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Caries prevalence, oral health behavior, and attitudes in children residing in radiation-contaminated and -noncontaminated towns in Ukraine

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Abstract – *Introduction:* Several studies investigating the oral health status of children living in Ukraine after the Chernobyl catastrophe revealed an increase of caries in children residing in radionucleotide-contaminated areas. *Purpose:* (1) To compare prevalence of dental caries in contaminated and noncontaminated towns; and (2) to determine if there is a difference between dental behaviors and attitudes of children residing in contaminated and noncontaminated areas that may have contributed to differences in caries prevalence. *Methods:* Children aged 13–14 were randomly selected in two towns of approximately the same population size (33 000): Ovruch ($n = 119$) from a contaminated area and Mirgorod ($n = 100$) from a noncontaminated area. Data on behaviors and attitudes were collected via a self-administered questionnaire having six domains: (i) family background; (ii) dental anxiety; (iii) dental utilization; (iv) oral hygiene; (v) use of fluoride toothpaste; and (vi) sugar consumption. Oral examinations included information on carious lesions, restorations, missing teeth, and soft tissue abnormalities. Caries prevalence was compared using a *t*-test. Regression analysis was conducted to determine the independent contribution of oral hygiene behaviors and dental utilization. *Results:* There was a significant difference in caries prevalence in the contaminated town (mean DMFT $= 9.1 \pm 3.5$) versus the noncontaminated town (mean DMFT $= 5.7 \pm 1.4$; $P < 0.000$). Oral hygiene practices, age, and utilization of dental services were not found to be associated with differences in DMFT score between the two communities. *Conclusion:* There was a significantly higher caries prevalence in a radiation-contaminated town compared to a noncontaminated town of Ukraine. The difference was not explained by differences in oral health knowledge, attitudes or behaviors.

Key words: adolescents; dental behavior; dental caries; dental health surveys; DMF score; epidemiology; oral health; radiation; socioeconomic status; Ukraine

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The largest radiation accident involving a nuclear reactor occurred on April 26, 1986 at the Chernobyl Nuclear Power Plant in Ukraine. Heavy contamination spread over large areas of Ukraine and Belarus. It has been estimated that the total radioactivity of the material released from the reactor was 200 times that of the combined releases from the atomic bombs dropped on Hiroshima and Nagasaki. The amount released was about 3–4% of used fuel present in the reactor at the time, as well as up to 100% of noble gases, and 20–60% of volatile nucleotides (1). The nucleotides in the cloud over Chernobyl consisted

mainly of iodine-131, caesium-134, and caesium-137. The radioactive cloud was dispersed by the wind and the nucleotides were deposited as fallout over large areas.

Radioactive materials irradiate the body either through contaminated food or directly from external exposure to contaminated materials such as soil, buildings, etc. Radionucleotides were absorbed into the soil, and radioactivity entered the food chain via vegetables and plants eaten by animals. Drinking water was contaminated, resulting in more widespread exposure to radiation.

Because of the economic hardship in Ukraine, which is largely an agricultural country, the population relies solely on locally produced food. The Ukrainian government cannot afford to import uncontaminated food products to the affected zones. Therefore, people who reside in the contaminated areas are continuously re-exposed to radiation. Table 1 demonstrates the high concentration of caesium in the food grown in the affected areas as compared to acceptable standards.

Deterioration of oral health, and particularly dryness of the mouth, was a common complaint heard by medical teams in the contaminated areas. A number of studies have shown that radiation therapy induces damage in normal tissues resulting in oral sequelae such as xerostomia, mucositis, radiation caries, taste loss, trismus, soft-tissue necrosis, and osteoradionecrosis (2–7). Radiation therapy causes atrophy and fibrosis of the salivary glands, thus producing a permanent decrease in salivary flow and production. An impairment of salivary production often leads to rampant dental decay (8). This increased risk for dental caries probably stems from the loss of the protective power of saliva (9). For example, irradiation-induced xerostomia in patients who have undergone radiation therapy for head and neck cancer is associated with striking changes in oral microflora, including a rapid shift to highly acidogenic organisms such as *Lactobacillus* and *Streptococcus mutans* (10, 11).

