protocol were respected, regarding selection, pretreatment, preservation and preparation of artificial lesions. The selection criteria included the absence of dental caries, macroscopic fissures, abrasion or extended color changes. The pretreatment consisted in washing teeth with detergent followed by rinsing in distilled water; preservation consisted in the insertion of samples in physiological serum 0.9% for 48 h . 50 plaques (4 x 4 x 3mm) were prepared by sectioning of smooth dental surfaces . The samples were divided in 4 study groups and a control group (n=10x5).

I. Lot I (EP) PROFESSIONAL EROSION–study group submitted to an erosive cycle in chlorinated water for 4 h x 5 days= 20 h/week, corresponding to professional swimmers.

II. Lot II (EP+REM) PROFESSIONAL EROSION plus RECALDENT –study group submitted to an erosive cycle in chlorinated water for 4 h x 5 days = 20 h/week, corresponding to professional swimmers, and to remineralisation effect, by local applications with GC Recaldent MI Paste, for 15 min , 2 times daily (morning, evening) 7 days.

III. Lot III (EA) NON-PROFESSIONAL SWIMMERS–study group submitted to an erosive cycle in chlorinated water for 2 hx 2 days= 4 h/week, corresponding to non-professional swimmers.

IV. Lot IV (EA+REM) NON-PROFESSIONAL SWIMMERS plus RECALDENT – study group submitted to an erosive cycle in chlorinated water for 2 h x 2 days= 4 h/week, corresponding to non-professional swimmers, and to remineralisation effect, by local applications with GC Recaldent MI Paste, for 15 min, 2 times daily (morning, evening) 7 days.

V. Lot V (M) –control group, immersed only in artificial saliva.

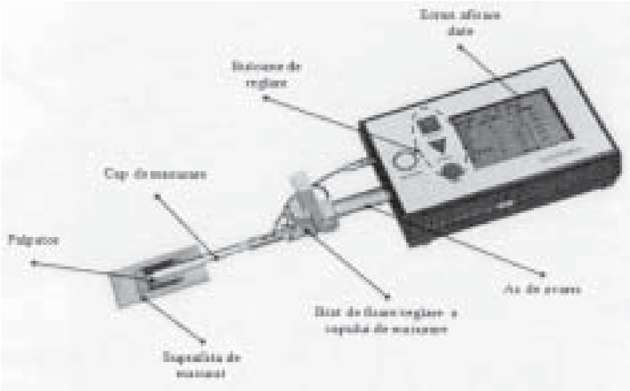


Fig. 1. Rugosimeter TAYLOR HOBSON Surtronic 25

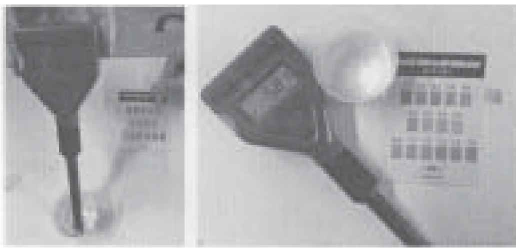


Fig. 2. *p*H values of water from swimming pools

To assess water *p*H in swimming pools from Iassy county, we used a pH-meter Checker (HANNA) and kit *p*H indicator (5.0 - 8.0) from GC Global Care 9 (fig.2).

