RĪGAS STRADIŅA UNIVERSITĀTE

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THE ROLE OF CARIES RISK ASSESSMENT METHODS IN THE DEVELOPMENT OF PREVENTIVE PROGRAMMES IN HIGH RISK REGION

Summary of Doctoral Thesis

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INTRODUCTION

Caries continue to be a problem throughout society, a problem that remains unsolved by both health providers, and by politicians (Editorial, The Lancet, 2009). Every day, many adults and small children experience pain due to caries that, to a certain extent, influence their quality of life (Petersen et al, 2010).

In Latvia in 2001, the prevalence of caries in 12 year olds still exceeds 70% (Bērziņa, 2004), and in the 21st century very few epidemiological studies have been conducted, which does not allow us to evaluate how the situation has changed in the last decade. Caries are usually only registered in the late stages when the cavity has already developed or when the tooth has been filled or extracted; however, it is widely known that the disease begins much earlier. Caries can be visually estimated several years prior to the development of the cavity, and detection at the early stages of the caries would allow purposeful caries treatment, interrupting early tooth damage and preventing its development, thus possibly delaying much greater tissue loss and the need for restoration with artificial materials (Pitts, 2004a) (Figure 1).

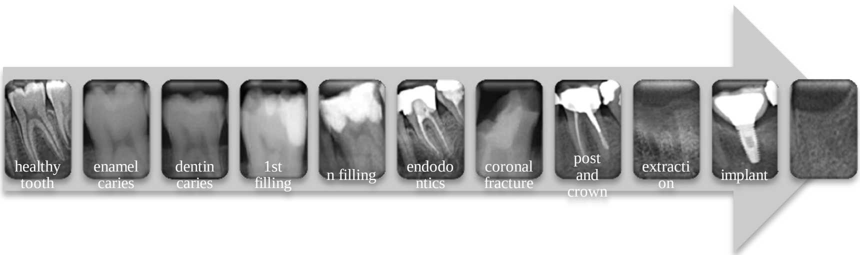


Figure 1. Life-hystory of the tooth
(X-rays from archives of Assoc. Prof. Sergio Uribe)

To support a decrease in caries prevalence, evidence-based preventive methods have to be introduced into practice in wide-ranging, long-term programmes. As has been proven, school is an ideal environment for such activities (Petersen et al., 2010). Discussions have involved taking a high-risk approach with preventive programmes – this would mean applying preventive methods only to high caries risk groups, thus saving financial resources. But in order for such programmes to be implemented, one has to estimate the caries risk – the possibility that the disease will develop in the future. This is already a great challenge (Burt, 2005).

Objectives: The objective of the current study is to evaluate the role of caries risk assessment methods in the development of preventive programmes in high risk regions.

Structure of the study: The study included three sections: (1) an epidemiological study to evaluate caries prevalence, severity, incidence and risk factors in 12- to 13-year-old schoolchildren in the Gulbene region; (2) a cohort study to evaluate the accuracy and cost effectiveness of caries risk assessment (CRA) methods using *Cariogram*, *CAMBRA* and Experimental 4-factor models on Gulbene region schoolchildren; and (3) a randomized controlled clinical trial to evaluate the effectiveness of the school prevention programme (toothbrushing in a school environment) for schoolchildren in the Gulbene region.

Novelty of research: For the first time in Latvia, ICDAS II was used for caries registration in an epidemiological study, which allowed us to assess real caries experience, including the early stages of caries. The significant caries index (SiC) was determined, showing caries experience in the part of the study group with the highest caries score. Three different CRA methods were used in the study – *Cariogram, CAMBRA,* and one that was formed especially for this study population, trying to simplify and to make the CRA process more cost effective for introduction in further epidemiological studies. It has been proven that in a high caries risk population, the CRA methods are not effective; additionally, it has been established that for each population there should be a customized CRA algorithm. It has been proven that caries progress can be reduced by introducing school programmes involving toothbrushing with fluoride toothpaste.

1. Evaluation of caries prevalence, severity and risk factors in 12- to 13-year-old schoolchildren in the Gulbene region

Aim of study: The aim of this study is to discover caries prevalence, severity, incidence and risk factors in 12- to 13-year-old schoolchildren in the Gulbene region.

Methods

Study design: An observational cohort study began in September 2009 (initial examination phase) and was completed in September 2010 (final examination phase).

Study location: The Gulbene region is the largest in the historical Vidzeme county, with an area of 1,876.1 km^2. The population in 2009 was 25,546, which makes the population density 13.62 people/km^2. Gulbene town area is 11.898 km^2, and the population density in 2009 was 785 people/km^2. Gulbene is situated 181 km from the capital of Latvia, Riga, and 60 km from Latvia's eastern border.

The average monthly salary in Vidzeme county was 173.46 LVL in 2009, while the average monthly salary in Latvia at the time reached 225.89 LVL. The unemployment level in the respective time period was 11.8%.

The natural fluoride level in the drinking water of Gulbene county ranges from 0.2-0.3 mg/l, and, as in Latvia, water fluoridation has never been introduced. Fluoride-containing toothpastes have been available since the 1980s, but they only took a prominent place in the market from the early 1990s. Fluoridated salt (250 mg/kg) is available in markets, and in pharmacies – with or without a doctor's prescription – people can buy NaF tablets (1.1 mg and 2.2 mg).

Gulbene has one of the lowest rates of access to dentistry services in Latvia, which was a reason for including this region in the study. Since the third study phase will investigate the effectiveness of the preventive method for caries risk decrease, it is essential that the results observed are attained due to the experimental programme and not because of the influence of individual specialists. In the Gulbene region in 2009, there was one dentist per 3,194 people and one dental hygienist per 25,546 people; while in Latvia, on average, there was one dentist per 1,514 people and one dental hygienist per 10,926 people. Additionally, in 2009 in Latvia there were two mobile dentist's offices, which provided dental service availability in Latvian rural regions, and since the beginning of 2011 in Latvia there has been a third mobile dentist's office, which provides extra support in Zemgale county.

On starting the study there were 18 schools in Gulbene county, three of which were situated in Gulbene town and 15 in the county. In 2009, Revele Elementary School was closed, thus decreasing the number of schools to 17.

Study settings: Both initial and final dental examinations were carried out on the school premises using a portable light source, a dentist's mirror and a probe for the removal of plaque. Caries diagnostics was done visually, not by applying the probing technique (Pitts, 2001). For moisture control, cotton rolls were used (Pitts, 2009). Radiographic examination was not done. Both the interviews and clinical examinations were performed by the author of the study.

Study participants: The selection of study subjects was done by a simple random sampling method. The 12- to 13year-old schoolchildren group corresponds to 6th and 7th grade children. Of the number of children in all 17 Gulbene county schools, grades 6 and 7 (406 schoolchildren), each pupil was assigned a 4-digit code where the first two digits represented the school and the second two the sequence number on the class register. In order that the data would accurately characterize the Gulbene county 12- to 13-year-old schoolchildren population, the study included 122 pupils from the 6th and 7th grades, which corresponds to 30% of the relevant population. Using Microsoft Visual FoxPro, 188 pupils were selected (including more schoolchildren than planned to compensate for the refusal of potential participants and drop-outs during the observation period).