Several studies investigating the oral health status of adolescents living in the Ukraine after the Chernobyl catastrophe revealed a high incidence of caries and various pathological changes in oral mucosa (12, 13). The authors of these studies attributed their findings to radiation, but the studies did not consider dental health attitudes, knowledge, behaviors, or diet of the adolescents, all of which potentially could have contributed to the high incidence of caries found in the studies, which may have confounded the results. From the standpoint of prevention, enforcing good dental health behavior is the main goal of interventions aimed at reducing levels of dental caries and periodontal disease. Indeed, a number of studies have found dental attitudes to be the most powerful predictors of dental care utilization (14–16).

Table 1. Presence of radioactive element ^{137}Cs in Ovruch

	Found ^{137}Cs (Bq/kg)	Normal ^{137}Cs (Bq/kg)
Meat	50100	200
Fish	1,240	150
Milk & diary product	718	100
Fruits & vegetables	267	40
Mushrooms	136000	500

The purpose of this investigation was to: (i) compare prevalence of dental caries in two towns in Ukraine, a contaminated and a noncontaminated town; (ii) determine if there is a difference between dental behavior and attitudes of children residing in contaminated areas versus uncontaminated areas in Ukraine that may have contributed to differences in caries prevalence.

Materials and methods

Research design

A cross-sectional study was conducted to evaluate the association between oral health knowledge, attitudes, behaviors, and oral health outcomes in two Ukrainian communities, one exposed to radiation and another that had not been exposed.

Sample selection

The study population consisted of children aged 13–14 who were randomly selected from two comparable towns, Ovruch and Mirgorod in Ukraine. After Chernobyl, officials established five zones to differentiate radiation contamination. Zones 1 and 2 are within a 30 km radius of the reactor site and are uninhabitable. Zones 3 and 4 are radiation-contaminated zones but inhabitable. The city of Ovruch which is 70 km away from the nuclear reactor was selected from the Strictly Controlled Zone (Zone 3) where radioactive contamination of soil is 555–1480 kBq/m^2. Mirgorod is 360 km away from the nuclear reactor and is considered to be in a noncontaminated area (Figs 1 and 2). The population of Ovruch is approximately 33,000 people and it has four public schools. Mirgorod has approximately the same population size and number of public schools. Both communities rely on a nonfluoridated