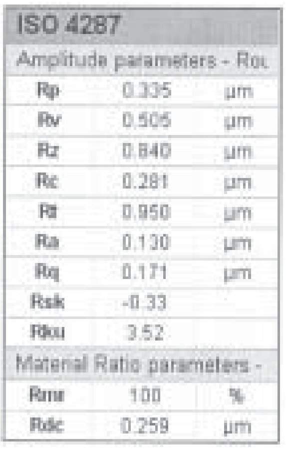
The researched surfaces were succesively polished and covered with acid-resistant varnish (Farmec ultrarezistent, Farmec SA Romania), as to leave half of surface uncovered and submitted to erosive acid action of chlore from water swimming pool. Between erosive cycles, samples were immersed in artificial saliva Fusayama-Mayer (32 mL/ sample) to room temperature. The research was performed 7 days. After the erosive cycles were finished, all samples were stored in artificial saliva for 18 h. For study groups II and IV the erosive cycles were associated daily (in the morning and in the evening, before and after erosive cycles), in sessions of 15 min , at an interval of 12 h, for a week, with local applications of remineralisation agent GC Recaldent MI Paste. After the end of *p*H cycles, varnish was cleaned with cotton and acetone. The degree of erosion was determined by profilometric method related to reference surface, using rugosimeter TAYLOR HOBSON Surtronic 25 (fig. 1)**.** The trace parameters were set Lt: 1.5 mm and Lc: 0.25 mm, with profilometric accuracy 0.4 μm. Five readings were performed for each sample and mean erosion quantity was calculated. The profilometric traces were performed by moving stylus from reference surface to exposed surface.Statistical analysis imposed the verifying of equality hypothesis of variations and normal distribution of errors. As equality hypothesis were satisfied, tests ANOVA and Scott-Knott were performed for statistical comparisons, with significance limit established to 5%.

Results and discussions

To assess water *p*H from swimming pools in Iassy we used pH-meter Checker (HANNA).The values varied between 4.90-6.72. (fig. 2, table 1). The collected samples (n = 50) were analysed by profilometry using rugosimeter TAYLOR HOBSON Surtronic25. The research aimed to analyse the erosive changes provoked by chlorine from swimming pool water on dental surfaces immersed for a 20 h/week. (group I), 4 h/week (group III) as well as the protective effect of remineralisation agent GC Recaldent MI Paste applied to groups II and IV (15 min, 2 times/day, 7 days). The samples from control group were also analysed.

Table 1
*p*H VALUES (WATER FROM SWIMMING POOLS)

pH values water swimming pools	
1	5.62
2	5.81
3	5.80
4	5.96
5	6.22
6	5.43
7	4.90
8	6.72



ISO 4287		
Amplitude parameters - Ro		
Rp	0.335	µm
Rv	0.505	µm
Rz	0.840	µm
Rc	0.281	µm
Rt	0.950	µm
Ra	0.130	µm
Rq	0.171	µm
Rsk	-0.33	
Rku	3.52	
Material Ratio parameters -		
Rmr	100	%
Rdc	0.259	µm

Table 2
EROSION PROFILE VALUES

In the table 2, figure 3 is an example of erosive changes obtained by profilometric method.

Table 3 (descriptive statistics) shows the next reports between mean erosion of study groups and control group: mean of group I EP is 8.02 times higher than control group, mean of group II EP+R is 3.65 times higher than control group, mean of group III EA is 4,16 times higher than control group, mean of group IV EA+R is 1.81 times higher than control group.

We are interested to find if there is a significant statistical difference between these means. We apply test ANOVA to find significant statistical differences for each element within five study groups. Null hypothesis: between five study groups there are no significant statistical differences. Research hypothesis: there are significant statistical differences for each study group.

Table ANOVA contains the result of test F (538.391), for p 0.0001; the null hypothesis is rejected and research hypothesis is accepted, erosion values varies significantly (table 4).

Significant statistical differences between five study groups were found for each element (table 5).After comparison of EP group with the others, were recorded positives means; highest erosion values are recorded in study group EP.

The mean values for the five study groups are as follows: 1.4912 for group I, 0.6783 for study group II, 0.7737 for study group III, 0.3515 for study group IV, 0.1858 for study group V. The enamel exposed to acid lost minerals from subsurface layer during demineralisation process [18]. As demineralisation advances, the dissolution of enamel surface layer will reach the point to determine complete dissolution of surface layer. In vivo, erosion could be associated with two enamel wear categories: direct elimination of hard dental tissue by complete dissolution and creation of thin layer vulnerable to further mechanical wear.

