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CIGARETTE SMOKING AND ITS CONSEQUENCES ON PERIODONTAL HEALTH IN TEENAGERS: A CROSS-SECTIONAL STUDY

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SUMMARY

Objectives: Smoking has been extensively investigated as a risk factor for periodontal disease and many studies have confirmed it. The aim of this study was to show data from Croatia on periodontal health among high school students, with the focus on association of tobacco use and oral hygiene habits, and the periodontal parameters.

Methods: Pocket probing depth (PPD), bleeding on probing, supragingival calculus, and oral hygiene habits were recorded for each examinee out of 517 high school students. PPD was measured at 4 interproximal sites on all first molars and central incisors (index teeth).

Results: There were 34.6% smokers among subjects, who started smoking on average at the age of 14. More than half of the smokers (55.3%) smoked 1–10 cigarettes per day and intensity of smoking increased with age. PPD was significantly greater ($p = 0.012$) in smokers (1.69 mm) than in non-smokers (1.59 mm). In non-smoking subjects, increased values of PPD were in direct proportion to the reduced frequency of brushing, while there was no difference in smokers. The number of cigarettes smoked and duration of smoking had a great influence on PPD. Smokers had on average more teeth with supragingival calculus than non-smokers, while non-smokers had more bleeding on probing, and the difference was statistically significant ($p < 0.001$).

Conclusions: This study indicated that cigarette smoking was associated with decreased periodontal health even in this young population. Irregular oral hygiene was associated with decreased periodontal health only in non-smokers. Therefore, it should be important to inform young smokers about the negative effects of cigarette smoking on periodontal health, to provide consultations and reinforce smoking prevention measures.

Key words: cigarette smoking, adolescents, supragingival calculus, periodontal disease, periodontal health

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INTRODUCTION

Despite efforts and programmes of various institutions (government, medicine, education) tobacco epidemic has been deeply embedded in countries all around the world. The WHO claims that the tobacco use is the single most preventable cause of death and disease. Among the European countries, Croatia has one of the highest prevalences of tobacco smoking among adults (33%), ranking third highest per number of smokers in the European Union. Croatia is also among the highest in Europe in prevalence of tobacco use by adolescents (1).

Over the past two decades, numerous studies examined the influence of smoking on periodontal health (2). These studies found that cigarette smoking is an important risk factor for periodontal disease development and progression. Studies that have examined smoking as a risk factor ascertained that smokers, as compared to non-smokers, have greater periodontal connective tissue and bone loss, a larger number of deep periodontal pockets and greater prevalence of supragingival and subgingival calculus (3). What are the pathways by which tobacco smoking affects periodontal health is still unclear, but there are some potential mechanisms. They include the immune response, immune mediators, microbiota composition, and the healing capacity of the periodontal tissue. Smoking was a factor in the delay of neutrophils recruitment and migration into periodontal tissues, thus compromising the acute immune response. Also, smoking may lead to a change in the composition of the subgingival biofilm with an increase in the prevalence of periodontal pathogens (4).

Most of the studies of young subjects focused on aggressive forms of periodontitis (5, 6), as they are a concerning and acute health problem. Lately, several population studies (7, 8) were conducted on epidemiology and risk factors in young age groups. There were some differences in results, but all are uniform in attributing cigarette smoking as a risk factor for decreasing periodontal health.

In our study, we wanted to assess the prevalence of tobacco use in young people of Croatia in their adolescent age and screen periodontal health, because this is the age when tobacco use usually starts and in this period of life the young population is very vulnerable. Aside from starting smoking and becoming addicted to nicotine, during adolescence they go through rapid hormonal and cognitive changes, and they are influenced by cultural, social,

familial, and behavioural factors (9). There are very few studies that have looked into the effect of smoking on the beginning of decrease or change of periodontal health in adolescents. In a young population gingivitis is a common finding due to different factors (hygiene, hormones) (2). Gingivitis in young individuals typically remains chronic for a prolonged period of time without causing any damage to the periodontal ligament or bone. However, an alteration of the balance between the biofilm and the host can give rise to loss of periodontal attachment. Partly calcified, dysbiotic bacterial biofilm is one of the main basic causes of the periodontal disease and the main risk factor for subclinical periodontitis in adolescents. It also interacts with the immune defences of the host, while the smoking helps make the biofilm more pathogenic. This all leads to increasing gingival inflammation, and eventually to a deepening of periodontal pockets, as suggested by a new study on teenagers (8).