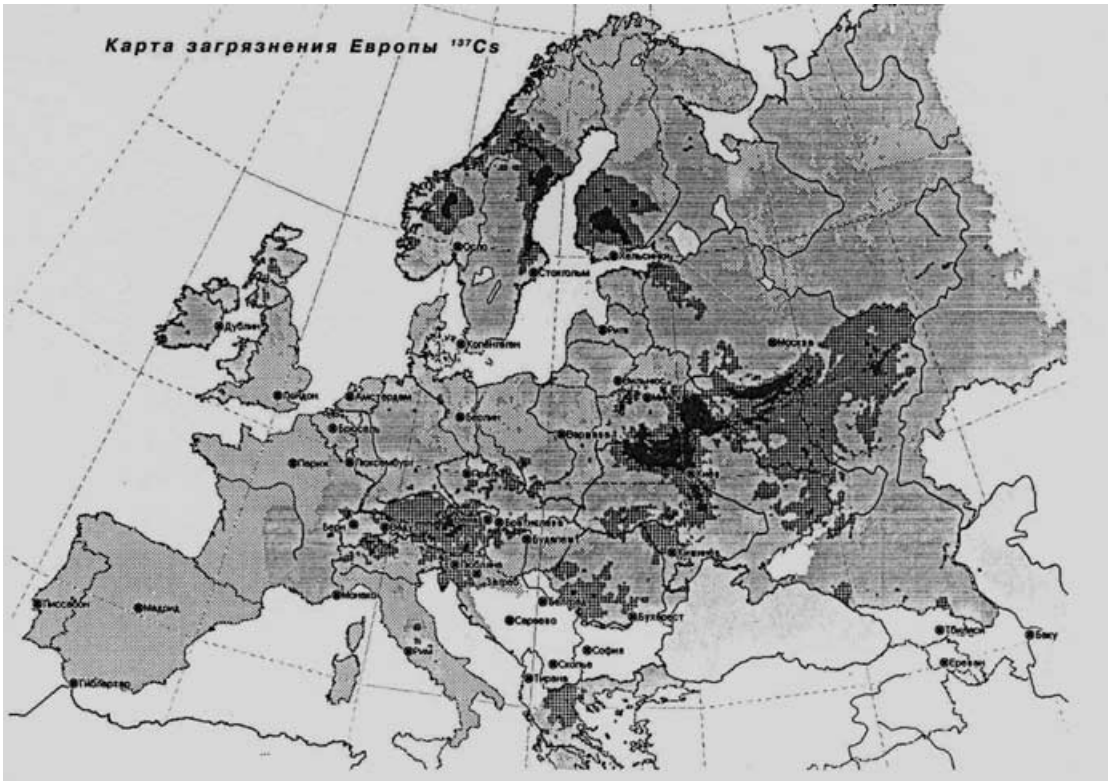

Fig. 1. The map of radiation-contaminated areas of Europe with ^{137}Cs.

municipal water supply for all their water needs. The fluoride concentration was measured in the two towns prior to the investigation. The fluoride levels of drinking water were shown to be 1.4 ppm in Ovruch and 1.9 ppm in Mirgorod.

Twenty-five percent of 8th graders, aged 13–14 (150 children) from each town were randomly selected, of these 119 (48% female, 52% male) from Ovruch and 100 (50% female, 50% male) from Mirgorod participated. The Education Authority of each town provided a list of all students in each school that was used to randomly select the children. The children's parents were contacted using school records that provided the most recent addresses and phone numbers of all attending students. The parents and children were provided with the

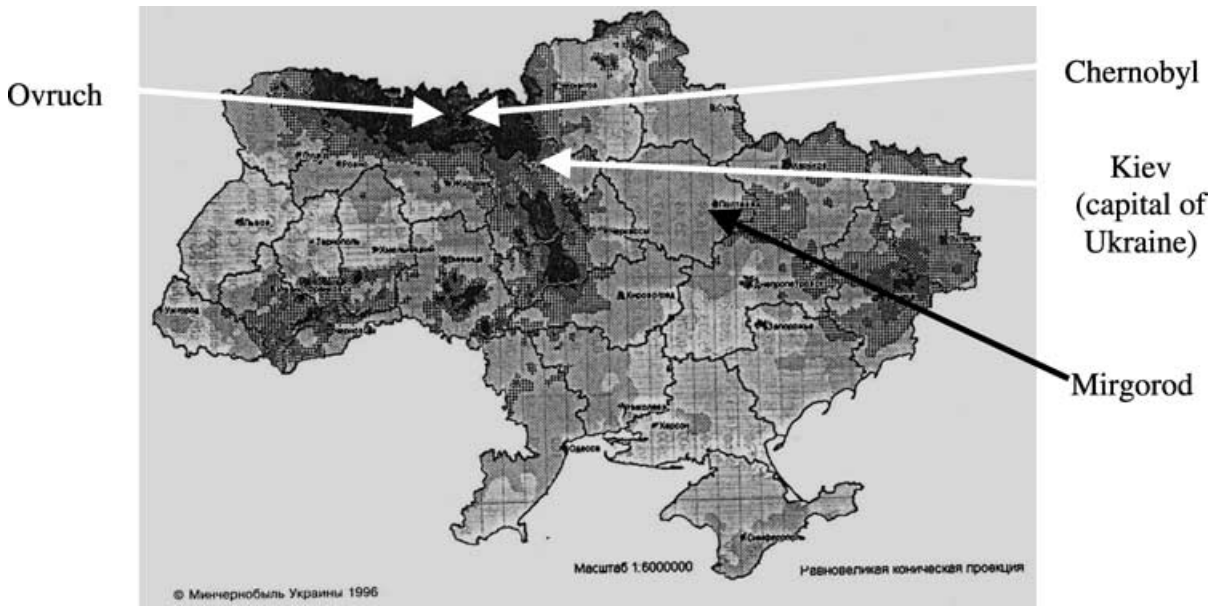

Fig. 2. Map of Ukraine showing areas contaminated by radiation from ^{137}Cs.

outline, aims, and procedures of the study. Parents provided a verbal consent by telephone for the enrolment of their children in the study and gave permission for an examination and completion of questionnaire. The clinic director at each site reviewed and gave written approval for the study proposal.