In 2006 A.M. Lennon [19] investigated the protective ability against enamel erosion of casein-calcium phosphate paste, in a study conducted on bovine enamel samples divided in five groups: control (untreated), group 2 = caseine-calcium phosphate applied for 120 s, two times daily, group 3 = 250 ppm natrium fluoride for 120 s, two times daily, group 4 = combination of caseine-calcium phosphate for 120 s, two times daily and 250 ppm natrium-fluoride for 120 s two times daily, group 5 = gel amino-fluor with 12500 ppm fluor for 120 s two times daily. The conclusion of this study was that the only effective protection is provided by high concentration fluor gels (amino-fluor gels, 12500 ppm) [19].

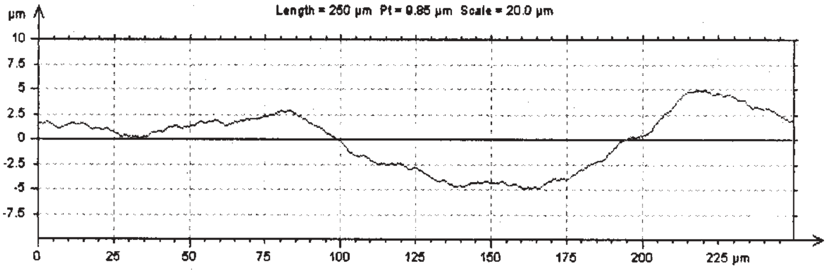


Fig. 3. Values of erosion profile

	Mean	Std. Deviation
Group I EP	**1.4912**	.04246
Group II EP+R	**.6783**	.09336
Group III EA	.7737	.07458
Group IV EA+R	**.3515**	.06565
Control group	**.1858**	.05689
Total	.6961	.46047

Table 3
DESCRIPTIVE STATISTICS

Table 4
ANOVA TEST

Erosion

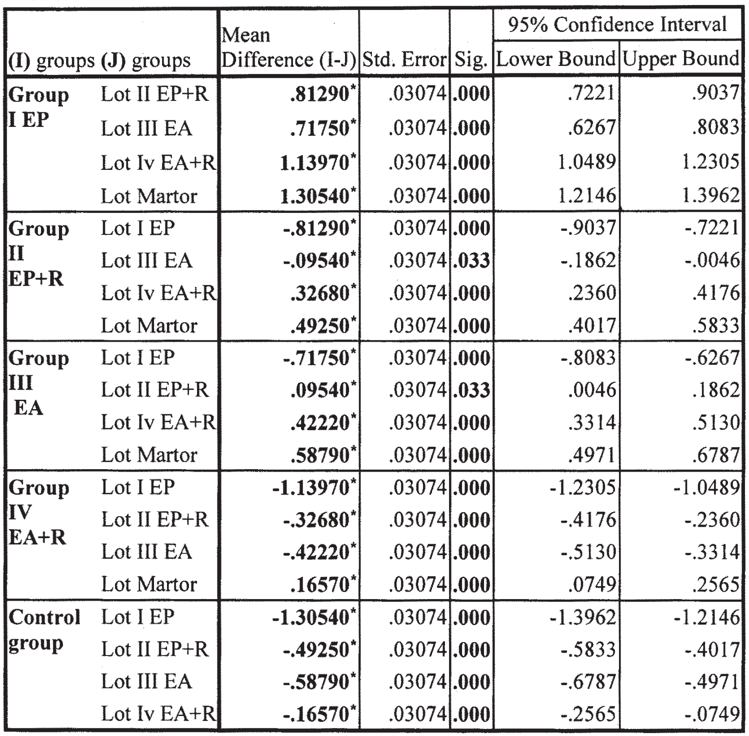
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.177	4	2.544	538.391	**.000**
Within Groups	.213	45	.005		
Total	10.389	49			

A similar study, performed by A. Wiegand in 2009 [20], analysed bovine enamel samples submitted to cycles of demineralisation/remineralisation for 3 days, each sample exposed each day for 120 min to human saliva and treated by fluoride solutions for 3 min : amino-fluor 0.5%, respectively 1%, natrium fluoride 0.5% respectively 1% and stanium fluoride 0.5%, respectively 1%. Accordingly to profilometric analysis, the research group concluded that only amino-fluor solutions 1% , respectively stanium fluoride 0.5% and 1% have the ability to protect enamel samples against erosion [20].