Corresponding to each pupil's code, schools were given explanatory letters with a consent form for parents. Teachers, according to the numbers on the schoolchildren's register, distributed the letters. Students were included in the study only after informed parents' written consent was received with the child's name and surname. In total, 138 parental consent forms were received (the response rate was 73.4%), but by the beginning of the study one family had moved out of Latvia and one child had not been at school on initial examination day – the study was therefore started with 136 pupils, which makes up 33.5% of the Gulbene county 12- to 13-year-old population.

On the final examination day of the study, eight pupils were absent from school, two pupils had moved to a different region, and three refused to continue with their participation in the study. Consequently, 123 schoolchildren were examined in the final study phase (follow-up rate was 90.44%).

Outcomes: Both in the initial and final dental examinations, the students' anamnesis were acquired through interviews, while additional information on their parents' education level was obtained via a questionnaire for the parents (the response rate for the parental questionnaire was 61.8%). The use of interviews provided for additional questions to ensure that the acquired information was as accurate as possible.

Clinical examination included caries diagnostics, using the codes of the ICDAS – the International Caries Detection and Assessment System (Pitts, 2009; Topping et al., 2009). For the registration of caries scores, five indices were used – D_3MFT, D_3MFS, D_1MFT, D_1MFS and the SiC index. The amount of plaque was assessed by the Silness-Löe index (Silness, Löe, 1964).

Saliva examination included three chair-side diagnostic tests – stimulated saliva secretion rate, saliva buffer capacity (GC Saliva Check Buffer, GC Europa) and the amount of bacteria in saliva (Streptococcus mutants (SM) and Lactobacillus spp. (LB)) (CRT Bacteria, Ivoclar Vivadent, Switzerland).

Caries risk was determined by the *Cariogram* method (Malmö University, Sweden) (Bratthal, 1996).

Statistical analysis: Data was analyzed for 136 participants in the initial phase and 123 in the final phase. For the assessment of caries prevalence, rate, incidence and risk factors, descriptive statistical methods were used. To evaluate whether the data corresponded to the normal distribution, the Kolmogrov-Smirnov test was used. For the comparison of results in 2009 and 2010, a Wilcoxon signed-rank test and paired sample t-test was used.

To determine which caries risk factors influence caries incidence, a multivariable logistic regression was used.

Results

In the initial study phase, 136 students (33.5% of the 12- to 13-year-old schoolchildren population of Gulbene county) were examined, including 69 boys (50.7%) and 67 girls (49.3%).

Caries prevalence was 89% and the mean D_3MFT index (SD) was 5.61 (4.22); the D_3MFS was 8.85 (8.77); the D_1MFT was 10.56 (6.36); the D_1MFS was 17.04 (13.15); and the SiC index was 10.38. Only 37.8% of teenagers had a D_3MFT value of 3 or lower. On average, the Silness-Löe index was 1.78 (0.67), which points to poor oral hygiene of the students. Visible dental plaque could be observed in 86.8% of students.

The salivary examination showed that 28% of students had a decreased saliva secretion rate (less than 1 ml/min); only 21% had a high buffer capacity; and 78% had a high level of SM and LB in saliva ($>10^5$ CFU).

According to information obtained from interviews, questionnaires and the clinical and saliva examinations, CRA was done for each student (Figure 1.1.).

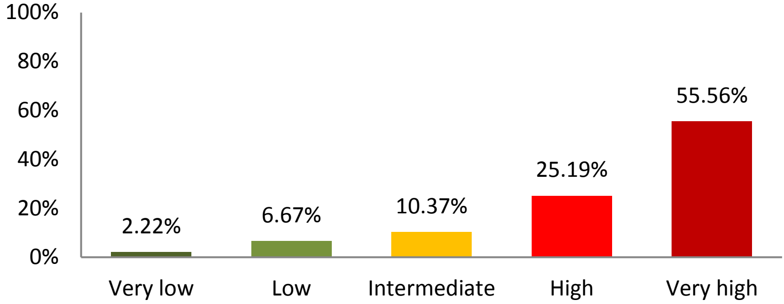
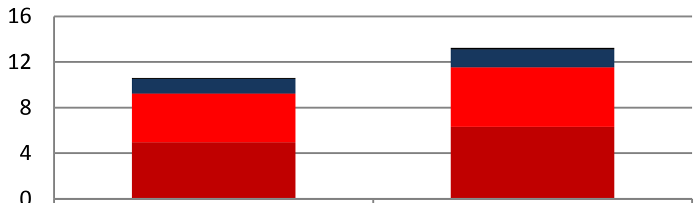


Figure 1.1. Caries risk groups by *Cariogram* (2009)

Within the year, the amount of plaque remarkably increased (from 1.78 to 2.01; p<0,0005), caries risk increased (from 91.11% in the high risk group to 96.75%; p=0.042), as well as all caries severity indices (p<0,0005) (Figure 1.2.).



	2009	2010
M	0.07	0.14
F	1.30	1.59
D3	4.26	5.20
D1	4.96	6.32

Figure 1.2. Caries experience in the initial and final study phases

In the logistic regression analysis, seven independent variables were included, expressed by binary values: previous caries experience (caries free (0) or with caries experience at D_1 level (1)); general illnesses (none (0) or existent

(1)); food content (4-5 times a day, snacks and "noncaries" products (0) or >5 times per day, with fermentable carbohydrate-containing products in snacks(1)); the amount of plaque (no visible plaque (0) or visible plaque (1)); the saliva buffer capacity (high (0) or lowered (1)); regular visits to the dentist (visits the dentist at least once a year (0), rarer than once a year (1)); and smoking (does not smoke (0), has smoked in the last six months(1)).

Table 1.1. shows that neither the risk factors, nor a combination thereof, have a statistically significant effect on the caries increase within a year; however, the odds ratio (OR) values point to the fact that children with previous caries experience have on average a 4.2 times higher risk for new caries to develop. If plaque is found on the teeth, the caries risk increases 2.2 times; "cariogenic" food and rare visits to the dentist double the risk for new caries to develop.

Table 1.1.

Role of risk factors in caries progression using a logistic regression analysis

Factors	Coefficient	p value	OR	CI 95%
Caries experience	1.44	0.35	4.22	0.20 – 87.01
General diseases	0.79	0.40	0.45	0.07 – 2.87
Diet	0.70	0.17	2.01	0.74 – 5.47
Plaque	0.78	0.12	2.17	0.82 – 5.74
Saliva buffer capacity	0.29	0.19	1.34	0.86 – 2.09
Dental check-ups	0.69	0.40	2.00	0.41 – 9.86
Smoking	0.34	0.64	0.71	0.17 – 3.05
Chi-square (7) = 7.79				
p = 0.35				

Discussion

In the current study, a very high caries prevalence, rate and incidence within one year was found, but when applying a multivariable logistic regression analysis not a single definite caries risk factor, nor a combination thereof, emerged within the population.

Caries prevalence in 2009 was 89%, which increased to almost 92% within a year. A similar caries prevalence in the epidemiological studies of the 21st century was found only in Russia (Gorbatova et al., 2012), New Zealand (Gowda et al., 2009), India (Grewal et al., 2009) and Greenland (Petersen et al., 2006), but in all the mentioned countries the caries experience was evidently lower, most commonly not exceeding, on average, two damaged teeth (DMFT). The only country with a similar situation in respect to prevalence and experience is Lithuania, where in some regions the DMFT value reaches 5 (Milčiuviene et al, 2009).