Survey procedure

Randomly selected individuals were contacted by telephone and asked to fill out a questionnaire at each city's Children's Dental Clinic, which permitted us to use its facility. The selected individuals were given a basic explanation of the request and told that a free toothbrush and toothpaste sample would be given to the participants at the end.

The questionnaires were completed in the dental clinic and supervised by one of the authors (K.S.). A standard introduction that outlined the purpose of the study and the confidential nature of the information was provided to the participants. The adolescents who participated in the study were allowed a few minutes to look over the questionnaire and ask any questions concerning its contents. Care was taken to ensure that the entire questionnaire was completed independently and without consultation from other individuals. The moderator was available while the questionnaire was completed to address any problems that arose. Most of the children completed the questionnaire in approximately 20–25 min.

Survey description

A self-administered, structured questionnaire was developed and finalised following piloting of a small number of children of similar age group (available on request from the author). The questionnaire had six domains: (i) personal and family background; (ii) measurements of dental anxiety; (iii) dental experience and attendance; (iv) oral cleanliness habits; (v) the use of fluoride toothpaste; and (vi) information on sugar consumption. The survey had been revised several times and field tested.

Clinical examinations

A dental screening examination was conducted in order to assess the current oral health status of the participants. At each clinic, a single dentist conducted all dental examinations; they were unaware of the results of the questionnaire survey at the time of examination. There was no calibration between these two individuals. Illumination was provided by a Daray lamp placed 1 m from the subject's head. Examinations were performed using a plane mirror and explorer without drying the teeth. No radiographs were taken. The chart for each child contained the following information:

1. Number of teeth and the status of each tooth (decayed, missing and filled).
2. Any abnormalities/lesions of the soft tissues of cheeks, gums, tongue, floor of the mouth, roof of the mouth, and lips.

The clinical examination data were used to calculate the DMFT scores for each study subject. Soft tissue lesions were recorded, but the low prevalence of such lesions did not warrant evaluation. The DMFT scores were compared to determine if differences existed between study groups. The findings of the clinical examinations were correlated with the interview data to determine if differences in knowledge and attitudes were associated with oral health status.

Data analysis

The clinical findings and questionnaire data were entered into an Excel spread sheet and were analyzed using STATA. Descriptive statistics were calculated for all study variables. The mean caries rate comparing the two towns was compared using a *t*-test. The differences between the two towns with respect to socioeconomic status, dental health behavior, knowledge, and attitudes as well as diet were compared using a chi-square test. Regression analysis was conducted to determine the independent contribution of oral hygiene behaviors, dental utilization, family background, dental anxiety, fluoride, and sugar consumption.

Results

Table 2 summarizes the socioeconomic status of the parents of children in the study sample. Table 2 includes the data on the parents' education and if the parents received their salary on time. Because of economic hardship in Ukraine, the government and private sector often cannot pay salaries on time. Table 2 shows that there is no statistical difference in the parents' level of education between the towns; 71% of the parents in Ovruch had completed a college education versus 77% of parents in Mirgorod ($P = 0.306$). Concerning timely salary compensation, 30 and 22% did not receive a salary within 3–6 months, and 68 and 77% received a salary after 6 months in Ovruch and Mirgorod, respectively. There was no statistically significant difference