Data about smoking and periodontal health in young subjects from Europe, and especially from southeast Europe, are scarce (4). Our aim was to show data from Croatia about the periodontal health among high school students, focusing on tobacco use and oral hygiene habits, and to evaluate the effect of tobacco smoking on the periodontal parameters in this young population, when tobacco use usually starts.

MATERIALS AND METHODS

Study Design

This cross-sectional study was conducted in the County of Zadar, Croatia, in full accordance with ethical principles of the World Medical Association Declaration of Helsinki. The study was approved by the Ethical Committee of the Dental School (No. 05-PA-26-4-205/06), University of Zagreb, Croatia. The size sample calculation was performed with a confidence level set to 95% and the 5% margin of error. The City of Zadar has high school population of 7,200 and a minimal sample of 356 participants was calculated.

Subjects

Five high schools, out of nineteen, were randomly chosen and students were invited to participate in the study on a voluntary basis. The selection was made using a table of random numbers. All participants who responded, and their parents or guardians, received written information about the aims and design of the study and signed a written informed consent form. The study population consisted of 517 high-school students aged 14–18. Exclusion criteria were ongoing orthodontic treatment and chronic diseases under medication.

Questionnaire

Subjects were interviewed to gather information about their age, gender, cigarette use, oral hygiene habits, and socioeconomic status using a structured written questionnaire developed for the purpose of this study. Detailed information about the number of cigarettes smoked per day, onset and duration of cigarette smoking were also recorded. Subjects were considered smokers if they smoked regularly for at least a year before the examination took place (10). In order to avoid bias, the examiner asked questions referring to the smoking status of each subject after the clinical examination has been made.

Clinical Examination

Clinical examination was carried out by one calibrated examiner (I.Š.), using headlamps, dental mirrors, dental probe, and calibrated manual periodontal probe University of North Carolina (UNC) 15mm probe (Hu-Friedy, Chicago, IL, USA) with markings at each millimetre. Inter- and intra-examiner probing calibration were performed to a standardized 25 g force. For each subject examination was done on index teeth at six sites per tooth: the right first molar, the right first incisor and the left first molar in the maxilla; and the right first molar, the left first incisor and the left first molar in the mandible (11). The periodontal examination was assessed for clinical attachment loss, presence of supragingival calculus and bleeding on probing. The deepest probing depth was recorded for each tooth. If the first molar was missing, it was substituted by the second molar (12).

Clinical Measurements

The presence or absence of bleeding on probing (BOP) was elicited by gently running a periodontal probe around the gingival margin and was recorded as 0 = no bleeding, 1 = bleeding. Supragingival dental calculus was detected with use of dental probe. Periodontal pocket depth (PPD) was measured from the cemento-enamel junction to the most apical penetration of the probe at 4 interproximal sites on all first molars and central incisors (index teeth). All measurements were carried out according to the WHO recommendations (11).

Statistical Analysis

Data analysis was performed with the software package SPSS 21.0 (SPSS Inc., Chicago IL, USA). Non-parametric variables were tested with the chi-square and Fisher's exact tests. Parametric tests were done using the Student's t-test and the one-way analysis of variance. Covariate analyses were used to provide information about age influence on periodontal pocket depth. Significance was set at $p < 0.05$.