When comparing the current findings with earlier caries prevalence studies in Latvia, no improvement is seen. When in the first international study after regaining of independence a serious caries problem was found in Latvia (Urtāne et al., 1994), Bjarnsone and co-authors wrote that in Latvia the situation at the beginning of the 1990s was similar to that in which the majority of European countries were 10 years ago, and that by introducing fluoride and educational prevention programmes now, Latvia will experience a remarkable decrease of caries prevalence as well (Bjarnson et al., 1995). However, this was not found to be the case in 2001 (Bērziņa, 2004), when there was only a slight decrease of prevalence but no decrease of caries experience. In 2009, 16 years after the ICS-II (International Collaborative Study) (Urtāne et al, 1994), no improvement of the situation was seen in Gulbene county.

It can be asserted that in Gulbene the WHO aim, which was set for the year 2000, has not yet been achieved even in 2009 (the DMFT still exceeds 3); and there are no signs of approaching the next target whereby the SiC index would not exceed the value 3 (Brathall, 2000), because in the current region it still exceeds 10. There are only a few epidemiological studies where the SiC index value is estimated; for comparison, in the state of Nevada in the USA it is 6.74 (Ditmyer et al., 2011), which is also a high value and far from the WHO target, while in Zurich its value in 2009 was already 2.20 (Steiner et al., 2010).

Different epidemiologic studies are not equally comparable, especially to the data of the current study, because of several limitations. Although all children were examined only by one specialist, the author of the study was not calibrated with other specialists and no intra-examiner reliability was assessed. The results are likely to have been underestimated, because only visual caries diagnostics was used without an X-ray examination (Gowda et al., 2009b).

The caries increase within the year should also be evaluated at the enamel caries level, especially for teenagers, when permanent dentition is forming and new proximal surfaces are appearing, but due to contact between teeth the damage is often not visible without a Bite-Wing examination (Gowda et al., 2009b). Considering this, caries incidence has probably affected more than 80% of children.

Caries in epidemiological studies are rarely registered at the D_1 level, therefore, in comparison with other populations, it should be mentioned that the caries incidence in the cavity level affected 60% of Gulbene teenagers. Besides this, the mean incidence value was 2.58 DMFS in one year, which is twice as much as in Sweden 10 years ago in the high risk 10- to 11-year-old population (1.3 DFS per year) (Hänsel Petersson et al., 2003).

The data of the study does not allow us to judge adequately the objective reasons for caries progression because, according to the multivariable analysis, neither of those factors showed statistically significant influence.

Several caries risk factors were observed in the study population, including previous caries experience, the amount of plaque, the saliva secretion rate and buffer capacity, the amount of microoragnisms in saliva, the general health and use of medication, regular visits to the dentist and access to dentists' services, dietary habits, smoking, the frequency of toothbrushing and the use of fluorides, as well as parents' education level. Some significant factors or predictors mentioned in the literature were not assessed – such as the childrens' socioeconomic situation (Ferro et al., 2012), whether they belong to a certain ethnic group, their body mass index (Ditmyer et al., 2011) and the morphology of the occlusal dental surfaces (Sánchez Pérez et al., 2008).

Almost 90% of teenagers have some caries experience, and the average damaged teeth in cavity level was 4.22, which evidently explains the high amount of microorganisms in saliva (Takahashi et al., 2011).

In the DMFT index, the proportion of filled teeth was 23%, but those caries with cavities were 76%, which points to insufficient dental care. Although all children theoretically live within 30 minutes of a dentist, the reality that there is only one dentist per more than 3,000 people in such a high caries risk population is insufficient, especially considering that because of the inadequate payment for public dental services, dentists are not interested in treating children, and the elective appointment line for children is longer than that for adults. In addition, the existence of one dental hygienist in a county with a population of more than 25,000 is not sufficient, and the mentioned specialist cannot do either individual preventive work with patients or participate in public health programmes, which is the professional standard for dental hygienists.

No great differences were seen in eating habits – most children prefer sugar-containing products, consuming them several times a day. Since the specificity of the region points to its low socioeconomic situation, and the majority of children live in the countryside, children mostly consume sweets at school. Therefore, this emphasizes the necessity of school programmes that include both restrictions on sweets and provision of information about the harm they can cause (Petersen et al., 2004; Tomar et al., 2009; Petersen et al., 2010).

The current study showed that 11% of 12 to 13 year olds either smoke or have smoked during the last 6 months, which, in comparison with the data of the National Health Agency report, is lower prevalence than the 54% of 13-year-old Latvian schoolchildren who have tried smoking (ESPAD, 2007). Smoking not only increases the general health risks but also weakens oral mucosa, as well as increases caries risk (Campus et al., 2011; Ditmyer et al., 2011).

Toothbrushing with a fluoride toothpaste is still the most effective method for caries prevention (Marinho et al., 2009b), but only one-third of children admit that they brush at least twice a day. Although the majority of teenagers claim to brush at least once a day, almost 90% of schoolchildren had visible plaque. The only fluoride supplements that the children had ever used were NaF tablets, whose efficiency is compromised (Tubirt-Ieannin et al., 2011).

There are authors who relate parents' education level to the caries experience of their children, and even include it as a factor in CRA methods (Gao et al., 2010); but in Gulbene, no correlation was observed between caries experience of the children and their mother's or father's education level.

To analyze the effect of each potential risk factor, these should be followed up prospectively, and as caries is a multifactoral disease, one should analyse risk factors by using multivariable methods. Additionally, confounding factors should be taken into consideration. In the current study, a multivariable logistic regression analysis was done using independent factors expressed in dichotomic values. However, considering the previously mentioned statements and applying an analysis of various factor combinations, no statistically significant risk factor combination was found. The reason might be the unequal size of cohort groups, because only one-fifth of children were in a low caries risk group.

For example, previous caries experience was not observed in only eight of 93 children in the high risk group and in five of 29 children in the low risk group, and general diseases existed only in four high risk and two low risk children. As concluded in a recent publication on the logistic regression analysis, when choosing a sample size, one should take into account several factors (Courvoisier et al., 2011). We can conclude that in the current study, in order to clarify the risk factors for the population, the sample size was not sufficient.

2. Evaluation of caries risk assessment methods by accuracy and cost effectiveness

Aim of study: The aim of the study is to evaluate two methods analyzed in the literature and one experimental caries risk detection method with regard to their application possibilities in high caries risk populations, and their cost effectiveness.

Methods

Study design: This was a cohort study, started in September 2009 and completed in September 2010.

Study location, settings and subjects: See above.

Outcomes: Caries risk for study participants in the initial examination in September 2009 was assessed by three various CRA methods:

1. Cariogram;
2. CAMBRA (Caries Management By Risk Assessment);
3. Experimental 4 factor method.

The necessary information to apply the methods was obtained through interviews, and clinical and saliva examination (a more detailed description can be found above).

Analyzing the accuracy of CRA methods, caries progression in the D_1 level was detected.

For the application of **Cariogram** (Malmö University, Sweden), data on previous caries experience, general health, dietary habits, the amount of plaque, the amount of Streptococcus mutants, and the saliva secretion rate and buffer capacity were entered into the computer programme.

Taking into account the low fluoride level in the water in Gulbene county and the socioeconomic situation, the region was estimated to be a high caries risk region. Also, since the patients had mixed dentition, or just formed permanent dentition, the individual patients' risk group was also estimated to be high.

Caries risk was calculated in percentage values, dividing patients into "very low", "low", "intermediate", "high" and "very high" caries risk groups.