N. Schlueter in 2009 [21] uses a cyclic model of demineralisation/remineralisation in situ on human enamel and dentine samples mounted on intraoral appliances introduced to 20 healthy subjects. For enamel samples, tissue lost was 33.6 +/- 15.4 µm in negative control group (placebo), 24.2 +/- 9.2 µm for positive control group and only 9.2 +/- 3.4 µm for study group submitted to erosion prevention by a combination of stanium clor, natrium fluor, amino-fluor solutions [21].

Despite some results [22, 23] that show that low *p*H of water in swimming pools is principal factor determining erosion, also are implied the hydroxyapatite dissolution degree and calcium and phosphate ions saturation. Dental erosion could be initiated even in swimming pools with water neutral *p*H. A low degree of water ions can induce incipient erosions, followed by *p*H increasing and mineral

Erosion Bonferroni



(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Group I EP	Lot II EP+R	**.81290***	.03074	**.000**	.7221	.9037
	Lot III EA	**.71750***	.03074	**.000**	.6267	.8083
	Lot Iv EA+R	**1.13970***	.03074	**.000**	1.0489	1.2305
	Lot Martor	**1.30540***	.03074	**.000**	1.2146	1.3962
Group II EP+R	Lot I EP	**-.81290***	.03074	**.000**	-.9037	-.7221
	Lot III EA	**-.09540***	.03074	**.033**	-.1862	-.0046
	Lot Iv EA+R	**.32680***	.03074	**.000**	.2360	.4176
	Lot Martor	**.49250***	.03074	**.000**	.4017	.5833
Group III EA	Lot I EP	**-.71750***	.03074	**.000**	-.8083	-.6267
	Lot II EP+R	**.09540***	.03074	**.033**	.0046	.1862
	Lot Iv EA+R	**.42220***	.03074	**.000**	.3314	.5130
	Lot Martor	**.58790***	.03074	**.000**	.4971	.6787
Group IV EA+R	Lot I EP	**-1.13970***	.03074	**.000**	-1.2305	-1.0489
	Lot II EP+R	**-.32680***	.03074	**.000**	-.4176	-.2360
	Lot III EA	**-.42220***	.03074	**.000**	-.5130	-.3314
	Lot Martor	**.16570***	.03074	**.000**	.0749	.2565
Control group	Lot I EP	**-1.30540***	.03074	**.000**	-1.3962	-1.2146
	Lot II EP+R	**-.49250***	.03074	**.000**	-.5833	-.4017
	Lot III EA	**-.58790***	.03074	**.000**	-.6787	-.4971
	Lot Iv EA+R	**-.16570***	.03074	**.000**	-.2565	-.0749

*. The mean difference is significant at the 0.05 level.

$p < 0,05$ (statistic significance) is associated with mean significant statistical differences.

Table 5
TEST BONFERRONI
MULTIPLE COMPARISONS

content increasing to the level of liquid adjacent to dental surface. This protective layer will not allow demineralization.

Our study found, like other similar studies, that water *p*H values are acids in all 8 swimming pools (under *p*H 7), and have an erosive potential. The erosive effect of swimming pool chlorinated water, assessed by profilometry values, is direct related to exposure duration (higher in group I- professional swimmers, lower in group III- non-professional swimmers). In the study groups submitted to remineralisation therapy with GC Recaldent MI Paste (groups II, IV), it was recorded a tendency to counteract the erosive effect.

Conclusions

The *p*H values of water in all 8 swimming pools were acids (under *p*H 7), with values between 4.90-6.72. Accordingly to profilometry test, the erosive effect of chlorinated water from swimming pools, is direct related to exposure duration (higher for group I, corresponding to professional swimmers, lower for group III, corresponding to non-professional swimmers). Significant statistical differences were found between erosion values for groups I (professional swimmers) and group III (non-professional swimmers). In the study groups submitted to remineralisation therapy (group II, IV), it was recorded a tendency to counteract the erosive effect, with significant statistical differences between groups.