RESULTS

The study group consisted of 517 adolescents, 14–18 years of age, with 229 (44.3%) males and 288 (55.7%) females, with the response rate of 99.5%. Table 1 shows demographic information and characteristics of study subjects stratified by smoking status. Of all examinees, 34.6% were smokers, with no difference in distribution between genders. On average, examinees started smoking at the age of 14. As expected, the duration of smoking and tobacco consumption increased with age ($p = 0.003$). The percentage of smokers also increased with age, to a statistically significant degree ($p < 0.001$).

The major finding of this study, by statistical analysis, is that smokers showed a greater value in average periodontal pocket depth (PPD) compared to non-smokers. In smokers the aver-

Table 1. *Study population demographics and other characteristics stratified by smoking status (N = 517)*

	Total n	Smoker n (%)	Non-smoker n (%)	χ^2 test
Overall	517	188 (36.4)	329 (63.6)	
Gender				
Male	229	85 (37.1)	144 (62.6)	ns
Female	288	103 (35.8)	185 (64.2)	
Age				
14	43	6 (21.6)	37 (86)	$\chi^2 = 39.5$, df = 4 p < 0.001
15	102	22 (21.6)	80 (78.4)	
16	143	45 (31.5)	98 (68.5)	
17	144	73 (50.7)	71 (49.3)	
18	85	42 (49.4)	43 (50.6)	
Hygiene				
Not brushing	27	12 (6.4)	15 (4.6)	$\chi^2 = 0.83$, df = 2 p = 0.66
Brushing once a day	161	57 (30.3)	104 (31.6)	
Brushing twice or more a day	329	119 (63.3)	210 (63.8)	
Bleeding on probing present				
Yes	221	47 (25)	174 (53)	$\chi^2 = 10.6$, df = 1.51 p < 0.001
No	296	141 (75)	155 (47)	
Supragingival calculus present				
Yes	268	133 (71)	135 (41)	$\chi^2 = 25.80$, df = 1.51 p < 0.001
No	249	55 (29)	194 (59)	

ns – not significant

Table 2. *Periodontal pocket depth in smokers and non-smokers, according to duration of smoking and tobacco consumption measured in millimetres (N = 517)*

Variable	n	PPD Mean (SD)	95% CI	F	p-value	η^2
Smoking						
No	329	1.59 (0.41)	1.55–1.64	6.36	0.012*	0.012
Yes	188	1.69 (0.41)	1.63–1.75			
Years of smoking						
1 year	38	1.59 (0.41)	1.46–1.73	3.18	0.015*	0.065
2 years	55	1.61 (0.33)	1.53–1.70			
3 years	42	1.68 (0.39)	1.56–1.80			
4 years	34	1.76 (0.44)	1.60–1.91			
≥ 5 years	19	1.95 (0.52)	1.69–2.20			
Tobacco consumption						
1–10 cigarettes per day	104	1.63 (0.40)	1.56–1.72	3.44	0.034*	0.036
10–20 cigarettes per day	73	1.72 (0.37)	1.63–1.81			
≥ 21 cigarettes per day	11	1.96 (0.66)	1.52–2.41			

PPD – periodontal pocket depth (in mm); *statistically significant p < 0.05, ANOVA with Bonferroni test

age PPD was 1.69 mm, compared to 1.59 mm in non-smokers (p = 0.012).

Intensity of smoking, measured by number of cigarettes smoked daily, was positively correlated with increased PPD. Similarly, longer duration of smoking resulted in greater PPD (Table 2, Fig. 1). Smoking was significantly associated with higher PPD (p = 0.012), while age did not have statistically significant effect (F (4,512) = 1.19, p = 0.316). After applying ANOVA adjusted for age and smoking, age remained statistically non-significant on PPD (p = 0.446). Also, when analysis of variance was applied (factorial ANOVA), only smoking showed statistically significant differences in PPD (p = 0.006). There was no difference in clinical attachment loss (CAL) results in cases when the first molar was missing and the second molar was used.