For the application of the **CAMBRA** method, a special form was filled out (Featherstone, 2004), the questions on which were divided into three sections – disease indicators (clinical finding), risk factors and protective factors.

After the questioning, all "Yes" answers are counted and the caries risks were assessed and expressed as "low", "medium", "high" or "extremely high".

When determining the caries risk by the **Experimental 4-factor method**, previous caries experience and the amount of plaque were determined clinically, and the eating habits and the use of fluoride were assessed from patients' interviews. Each of the four factors were evaluated with scores of 1 to 3 (Table 2.1.).

Table 2.1.

Scores and their interpretation for 4 factor CRA method

Caries risk factors	**Score**	**Interpretation**
Caries experience	1	No caries experience, no white spot lesions
	2	Caries experience is lower than average for the age group in Latvia
	3	Caries experience reaches or exceeds the average for the age group in Latvia
Plaque	1	No visible plaque even after drying
	2	After drying a small amount of plaque is visible near gumline or in proximal areas
	3	Visible plaque
Diet	1	No snacks
	2	1 to 2 snacks, but very rarely including fermentable carbohydrates
	3	More than 2 snacks or 1 to 2 snacks, but with fermentable carbohydrates
Fluoride	1	Fluoride toothpaste twice daily, professional fluoride applications at least two times per year
	2	Fluoride toothpaste at least once per day, no other regular fluoride applications
	3	Topical fluorides (toothpaste) less than once per day

Since the method is to be used for fast screening, the detection of each indicator should last not longer than three minutes. After all values were obtained, the mean was calculated and the caries risk was rated as:

- 1-1.5 – very low;
- 1.75-2.25 – medium;
- 2.5-3 – high.

For all three CRA methods to be comparable, it was decided to divide the participants into only two caries risk groups (National Institutes of Health, 2001):

- 0 – low caries risk (61%-100% possibility to avoid caries by using *Cariogram*, low risk in case of *CAMBRA* and scores 1-1.5 by using 4 factor method);
- 1 – high caries risk (0%-60% possibility to avoid caries by using *Cariogram*, medium, high or extreme high risk in case of *CAMBRA* and scores 1.75-3 by using 4 factor method).

To analyse the **cost-effectiveness** of CRA methods, the price and effectiveness of each method was calculated.

Costs: In calculations, the costs of materials, work and equipment were taken into account.

The calculation of material costs included single-use dental instruments, examination gloves, disinfectants, saliva tests and paper copies of forms. Prices were acquired from the 2012 price lists for medical product distributors.

The necessary time that has to be devoted to each method by the doctor or the assistant was calculated for the use of each method. It was assumed that acquiring information about one question (for example, eating habits, general illnesses and so on) requires on average three minutes; for clinical examinations used to assess an index (DMF or Silness-Löe), 10 minutes can be spent – but if it is only to assess a state such as evident plaque, exposed root surfaces, the anatomy of occlusal surfaces, and so on, it takes on average three minutes. The saliva secretion rate detection takes eight minutes; buffer capacity detection takes five minutes; and the detection of the amount of SM and LB is five minutes of the assistant's work. To calculate work costs, the Cabinet of Ministers regulation Nr.1046 article 180 states the average salary for doctors (according to regulation article 180.1., the amount is Ls 524.00 for full time work) and for assistants (according to regulation article 180.2., this is Ls 314.00 for full time work). Average working hours per month in 2012 amount to 167.67 hours; as a result, the average salary for one working hour for doctors is Ls 3.13, and for assistants is Ls 1.87. According to this data, work costs surrounding the time spent for the application of each method were calculated.

The necessary equipment needed included a portable dental chair with light appliance (average cost in 2012 – Ls 3000.00) and an incubator for the detection of SM and LB in saliva (average cost in 2012 – Ls 800.00). The costs over one year, in accordance with the law "On Corporate Income Tax" article 13, have to be calculated as 20% of their values, but for computers the cost (average cost in 2012 – Ls 400.00) is calculated at 35% of their value. To calculate the costs per patient's examination, it was calculated how many examinations can be done in one year, taking into account the fact that in 2012 there are 2,016 working hours.

Effectiveness: The area under the curve (AUC) includes sensitivity and specificity values, thus demonstrating the ability of the method to select patients with the present illness (in this case – caries risk) and patients without the illness. It was assumed that the effectiveness of the method can be numerically expressed as an AUC value.

Statistical analysis: Since the results of each of the caries risk detection methods is interpreted differently (with the Cariogram model, five risk groups are acquired; with CAMBRA there are four risk groups; and with the 4-factor method only three caries risk groups), codes were added to each of the risk groups (Table 2.2.).

Table 2.2.

Interpretation of caries risk codes by using different CRA methods

Code	Interpretation	Cariogram	CAMBRA	4-factor method
1	Very low caries risk	0-20%	-	-
2	Low caries risk	21-40	Low	1.0-1.5
3	Intermediate caries risk	41-60%	Medium	1.75-2.25
4	High caries risk	61-80%	High	2.5-3.0
5	Very high caries risk	81-100	Extremely high	-

To apply a statistical method, it is necessary to get comparable results on a nominal scale with dichotomic values: for the low caries risk (code 0) the codes 1 and 2, and for the high caries risk (code 1) the codes range from 3 to 5.

For the assessment of the accuracy of the method, an ROC (Reciever-Operating Characteristic) curve was used, expressing values such as the area under the curve (AUC), sensitivity, specificity and odds ratio (OR).

Results

A caries risk was detected in 33.5% (136 schoolchildren) of Gulbene county 12- to 13-year-old schoolchildren using three different methods. By dividing patients into only two risk groups, 90.4% (123) by *Cariogram*, 96.3% (131) by *CAMBRA* and 86.8% (118) by the experimental 4-factor method corresponded to a high caries risk group.

A caries increase at the D_1 level was observed on average for 2.82 teeth (SD=3.47) or 7.04 surfaces (SD=6.07), but at the D_3 level the average was only 1.41 tooth (SD=1.74) or 2.58 surfaces (SD=2.81). In Figure 2.1. it can be observed that in the caries risk group there is an increase in the average caries incidence.

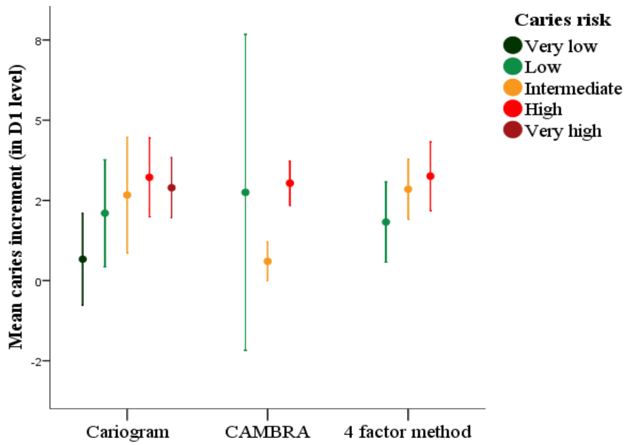


Figure 2.1. Caries incidence (mean and SD) according to caries risk groups detected by different CRA methods

Although all these methods demonstrate a very high sensitivity (from 0.882 (Experimental 4-factor method) to 0.957 (CAMBRA)), specificity is very low (from 0.037 (CAMBRA) to 0.222 (Experimental 4-factor method)), which demonstrates that all the tests have the ability to detect high caries risk when it really exists, but none of the tests are able to identify children with a low caries risk. As a result, none of methods demonstrate satisfying accuracy and statistically significant superiority over the others (Table 2.3.).