References

1.GHIORGHE, A., STOLERIU, S., PANCU, G., TOPOLICEANU, C. SANDU,A.V., ANDRIAN, S., Rev. Chim. (Bucharest), **65**, no. 9, 2014, p. 1021.

2.IONAS, M., BADEA, M.E., DUMITRESCU, L.S., IONAS, T., MOLDOVAN, M., Mat.Plast., **51**, no. 4, 2014, p. 435.

3.MUNTEANU, B., ANDRIAN, S., IOVAN, G., GHIORGHE, A., NICA, I., STOLERIU, S., Mat.. Plast., **51**, no. 3, 2014, p. 279.

4.ANDRIAN, S., IOVAN, G., TOPOLICEANU, C., MOLDOVANU, A., STOLERIU, S., Rev. Chim. (Bucharest), **63**, no. 12, 2012, p. 1231.

5.STOLERIU, S,. IOVAN, G., PANCU, G., GEORGESCU, A., SANDU, A.V., ANDRIAN, S., Mat. Plast., **51**, no. 2, 2014, p. 162.

6.STOLERIU, S., IOVAN, G., PANCU, G., GEORGESCU, A., SANDU, A.V., ANDRIAN, S., Rev. Chim. (Bucharest), **63**, no. 11, 2012, p. 1120.

7.PANCU, G., ANDRIAN, S., MOLDOVANU, A., NICA, I., SANDU, A.V., STOLERIU, S. Mat. Plast., **51,** no. 4, 2014, p. 428.

8.MEURMAN, J., FRANK, R., Caries Res., **25**, no.1, 1991, p.1.

9.BRUGGEN, CATE, H.F., Br. J. Ind. Med., **25,** 1968, p. 66.

10.PETERSEN, P., GORMSEN, C., Comm. Dent. Oral Epidemiol., **19,** 1991, p.104.

11.CENTERWALL, B., ARMSTRONG, C., FUNKHOUSER, L., ELZAY, R., Am. J. Epidemiol., **123**, 1986, p. 641.

12.SAVAD, E.N., J. Dent. Assoc., **53,** no. 32, 1982, p. 35.

13.GABAI, Y., FATTAL, B., RAHAMIN, E., GEDALIA, I., Am. J. Dent., **1**, 1998, p. 241.

14.DAWES, C., BORODITSKY, C.L., JADA, **74**, 2008, p. 359.

15.LOKIN, P., A., HUYSMANS, M.C., Ned. Tijdschr. Tandheelkd, **111,** 2004, p. 14.

16.JAHANGIRI, L., PIGLIACELLI, S., KERR, R.O., J. Prosth. Dent., **106**, no. 4, 2011, p. 219.

17.BAGHELE, O.N., INDRANIL, A.M, MANOJKUMAR, S.T., RAMCHANDRA, N., MANGALA, O.B., SNEHAL, M., Compend. Contin. Educ. Dent., **34**, 2013, p. 4.

18.ADDY, M., SHELLIS, R.P., Monogr. Oral Sci., **20,** 2006, p. 17.

19.LENNON, A.M, PFEFFER, M., BUCHALLA, W., BECKER, K., LENNON, S., ATTIN, T., Caries Res., **40**, 2006, p. 7.

20.WIEGAND, A., BICHSEL, D., MAGALHAES, A., BECHER, K., ATTIN, T., J. Dent. **37**, no. 8, 2009, p. 591.

21.SCHLUETER, N., KLIMEK, J., GANSS, C., J. Dent., **37**, 2009, p. 944.

22.LUSSI, A., JAEGGI, T., Clin. Oral Invest., **12**, 2008, p. 5.

23.ZERO, D.T., LUSSI, A., Int. Dent. J., **55**, 2005, p. 285.

Manuscript received: 25.07.2015