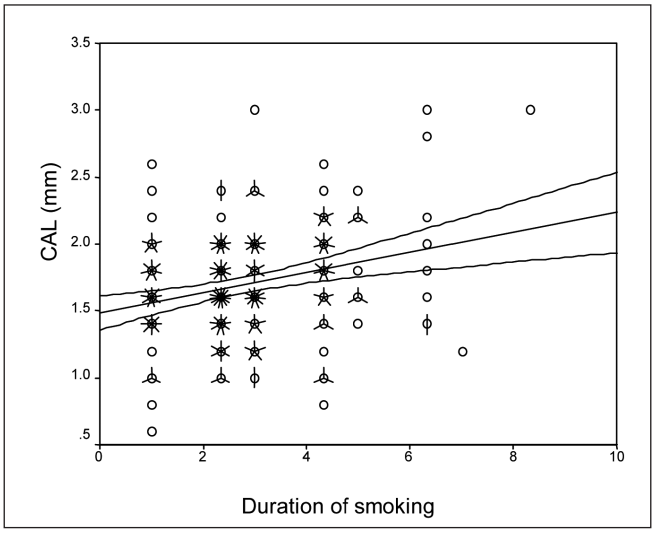

Fig. 1. *Scatter plot demonstrating relationship between periodontal pocket depth in millimetres and duration of smoking in years (p = 0.001).*

Since the difference is statistically significant, but the measured value in mm is small, we calculated the effect size for main variables affecting PPD to investigate its clinical significance. The effect size of smoking on PPD is small ($\eta^2 = 0.012$), only 1% of the variability in PPD can be explained with tobacco use. The effect size of years of smoking on PPD is medium ($\eta^2 = 0.065$), almost 7% of the variability in CAL can be explained by the years of smoking. Bonferroni post hoc test revealed a significant difference in PPD between those who smoke 5 and more years and those who smoke only 1 year (Mean difference = 0.36, p = 0.021, 95% CI difference = 0.032–0.678) and 2 years (Mean difference = 0.33, p = 0.024, 95% CI difference = 0.026–0.638). The effect size of smoking on PPD is small ($\eta^2 = 0.036$), almost 4% of the variability in PPD can be explained with tobacco consumption.

While there *were no differences between oral hygiene habits in smokers and non-smokers, there was a difference between genders with males having poorer oral care ($\chi^2 = 101.1$, df = 2, p < 0.001, OR = 6.8). Teeth brushing showed different results on PPD in the smoking and non-smoking group, with non-smoking subjects PPD being in direct proportion to the frequency of brushing (Table 4, Fig. 2), while the smoking group showed no significant differences related to the frequency of brushing.

Table 4. *Average PPD in millimetres in smokers and non-smokers stratified by oral hygiene habits (N = 517)*

Smoking habit	Brushing frequency	Subjects	Average PPD
Yes	Do not brush	12	1.694
	Once a day	58	1.674
	Two or more times a day	118	1.697
No	Do not brush	15	1.878
	Once a day	105	1.666
	Two or more times a day	209	1.539

PPD – periodontal pocket depth (in mm)

Bleeding on probing was high in all subjects, with smokers tending to show smaller values than non-smokers, while supragingival calculus had greater prevalence among smokers (p < 0.001) (Tables 1 and 3).

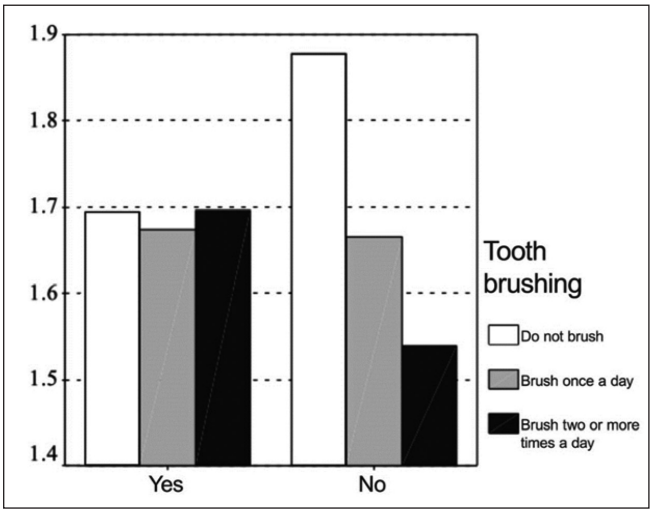

Fig. 2. *Average values of periodontal pocket depth measured in millimetres in smokers and non-smokers stratified by oral hygiene habits (N = 517).*