Table 2.3.

Accuracy of CRA methods

Method	**Sensitivity (CI)**	**Specificity (CI)**	**AUC (CI)**	**OR (CI)**
Cariogram	0.914 (0.839-0.956)	0.185 (0.082-0.367)	0.550 (0.423-0.677)	2.415 (0.719-8.112)
CAMBRA	0.957 (0.895-0.983)	0.037 (0.007-0.183)	0.593 (0.461-0.725)	0.856 (0.092-7.994)
4 factor method	0.882 (0.801-0.933)	0.222 (0.106-0.408)	0.629 (0.513-0.745)	2.130 (0.706-6.425)

The ROC curve shows that the probability to assess caries risk using some of these methods only slightly exceeds the probability to detect caries risk by chance (Figure 2.2.).

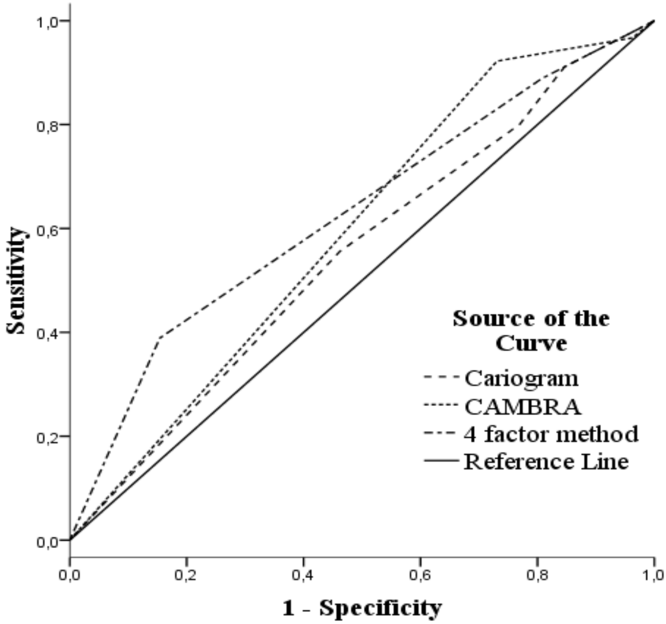


Figure 2.2. ROC curves for CRA methods

The Experimental 4-factor method is cost effective when compared to *Cariogram* or *CAMBRA* (for a decision making analysis, see Figure 2.3.). Table 2.4. shows that the experimental method is effective in respect to both time and costs.

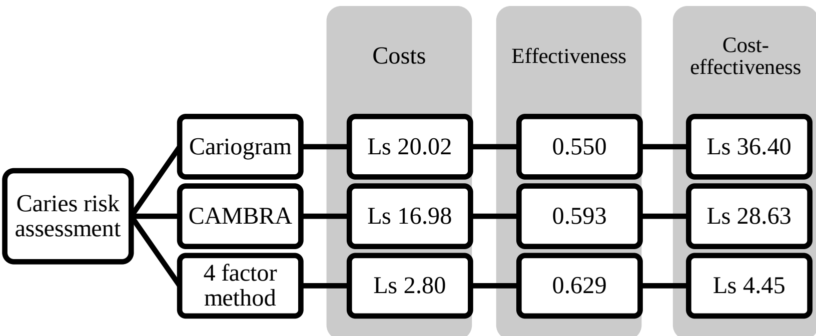


Figure 2.3. Decision making analysis when choosing a CRA method

Table 2.4.

Analysis of cost effectiveness of CRA methods

Mani-pula-tions	**Cariogram**				**CAMBRA**				**4-factor method**			
	Time (min)	**Materials**	**Work**	**Equipment**	**Time** (min)	**Materials**	**Work**	**Equip-ment**	**Time** (min)	**Materials**	**Work**	**Equipment**
		(LVL)				(LVL)				(LVL)		
Anamnesis	18	-	1.50[1]	-	24	-	2.00[2]	-	6	-	0.50[3]	-
Clinical examination	20[4]	1.52[5]	1.66[6]	0,30[7]	22[8]	1.52[5]	1.83[9]	0.30[7]	6[10]	1.52[5]	0.50[3]	0.08[11]
Saliva examination	13 + 5[12]	13.00[13]	1.24[14]	0.09[15]	8 + 5[16]	10.04[17]	0.82[18]	0.09[15]	-	-	-	-
Processing of the data	10	0.12[19]	0.52[20]	0.07[21]	5	0.12[19]	0.26[20]	-	3	0.04[19]	0.16[20]	-
Total	61	14.64	4.91	0.46	59	11.68	4.90	0.39	15	1.56	1.16	0.08
Total costs	20.02				16.98				2.80			
Cost-effectiveness	36.40				28.63				4.45			

[1] For the dentist Ls 0.94, for the assistant Ls 0.56
[2] For the dentist Ls 1.23, for the assistant Ls 0.77
[3] For the dentist Ls 0.31, for the assistant Ls 0.19
[4] To detect DMF index – 10 min, to detect Silness-Löe index – 10 min
[5] Single-use dental instruments – Ls 1.40; examination gloves – Ls 0.08; disinfectant – Ls 0.04
[6] For the dentist Ls 1.04, for the assistant Ls 0.62
[7] Mobile dental chair, making 2012 examinations per year
[8] To detect DMF index – 10 min; to assess the plaque – 3 min; to assess the anatomy of occlusal surfaces – 3 min; to assess exposed root surfaces – 3 min; to assess of existing orthodontic appliances – 3 min
[9] For the dentist Ls 1.15, for the assistant Ls 0.68
[10] To assess existence of the caries – 3 min; to assess the plaque – 3 min
[11] Mobile dental chair, making 8048 examinations per year
[12] To assess the saliva secretion rate – 8 min; saliva buffer capacity test – 5 min; amount of SM and LB in saliva – 5 min (work for assistant)
[13] Saliva buffer capacity test – Ls 3.00; SM and LB test – Ls 10.00
[14] For the dentist Ls 0.68, for the assistant Ls 0.56
[15] Incubator, making 2012 analyses per year
[16] To assess the saliva secretion rate – 8 min; amount of SM and LB in saliva – 5 min (work for assistant)
[17] Single-use cup for collecting the saliva – Ls 0.04; SM and LB test – Ls 10.00
[18] For the dentist Ls 0.42, for the assistant Ls 0.40
[19] Paper copies of the forms
[20] Work for the dentist
[21] Computer, making 2012 processing of data per year

Discussion

The study clarified that caries risk assessment methods are ineffective in a high caries risk population. However, by comparing the methods used it was found that the experimental method developed in the study is more cost-effective than the methods developed in Sweden or in the USA.

Although the opinion exists that caries reduction at a global level can be achieved by an approach that targets high risk patients (Zero et al., 2001), two problems still remain: (1) on the basis of the existing evidence, there is no ideal caries risk assessment method, and (2) if it were even possible to identify the risk groups, it would be complicated to plan the implementation of the programme, for example, for some children at school. Due to these reasons, a kind of interim strategy is recommended – a geographic strategy, including targeting high-risk individuals, towns, regions or even the whole country (Burt, 2005; Tomar, 2009). This means that when planning population-targeted preventive programmes, at present, considering the existing possibilities, it is not recommended to apply CRA methods either in low or high risk populations, which was also proven in the current study.