Table 2. Socioeconomic status of children by town

Category	Ovruch $n = 119$ (%)	Mirgorod $n = 100$ (%)	Chi-square P-value
Parent education			0.306
High school	33 (29)	22 (23)	
College	79 (71)	73 (77)	
Receive salary on time			0.294
Within 3 months	2 (2)	1 (1)	
Between 3 and 6 months	37 (30)	22 (22)	
After 6 months	81 (68)	77 (77)	

Table 3. DMFT by town

	Ovruch (mean ± SD)	Mirgorod (mean ± SD)	t-test P-value
DMFT	9.1 ± 3.5	5.7 ± 1.4	< 0.001
Decayed teeth	3.3 ± 2.9	0.3 ± 0.5	< 0.001
Missing teeth	4.4 ± 0.9	4.3 ± 0.6	0.381
Filled teeth	1.4 ± 1.6	1.1 ± 1.1	0.147

($P = 0.294$) with respect to the parents' receiving salary on time between Ovruch and Mirgorod.

Table 3 presents the difference in DMFT scores between the two towns. These data indicate that children who reside in the radiation-contaminated town have a higher dental caries rate than those children who reside in the noncontaminated town. Table 3 shows that the mean DMFT values were found to be significantly different for children who reside in Ovruch ($P < 0.001$) (mean = 9.1 ± 3.5) versus Mirgorod (mean = 5.7 ± 1.4). The decayed component of the DMFT accounted for the higher DMFT score in Ovruch. There was a statistically significant difference in the number of decayed teeth in Ovruch (mean = 3.3 ± 2.9) than Mirgorod (mean = 0.3 ± 0.5). There was no significant difference between the two towns in the number of missing or filled teeth of the participants.

Table 4 contains information on the dental health behaviors of children in the two communities. The frequencies of brushing reported by the children who resided in Ovruch and Mirgorod were, once a day = 58% versus 54%; and less than once a day = 24% versus 36%, respectively. Concerning toothbrushing habits, there was no significant difference found between the towns ($P = 0.055$). No difference ($P = 0.253$) in dental attendance was observed; the majority of children had a dental visit 'within the past 1 year' (86 and 92%); fewer had not seen the dentist in more than 1 year (7 and 6%) in Ovruch and Mirgorod, respectively. The results showed a clear difference in fluoride toothpaste use in children; participants who resided in the noncontaminated town showed a lower use of fluoride toothpaste ($P = 0.001$).

Dental knowledge and attitude questions were included in the questionnaire. Table 5 shows that dental anxiety levels were significantly lower in the children who lived in the contaminated area when compared to children from the noncontaminated area. In Ovruch, fewer children reported fear of dental equipment ($P = 0.008$) and pain in general ($P = 0.008$). On the other hand, there was no statistical difference found between children from the two areas in terms of fear of dental providers ($P = 0.236$). With respect to oral health knowledge, the majority of the children in both towns were aware that poor oral hygiene contributed to caries ($P = 0.171$).

When candy and chocolate consumption were compared between the two towns, the results

Table 4. Dental health behavior of children by town

Category	Ovruch $n = 119$ (%)	Mirgorod $n = 100$ (%)	Chi-square P-value
Tooth brushing frequency			0.055
Twice or more daily	22 (18)	10 (10)	
Once a day	70 (58)	54 (54)	
Less often	28 (24)	36 (36)	
Dental attendance			0.253
Within the past 1 year	103 (86)	88 (92)	
>1 year	9 (7)	6 (6)	
Never	8 (7)	2 (2)	
Use of fluoride toothpaste			0.007
Yes	100 (84)	68 (69)	
No	19 (16)	31 (31)	

Table 5. Dental attitudes and knowledge of children by town

Category	Ovruch $n = 119$ (%)	Mirgorod $n = 100$ (%)	Chi-square P-value
Afraid of dental equipment			0.008
Yes	51 (48)	51 (68)	
No	55 (52)	24 (32)	
Afraid of pain			0.008
Yes	52 (48)	54 (68)	
No	56 (52)	26 (32)	
Afraid of dentist			0.236
Yes	9 (9)	9 (15)	
No	92 (91)	51 (85)	
Poor oral hygiene contributes to caries			0.171
Yes	103 (90)	90 (95)	
No	12 (10)	5 (5)	