Table 3. *Bleeding on probing in percentages and supragingival calculus finding in smokers and non-smokers by average number of teeth per subject (N = 517)*

Variable	n	Mean (SD)	95% CI	F	p-value	η^2
Bleeding on probing (%)						
Non-smoker	329	76.93 (24.90)	74.23–79.63	10.81	0.001**	0.021
Smoker	188	69.77 (21.82)	66.63–72.91			
Supragingival calculus (sum)						
Non-smoker	325	0.87 (1.25)	0.73–1.00	27.70	< 0.001***	0.051
Smoker	188	1.47 (1.23)	1.29–1.65			
Supragingival calculus (mean)						
Non-smoker	329	0.15 (0.21)	0.12–0.17	26.14	< 0.001***	0.048
Smoker	188	0.25 (0.21)	0.22–0.27			

**p < 0.01, ***p < 0.001 – statistically significant, ANOVA with Bonferroni test

DISCUSSION

The present study is the first assessment of the periodontal health of adolescents in Croatia. The results of this study provide valuable information about the association between smoking and periodontal health in healthy young teenagers. In our study, periodontal pocket depth was 1.69 mm in subjects who smoked, and 1.59 mm in non-smokers. Difference measured in millimetres was small, but statistically significant ($p=0.012$). As the study examined young subjects, a larger difference in PPD values were not expected. Since PPD increases with age, statistical processing separated the influence of these two variables and demonstrated conclusively that smoking as an independent variable is responsible for this difference. Results of increased PPD as a consequence of smoking are in agreement with findings of several previous studies (13, 14), while research among teenagers in Chile and Santo Domingo, Dominican Republic, failed to show similar results (15, 16). The research of risk factors for periodontal diseases indicates that decrease in periodontal health as a result of smoking is more clearly visible with increasing age of the subject, when subjects smoked more than five years, and with an increasing number of cigarettes smoked daily (14, 17). The results of younger subjects are uneven, because the periodontal disease depends on several risk factors being present over a period of time (18).

Intensity of smoking, measured by the number of cigarettes smoked daily, was positively correlated with increased PPD. These results match the findings of all research that looked into the influence of smoking on periodontal health. Recently, a systematic review article analysed prospective longitudinal studies that addressed the association between tobacco smoking and incidence and progression of periodontitis. The article found that smoking has a detrimental effect on the progression of periodontitis and its incidence (4). The results of the review showed that follow-up time affected the association between tobacco smoking and periodontitis. This could be relevant to our results which showed that adolescents that smoked more than 5 years had 0.36mm of PPD more than non-smokers. The larger difference and association are more prominent in studies where the age of subjects is greater (17). In younger subjects, the difference still exists, but it is smaller. This matches the explanation of the influence of tobacco on the periodontal attachment, which is cumulative and dose dependent (19).

Many studies so far found that bleeding on probing (BOP) is more common in non-smokers (20, 21). Our study, even though our subjects were teenagers, shows the same results. The explanation for this finding is that smoking or, more precisely, nicotine and cigarette smoke, negatively affect the peripheral circulation in the periodontium, leading to its decrease (22, 23), and consequently to lower incidence of BOP. Similar results can be found in a majority of studies (4, 13, 24), whereas only one study indicated reduced bleeding on probing among the non-smoking subjects (25). Furthermore, it was recently shown that smoking affects and modifies the genetic risk for early-onset periodontitis, and that tobacco smoke directly affects the expression of genes involved in bone homeostasis, tissue repair, and immune response (24).