Whatever method is found to be most useful, it has to have high sensitivity, specificity and reliability values. Up until now, no "gold standard" for CRA methods has been established. Therefore, when introducing new methods, one should calculate all values mentioned above.

Both the Experimental 4-factor method, and the more widely used *Cariogram* and *CAMBRA*, demonstrate high sensitivity indices, which means that with these methods one can identify the children with high caries risk who have a tendency to develop new caries. But specificity indices are very low, which proves the inability of these methods to accurately identify children with a low caries risk. Reliability was not determined, and there is no data about it in the literature. In the *CAMBRA* method, neither sensitivity nor specificity measurements were found in the literature, but for the *Cariogram* method they were determined both in the preschool-age children's group, where they are rather low – "sensitivity + specificity" was 134%-136% (Gao et al., 2010) – and school-age children (sensitivity 83%, specificity 85%) (Campus et al., 2012).

The closest population to the current study was in Sardinia where the caries risk was determined in 7- to 9-year-old schoolchildren and a caries increase was found within two years. However, there are several significant differences from the study carried out in Gulbene – the caries increase was 0.5 DFS (within two years), while in Gulbene it was 2.58 DMFS (within one year), and there were also differences in the number of participants (Campus et al., 2012).

Checked by different CRA methods, only 3.7-13.2% of Gulbene teenagers correspond to a low caries risk group, while up to 96.3% are in the high risk group. Caries incidence was experienced in 78.2% of schoolchildren, which means that the cohort group sizes were very different, including only 27 children in the low risk group. Another limitation of the current study was that there was no X-ray examination used, which would decrease the low caries risk group even more remarkably. Although, in individual work with patients, it has been proven that the use of BW, especially in low risk patients, promotes a potentially unnecessary treatment because the majority of the proximal damage can be treated by conservative methods (Mascarenhas, 1998); in high caries risk populations the use of solely clinical examination does not allow for the identification of all caries (Agustdottir et al., 2010; Gowda et al., 2009b).

A significant shortcoming of the study is a lack of calculation of the previous sample values in correspondence to the existing population, which prevents finding essential differences between the cohort groups.

Various populations need different CRA methods (Zero et al., 2001; Gao et al., 2010; Ditmyer et al., 2011). The most precisely described CRA methods targeting the population were found in the Nevada study, where caries risk factors were identified for the corresponding population performing a retrospective cohort study, using a regression analysis, and where the OR value was calculated, which was then included in calculating caries risk. The accuracy of the method developed is very good because both sensitivity and specificity indices exceed 70%, and they are tested at the population level (Ditmyer et al., 2011).

CRA methods including risk factors within the framework of the Gulbene study were chosen according to two principles – in the literature it has been proven that this factor has a role in caries development, and for its detection there are no special tools needed, nor is there a necessity for time devoted to additional standard examinations, thereby keeping costs low. Taking into account that the most significant risk factors and the proportion of their influence on each population differs, the method developed also fails to show sufficient precision for use universally in any region, for any age group.

3. Effectiveness of toothbrushing in the school environment as a caries preventive programme

Aim of study: The aim is to evaluate the effectiveness of toothbrushing in a school environment as a caries preventive programme in Gulbene county.

Methods

Study design: This was a randomized controlled parallel group study, started in September 2010 and completed in January 2011 (an observation period of four months).

Study location and settings: As described above.

Study subjects: The plan was to include at least 30 schoolchildren in each study group (experimental and control). Before the planned initial examination in September 2010, eight schools were randomly selected for inclusion in the experimental group by a cluster sampling method, consequently leaving the other nine schools for the control group. In the initial examination, 123 children were examined, which would allocate 56 schoolchildren to the experimental group and 67 to the control group; but as one of the schools refused to provide the possibility for children to brush their teeth once a day, the number of included children in each group changed to 50 and 73 respectively.

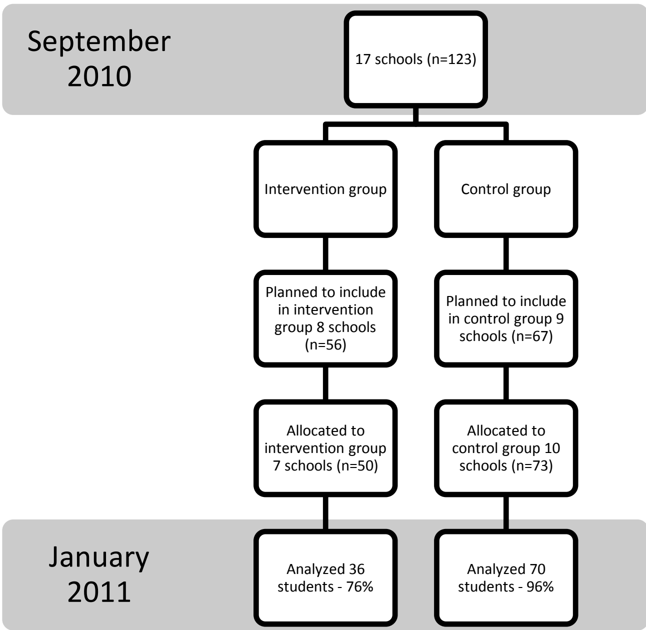


Figure 3.1. Flow diagram of study participants allocation in groups and follow-up

In January 2011, due to annual virus infections, three children from the control group could not participate and 12 (the whole class from one school) children from the experimental group could not participate, thus reducing the total number of participants to 108 (follow-up rate was 87.8%: 76% in the experimental group, 96% in the control group). The selection of participants is shown in Figure 3.1.

Intervention: The subjects of the experimental group were asked to brush their teeth once per day in school from September 2010 until January 2011 (four months). For toothbrushing, each child received both the toothpaste (Mirafluor, 1250 ppm aminofluoride, RDA 17) and the toothbrush (Miradent Alpha-Ion Carebrush, medium) from Hager & Werken, Germany.

In schools in Gulbene town (Gulbene Secondary School and Gulbene 2nd Secondary School), toothbrushing was controlled by the medical nurse of the respective school and took place in the medical room, but in the other five schools (Stāmeriena, Stāķi, Siltāji, Ranka and Druviena elementary schools) a teacher was placed in charge. Schoolchildren had a notebook to register each time their teeth were brushed. The adult in charge (medical nurse or a teacher) was instructed to keep the toothbrushes and toothpaste, as well as remind the pupils about the daily teeth brushing.

In the primary study phase after the examination (and with the school's consent for participation in the experimental group), toothbrushing training was carried out where it was explained how to properly brush teeth, and the proper technique was demonstrated on a dental model using a toothbrush. It was also explained how much toothpaste is needed (half-head of the toothbrush), and that after brushing there is no need to rinse but only to spit out the spare toothpaste. The training also stressed that teeth should be brushed after meals. At the end of the consultation, the children and teachers or school nurses had a chance to ask questions of interest.

Outcomes: In both the initial and final study phases, the children's anamnesis were collected in the form of interviews, and clinical examinations were performed.

Caries experience and incidence was expressed by using the D_1MFT index. The amount of plaque was determined by the Silness-Löe index (Silness, Löe, 1964). From saliva samples, Streptococcus mutans and Lactobacillus spp. were found in saliva (expressed by $< 10^5$ or $> 10^5$ CFU).