Table 6. Difference in diet of children by town

Category	Ovruch $n = 119$ (%)	Mirgorod $n = 100$ (%)	Chi-square P-value
Cookies, cakes and pies			0.403
More than once a day	32 (27)	20 (20)	
Once a day	35 (30)	36 (37)	
Less often	51 (43)	42 (43)	
Candy and chocolates			0.577
More than once a day	26 (23)	16 (17)	
Once a day	31 (27)	29 (31)	
Less often	57 (50)	48 (52)	

indicated that 50 and 52% consumed these products less than once a day, 27 and 31% once a day, and 23 and 17% more than once a day, in Ovruch and Mirgorod, respectively ($P = 0.577$). With regard to cookies, cakes, and pies, similar results were obtained, and there was no difference between the two towns ($P = 0.403$) (Table 6).

The results of the linear regression analysis are presented in Table 7. We included in the linear regression model all variables that were found to be significant in the bivariate analysis (town, sex, use of fluoride toothpaste, fear of pain, and dental equipment) and found that only the town remained significant in the multivariate model.

Discussion

The results of this investigation demonstrate that there was a difference in prevalence of dental caries in two towns from a contaminated and a noncontaminated area of Ukraine, and further that this difference was not explained by dental behavior, attitudes of children or socioeconomic status of their families.

Dental health behavior

Health-conscious behavior, which is reflected in sensible eating habits and regular oral hygiene using a fluoridated dentifrice, has been shown to reduce

Table 7. Linear regression analysis: DMFT and selected variables

Model	Unstandardized coefficients (B)	SE	Standardized coefficients (Beta)	t	Significance
1 (Constant)	13.512	1.677		8.057	<0.001
Town	−3.558	0.481	−0.519	−7.395	<0.001
Use of fluoride toothpaste	−0.297	0.351	−0.058	−0.847	0.398
Afraid of dental equipment	−1.091	0.558	−0.162	−1.954	0.052
Afraid of pain	0.219	0.562	0.033	0.390	0.697
Toothbrushing frequency	0.573	0.523	0.076	1.095	0.275
Sex	0.266	0.467	0.039	0.569	0.570

Dependent variable: DMFT.

caries incidence (14, 15). The results of the inquiries into dental health behaviors, particularly dental attendance, indicated that regular visits to a dentist were the same for children from both towns. Approximately 90% of the children saw a dentist at least once a year. Ukrainian prophylaxis standards differ from other industrialized nations; a child is expected to see a dental provider at least once a year. In Ukraine, each school has a dentist on staff who provides routine dental care to all enrolled students or refers to a dental clinic, if he or she comes across a complicated case. Students are screened by a dentist, informed of treatment needs and encouraged to attend. The present study also showed that children may only seek treatment when they are in pain. This occurred, despite the availability of free dental care with the general practitioner of their choice.

The present study demonstrates no significant difference in brushing frequency between children who resided in the contaminated area versus the noncontaminated area, thus implying that brushing frequency did not affect the differences in DMFT values in this study. The results of the inquiries into dental health behaviors demonstrated that only half of the children in both towns brushed at least once a day and almost 70% of the children from the two towns have never used dental floss and they were not familiar with it. While the frequency with which teeth are brushed does not necessarily imply effective plaque removal, as far as a caries-preventive effect is concerned, frequency of brushing is crucial, as fluoride toothpaste is effective, even when an unsatisfactory brushing technique is employed (17).

It is well known that fluoride significantly contributes to caries prevention. The effect of fluoride depends on the fluoride concentration in the mouth; therefore regular fluoride exposure is of crucial importance in reducing caries (15). Although the drinking water is not fluoridated in either community, the natural fluoride concentration in the drinking water was higher than the recommended level in both towns (Ovruch = 1.4 ppm and Mirgorod = 1.9 ppm). Therefore, fluoride concentration was unlikely to have been the sole contributing factor to explain the significant difference in DMFT values between the two towns. The hallmark 21 Cities Study did not demonstrate a difference in caries prevalence between these two levels of fluoridated water (18, 19). Although it is impossible to know to what extent the 0.5 ppm difference in F levels between two towns had effect on difference in caries rates, it is unlikely that it is the sole explanation for the observed differences. It is interesting to note that we observed a significant difference in fluoride toothpaste use. Children who lived in the contaminated area were found to use fluoride toothpaste significantly more than children from the noncontaminated area. This behavior should have protected them from caries, but when fluoride toothpaste use was plotted in a regression analysis against DMFT value, fluoride toothpaste did not contribute to DMFT difference.