Calculus, as a more common occurrence in smokers, was also reported in several studies (13, 26). Although the studies covered subjects of various age groups, calculus is consistent in all of them. Higher prevalence of supragingival calculus is in accordance with findings of recent studies by Tanner et al. (25) and Vered et al. (26) conducted on several thousand Finnish adolescents and young Israeli adults. We did not expect such a high percentage of teenagers to show calculus deposits in our study, mainly due to their young age and relatively short duration of tobacco use. Interesting results of a study following the subjects at 10 and then 15 years of age, found that change in lifestyle due to smoking within 5 years at this young age is strongly correlated with gingivitis and elevated C-reactive protein (CRP), as factors that contribute to an onset of periodontal disease during a lifetime (27). Diversity of randomly selected high schools included subjects of various educational and social levels, so the sample faithfully represented the diversity of the population of that age in the County of Zadar, where the range of dental care is great and varying and depends on the social environment of the subject.

Oral hygiene habits among the group did not vary. What we found as an interesting new finding, compared to the existing literature and studies on this general topic, is that the pocket probing depth stayed the same regardless of hygiene habits among smokers, while in non-smokers we noted a high increase in PPD in direct proportion to reduced oral hygiene. This could be due to influence of smoke on immunological cells of the crevicular liquid, whose activity is reduced by cigarettes smoke, so the smokers show a less prominent initial stage of inflammation (28). Equally, the smokers with good hygiene show a difference in PPD compared to non-smokers. The only way to explain the difference is the tobacco use itself.

The percentage of smokers in the subject group was 34%. This corresponds to the proportion of smokers in Croatia, while being above the 19% average proportion of smokers in the national high school student population as reported by the WHO in the latest global report (1, 29, 30). At the beginning of 2000, a strong national anti-smoking campaign managed to reduce this percentage a bit, but as the campaign ended, the trend became unstable. It is clearly necessary to encourage the relevant state authorities to start a similar programme, because education is an important factor in preserving dental health of schoolchildren. This was confirmed by Nazir and Almas in their study where schoolchildren with increased awareness of smoking effects on oral health were less likely to smoke (31).

On average, in our investigation adolescents started smoking at the age of 14, which correlates with the transition from primary to high school. This also corresponds with entering adolescence, where children are naturally looking for their own place among their peers, proving themselves to their surroundings, and rebelling against authority (2). Initial age when children start smoking matches smoking statistics of most European countries (29).

Study Limitations

The first limitation of this study is that the periodontal index was not measured at 4 sites per tooth in all teeth. The second limitation is that plaque index data were not recorded, because it was technically impossible within the given time period. The sample represents the population of large cities in Croatia, but not the capital. This is because there is a high concentration of educated population living in the capital (a quarter of the entire population of Croatia lives in the capital). Still, a large sample of subjects of similar age, with a sufficient number of smokers,

and clear, statistically significant differences among the groups, make the results of this study valuable in epidemiology of periodontal disease, and examination of effects of smoking on health of the periodontium.

CONCLUSION

The first signs of impact of smoking as a risk factor for periodontal health can be seen in early teenage years. Decrease in periodontal health, with greater periodontal pocket probing level and greater prevalence of supragingival calculus, was proved to be attributable to the cigarette smoking. While there were no differences between oral hygiene habits in smokers and non-smokers, a decrease in periodontal health parameters in direct proportions with reduced oral habits was noted only in non-smokers. Starting from the premise that prevention is the gold standard of health preservation, it is necessary to target the adolescent population, where tobacco use begins at an average of 14 years of age, with health education programmes and targeted consultations.

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Authors' Contributions

IŠ, DP – study conception, design; IŠ – material preparation, data collection, the first draft of the manuscript; DB – manuscript analysis and revision. All authors read and approved the final manuscript.

Conflict of Interests

None declared

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