Blinding: Participants of the study were not informed about whether they were included in the experimental or control group, yet the chance to find this out was not prevented. The study's aim and the structure was not explained to children or teachers of the schools involved in the control group; they were not informed of the existence of the experimental group. As the author of the study participated in the planning of the study, as well as in its realization, the operator of the study was not blind.

Statistical analysis: To assess the oral health of the study participants, descriptive statistics were used; and to determine the differences between the initial and final examination, a paired sample t-test was used.

Analyzing the histograms of data, it was assumed that the data corresponds to a normal distribution, however, to check and exclude type-I error (to reject the null hypothesis when in reality it is correct), the differences were again determined by nonparametric statistical methods (Mann-Witney U-test). To estimate the differences in caries incidence and caries risk factors between the intervention and control group, an independent sample t-test was used, but in cases when the data were in the nominal scale, a Mann-Witney U test was used instead.

Results

The study was completed by 108 schoolchildren (a follow-up rate of 87.8%), of whom 70 were in the control group and 38 were in the intervention group.

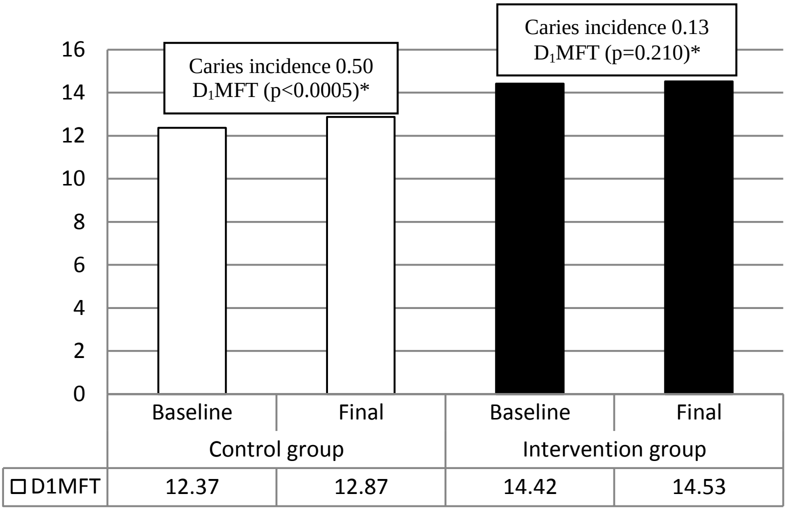


Figure 3.2. Differences in caries incidence between intervention and control groups

*** - paired samples t-test**

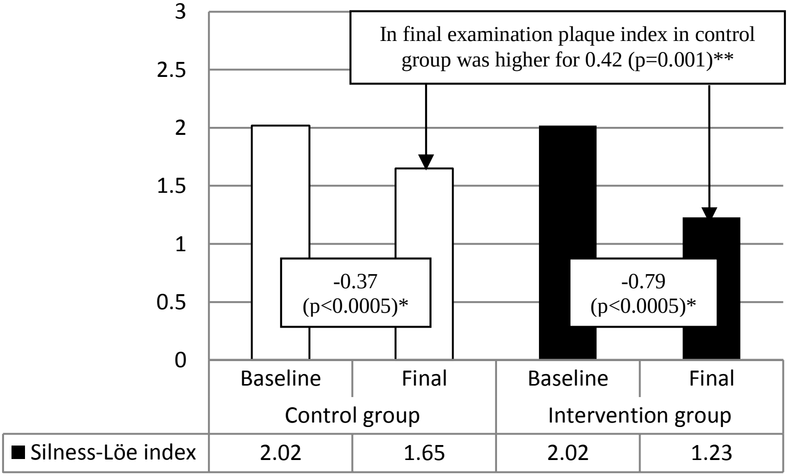


Figure 3.3. Differences in decrement of plaque amount between the intervention and control groups
*** - paired samples t-test ** - independent samples t-test**

At the start of the study there were no statistically significant differences observed between the groups according to both caries experience and amount of plaque ($p>0.05$), but differences were found in the frequency of tooth brushing ($p=0.025$).

Statistically significant differences between the intervention and the control group were observed in caries progression (Figure 3.2.), in the decrement of plaque amount (Figure 3.3.) and in the changes of behaviour (Figure 3.4.), but no differences were seen in the level of bacteria (Table 3.1.).

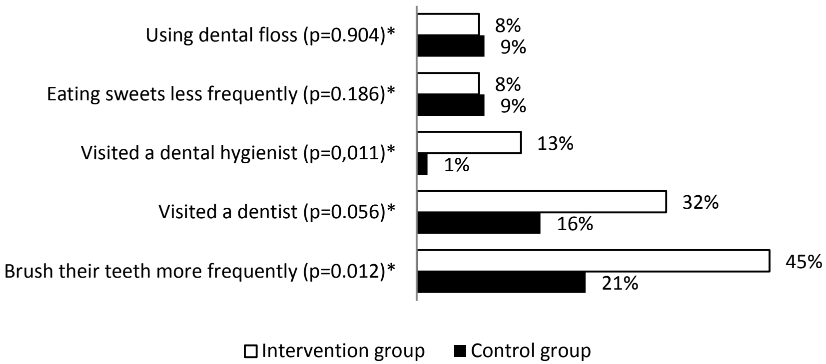


Figure 3.4. Differences in the changes of behaviour between the intervention and control group

*** - Mann-Whitney U test**

Table 3.1.

Changes in the amount of bacteria in saliva in the intervention and control groups

Bacteria	**Decrement (%)**		**p value (Mann-Whitney U test)**
	Control group	**Intervention group**	
Streptococcus mutans	40.0%	40.5%	0.665
Lactobacillus spp.	24.3%	24.3%	0.691

Discussion

The aim of the study was to assess the effectiveness of toothbrushing as a school-based caries preventive programme. After a four month randomized controlled study, it was found that by providing one additional toothbrushing at school per day, caries progression can be prevented.

The toothbrushing was organized so that each pupil involved in the study could attend a certain room after meals (Attin et al., 2005) (a nurse's office in Gulbene town schools, or a classroom in the county schools), where his/her toothbrush and toothpaste were kept. Depending on the school and the initiative of the person in charge, pupils were differently motivated to brush their teeth; therefore, supervision was limited and differed for different study participant groups (schools). But as it was necessary to be as close as possible to the real situation, as if it were a compulsory school programme, the course of the development of the procedure was estimated as appropriate for the target. However, after records of the pupils' toothbrushing were made in special notebooks, it was evident that some were involved in the brushing very rarely, and one pupil never brushed. In most cases, those who did not brush were boys, which indicates that supervision over boys could yield better results (Frazão et al., 2011).

By developing Scotland's guidelines for caries management and preventive programmes (Scottish Intercollegiate Guideline Network, 2005), it was found that there is a lack of evidence about the effectiveness of school toothbrushing programmes (Uribe, 2006).

The literature contains information on studies on the effectiveness of the toothbrushing, but most programmes provide strict supervision (Ferreira et al., 2005; Cunha-Cruz, 2005; Pine et al., 2007; Bebermeyer et al., 2003; Curnow et al., 2002; Jackson et al., 2005; Andruškevičiene et al., 2008). Although Robinson, in 1976, revealed the superiority of supervised toothbrushing over the programme without supervision (Robinson, 1976), in the case of Latvian schools it is practically impossible to realize this. Similarly, the majority of studies were done on preschool children, therefore their results cannot be compared with the ones acquired in this current study.