Dental attitudes and knowledge

Our study showed that there was a dental anxiety difference between the two communities. It appeared that children who resided in the noncontaminated area of Ukraine were more dentally anxious than children from the contaminated area. However, when the dental anxiety data were analyzed in the regression analysis against the DMFT score, it showed that difference in dental anxiety did not explain the statistical difference in the DMFT score between the two towns. The oral health knowledge of children was found to be adequate in both towns.

In previous studies, dental anxiety has been shown to be associated with a range of adverse behavioral and dental health characteristics (16). It has been established from a number of studies that dentally anxious patients avoid visiting the dentist, or while undergoing dental treatment, display behavioral problems. The dentally anxious more accurately perceived their treatment need, and were more likely to defer, cancel or not turn up for a dental appointment (20). They are also more likely to have decayed teeth. This would appear to be the inevitable consequence of personal neglect and avoidance of dental care as the result of anxiety (21).

Diet

This investigation demonstrated that half of the children in both communities had a sugar intake of 'less than once a day' and an additional one-third of them at 'once a day'. This is not surprising given the difficult economic situation which prohibits the purchase of this type of food. Because there was no significant difference between the two towns, diet was not considered as a contributing factor to the difference in DMFT score in this study.

DMFT score

The DMFT scores differed significantly between the two towns, with the D (decayed) component accounting for the difference. The difference in

dental behavior, attitude, and knowledge was not statistically significant and did not explain the difference in the prevalence of caries between the children residing in the two towns. As the above factors were not statistically significant, it can be hypothesized that the high prevalence of caries may be attributed to continuous radiation re-exposure through the consumption of locally produced food, contaminated water, and direct external exposure to contaminated buildings, soil, etc.

Limitations and future follow-up study

Although the results of this study highlighted some important observations about caries prevalence, dental health behaviors, attitudes, and knowledge in children, there are limitations which must be considered. There was the possibility that children increasingly gave the 'right' answer, rather than the truth. In addition, 40% of children in Mirgorod did not respond to the question regarding 'fear of dentists'. Although this is a large proportion of respondents it is unlikely that it provides the sole explanation for the observed differences. The examinations in the two towns were conducted by two independent examiners who were not calibrated, thus the observed difference may be related to the lack of calibration. This was a cross-sectional study which limits the implications of the findings. The future follow-up study should include a measure of salivary flow rate which can be correlated with the data obtained from the clinical examination using calibrated examiners and the self-administered questionnaire.

Implications

This study demonstrated a need for oral health education in both towns. Additionally, there is a need for further intervention to meet the dental needs of children residing in both towns. There appeared to be a need not only for traditional oral health advice from dental care providers, but also for a comprehensive community participatory oral health promotion initiative in coordination with other health care providers to emphasize the use of primary prevention (23). The goal of the planned health education programs is not only to bring about new behavior but also to reinforce and maintain health behaviors that will promote and improve individual and community health. Schools would be the most suitable environment to promote a health education program.

Although this is an important initiative, one needs to understand that the Ukrainian budget for health care is very limited, and, comparatively speaking, oral health has a low official priority.

Conclusion

The present study found that there was higher dental caries rate in children from radiation-contaminated areas compared to children from non-contaminated areas of Ukraine, which was not explained by differences in dental behavior, attitude, and knowledge. Therefore, we can hypothesize that continuous radiation re-exposure of children residing in Ovruch is a potential contributing factor to the difference in DMFT score between two communities. Further study of this comparison should be carried out to confirm these findings.

Acknowledgments

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