The greatest drawback of the current study is its short follow-up time. Some authors reveal the effectiveness of a pre-organized toothbrushing programme even seven years after its completion, and it is not clear whether it is the brushing effect as such or the promotion of a behavioural change by introducing such a programme (Pine et al., 2007) that has induced the improvement.

In Gulbene, although toothbrushing was done only for four months, various behavioural changes were observed. Firstly, in the control group, the amount of plaque reduced, although children less frequently admitted that they were brushing twice a day. This could be explained by a formation of trust, because the author of the study met three times with the same pupils. These meetings themselves can promote a change of pupils’ thinking on their oral health and initiate a sense of responsibility about their health (Axelsson, 1994). Secondly, it is important to note that although the decrease of plaque occurred in both groups, for the children who were brushing their teeth at school the changes in the plaque index were considerably greater, which is evidently connected with a greater percentage of children who visited the dental hygienist in the test group. In addition, teeth were more commonly brushed twice a day at home by children included in the school brushing programme, which can be evaluated as a positive sign because it means that the possibility or necessity to brush teeth at school is not perceived as a reason not to brush at home. The role of factors of behavioural changes (the frequency of the teeth brushing, attendance to the dentist and hygienist and a decrease in the use of sweets), which are recognized as potentially significant to the effectiveness of the preventive methods in the literature (Pine et al., 2007), would be investigated, including a greater number of participants observed for a longer period.

From the objective measurement analysis, there were no differences between the groups in either of the determined saliva parameters. Although in the literature it is uncommon to find that Streptococcus mutants and Lactobacillus spp. are related to an increased caries risk, which would denote potentially greater caries progression in future (Sarmadi et al., 2008; Gudkina et al., 2010; Ito et al., 2011), stronger evidence exists regarding the relationship of these microorganisms with the cavity level of the existing damage (Takahashi et al., 2011), whose severity in Gulbene county children exceeds an average of four damaged teeth in both experimental groups.

The fact that may cause doubt about the results of the study is that before starting the test group, pupils were already brushing their teeth more often at home; however, since there had not been any observed differences in the amount of plaque, and although numerically the test group pupils had higher caries experience, no statistically significant difference was observed between the groups. Therefore, it was admitted that the tendency for children included in the school programme to brush their teeth more often did not have a significant effect on the programme effectiveness measurements; although this difference might have been due to the small number of participants in the study and the unequal distribution of experimental groups, it still has to be considered as a drawback of the study. At the end of the period of examination in January 2011, one of the test groups at the schools involved was affected by a flu epidemic that radically worsened the withdrawal index of the test group. Daukstes Elementary School's refusal to participate in the toothbrushing programme intensified the differences in values of experimental groups too.

The design of the study did not include the principles of blinding, although the involved pupils in the majority of cases were not informed about the course of the study. Taking into account the specificity of the rural area, the small population and short distances between schools, it is not known how informed the participants were. It was also difficult to mask the specialist who did the examination (i.e. the author of the work), which might also affect the study results (Pannuti, 2009).

The effectiveness of the toothbrushing programme could also be due to the poor socioeconomic situation in Gulbene county – several authors have noticed the relationship of such methods targeted at a population to the economic level of the region (Frazão, 2011; Macpherson et al., 2010; Jackson et al., 2005; Bebermyer et al., 2003) and high caries experience (Curnow et al., 2002), as well as low fluoride content in the drinking water (Bebermyer et al., 2003). Therefore, it is necessary to carry out more extensive studies in various regions of Latvia in order to lay the groundwork for the implementation of such programmes at a national level.

Considering the limitations of the study, it can be concluded that the group preventive method of providing toothbrushing programmes at schools decreases the growth of caries and might also be a very cost effective method (Bebermyer et al., 2003; Splieth et al., 2004) to lessen social inequality in respect to oral health (Macpherson et al., 2010). We can therefore agree with a recent analytical publication on the necessity of introducing a school programme at the national level (Tomar et al., 2009).

4. Ethical considerations of study

The current study was approved by the Ethical Committee of Rīga Stradiņš University. Permission was received for undertaking the study by the RSU Department of Therapeutic Dentistry, Pauls Stradins Clinical University Hospital Center of Dentistry and Facial Surgery, and from the Gulbene county Education Agency. All interviews, the questionnaire and clinical examinations were done in conformity with the Helsinki Declaration (The World Medical Association Declaration of Helsinki). The study was carried out while taking into account Latvia's legislation on the protection of personal data, and all data was collected with parental written informed consent.

After the baseline (September 2009) and final examination (January 2011), pupils were handed written information on oral health and recommendations on how to improve present conditions.

5. Conflict of interests

Presents to pupils were provided by *Colgate-Palmolive*. They were handed out alongside informative material on toothbrushing with a *Colgate* advertisement, thus compensating for the company's input.

Toothbrushes were purchased from a *Miradent* representative in Latvia, but toothpaste was provided by the company free of charge; so in the informative letter to parents a *Miradent* advertisement was included.

The author denies any conflict of interest with the companies mentioned in the performance of the study, the data collection and its processing.

6. CONCLUSIONS

1. When planning to introduce a caries risk assessment in the state programme, it is important to determine the corresponding method for a definite population by analyzing the caries risk factors and extent of their effect in a long-term longitudinal study.
2. The experimental caries assessment method worked out in the study as cost effective in comparison to the *Cariogram* and *CAMBRA* methods.
3. Caries prevalence, severity and incidence in Gulbene county 12- to 13-year-old schoolchildren population is very high.
4. Previous caries experience, poor oral hygiene, fermentable carbohydrates in diets and irregular visits to the dentist are the leading cause of progression of caries.
5. Since the low caries risk group in Gulbene county is so insignificant, there is no need to apply a high risk strategy to introducing caries prevention programmes.
6. When planning caries prevention programmes for schoolchildren, one should use methods targeted at the whole population.
7. Toothbrushing at schools might be an effective prevention programme for decreasing caries prevalence and its rate for teenagers, but it is necessary to undertake additional studies with a larger number of participants, and it is also necessary to lengthen the follow-up period.

7. PRACTICAL RECOMMENDATIONS

When planning prevention programmes in Gulbene county, there should be introduced population-targeted preventive methods, for example, a provision of toothbrushing with fluoride-containing toothpastes on school premises, and additionally limiting the consumption of sugar-containing products, as well as providing teachers, school staff, schoolchildren and their parents with information on oral health issues.

For caries risk detection, from the three tested methods we recommend a 4-factor method, which is cost effective in comparison to *Cariogram* or *CAMBRA*.

8. SCIENTIFIC RECOMMENDATION

When planning epidemiological studies, one has to follow the guidelines that have been developed, precisely considering the methods, and it is useful to register caries visually or by additional means at acquired stages.

In Latvia should be subject to a well-planned longitudinal study with an accompanying multivariable risk factor analysis in order to find out the characteristic caries risk predictors for Latvia and the proportion of their influence, which could be then introduced in the algorithm of primary patients examinations.

It is important to prepare an investigation of population-targeted caries prevention programmes, analyzing those of them that were more effective and financially more plausible for the Latvian population.

9. ACKNOWLEDGMENTS

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10. LIST OF PUBLICATION

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