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Approximal caries increment in relation to baseline approximal caries prevalence among adolescents in Sweden with and without a school-based fluoride varnish programme

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Objective: Approximal surfaces are a focal point for caries prevention among adolescents in Sweden and the aims of this study were therefore to evaluate approximal caries incidence and caries progression among adolescents with and without a three-year school-based fluoride varnish programme in relation to approximal caries prevalence at baseline. ***Basic research design:*** In all, 758 (89%) 13-year-olds completed the three-year randomised controlled trial. They all used fluoride toothpaste at home and had regular dental check-ups at the public dental clinics. ***Results:*** The mean approximal caries incidence for the adolescents who were caries free on these surfaces at baseline was 0.13 (SD 0.54) in the fluoride varnish group and 0.79 (1.93) in the control group. The corresponding values for those who had caries at baseline in these groups were 1.29 (2.21) and 2.62 (3.22) respectively. The latter two groups also had 0.34 (1.00) and 0.70 (1.13) approximal enamel lesions that progressed. All differences were statistically significant ($p<0.001$). Among those individuals who had approximal caries at baseline, double the number of early approximal enamel lesions in the control group progressed compared with the fluoride varnish group. ***Conclusions:*** The school-based fluoride varnish programme inhibited new approximal lesions to a great extent and effectively kept approximal enamel lesions within the enamel among 13-16-year-olds. It is therefore recommended that such a programme is warranted when the approximal surfaces are still caries free in order to keep these surfaces free from caries and keep upcoming approximal enamel lesions within the enamel.

Key words: *adolescent, caries incidence, caries prevalence, enamel lesions, fluoride varnish, oral health prevention, Sweden*

Introduction

The caries prevalence among children and adolescents has decreased during the last 40 years in Sweden as in most other high-income countries (Norderyd *et al*., 2015; Petersen, 2010; Socialstyrelsen, 2015). Despite this fact, dental caries is still a major public health problem worldwide, as 60-90% of all children of school age and almost all adults are affected (Petersen, 2008; Splieth *et al*., 2016). Furthermore, the true caries prevalence among children and adolescents is underestimated in official caries data, as only dentin caries lesions and fillings are included in these data (Nyvad and Heidmann, 1999; Pitts, 1997; Sköld *et al*., 1995). Enamel lesions on the approximal surfaces among 16-year-olds in Sweden account for more than 80% of all caries lesions on these surfaces, no matter whether the caries prevalence in the population is high or low (Alm *et al*., 2007; Sköld, 2005; Sköld *et al*., 1995).

The approximal surfaces are a focal point for caries prevention among adolescents in Sweden today, as caries on these surfaces forms the basis of a need for dental treatment as an adult. There is a risk of caries increment on the approximal surfaces among the high-risk adolescents, due to the lack of compliance with caries-prevention programmes in this group, and this is a dental health problem (Hausen *et al.,* 2000; Mejàre *et al*., 1998).). Moreover, where causal carious factors for enamel lesions on approximal surfaces are not balanced by defence factors there is a potential risk of caries progression for all adolescents. (Gustafsson *et al*., 2000; Lith and Gröndahl, 1992; Mejàre *et al*., 2014). There is strong evidence of caries reduction as a result of fluoride exposure (Bratthall *et al*., 1996; Marinho *et al.*, 2004). Kay and Locker (1998) also stated that oral health programmes without fluoride failed to achieve a caries reduction and that the effectiveness of information and motivation alone should be questioned.

With these factors as the background, an earlier randomised controlled study performed in high-, medium- and low caries risk areas aimed at population-based prevention at school with fluoride varnish application for all 13 - 16-year-olds was conducted (Moberg Sköld *et al.*, 2005). The adolescents were in each area randomly allocated within each school class into four different groups with respect to the fluoride varnish applications. The results showed that fluoride varnish application every 6 months had great impact on new approximal caries lesions in these caries risk ages especially in medium and high caries risk areas. The aims of the present study were to re-evaluate the data from that study; firstly, to evaluate the approximal caries incidence among 13-to 16-year-olds after the three-year-school-based fluoride varnish programme in relation to the approximal caries prevalence at baseline and, secondly, to evaluate the progression rate of approximal enamel lesions with and without this fluoride varnish programme. The null hypothesis was that the approximal caries incidence was

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not influenced by approximal caries prevalence at baseline and that the progression rate of early approximal enamel lesions was equal with and without this programme among 13- to 16-year-olds.

Method

In all, 758 13-year-olds from high-, medium- and low-caries-risk areas in the western part of Sweden concluded the three-year randomized trial (Moberg Sköld *et al*., 2005). In each caries risk area, three test groups received fluoride varnish applications (Duraphat®, 2.26% fluoride) and were compared with a control group with no varnish applications at school. The application frequencies were twice a year at six-month intervals, three times a year within one week and eight times a year during term time at one month intervals. Three dental nurses and one dental hygienist came to the different schools with a simple mobile unit and performed all the varnish applications. This programme was supplementary to home care involving the regular use of fluoride toothpaste and to regular dental check-ups at the public dental clinics. These check-ups took place at an interval of 12-18 months for more than 70% of the adolescents, as the caries risk assessed by the dentists at the public dental clinics was considered to be low or medium. The dentists did not know to which group the adolescents belonged. Caries prevalence was defined according to the oral health surveys method designed by the WHO (1977). In addition, enamel lesions on approximal surfaces were recorded. The drop-out of 11% was evenly distributed between the areas and the reasons were mostly moving out of the region and then not attending all fluoride varnish sessions. In the present re-evaluation all fluoride groups in the three caries risk areas were pooled then separated according to approximal caries prevalence at baseline into two groups, one fluoride group who was caries free on the approximal surfaces at baseline ($DFS_a+D_eS_a = 0$), called Group 0_{FV} (n=276, 48% of those in the programme), and one fluoride group who had caries and/or fillings on the approximal surfaces at baseline ($DFS_a+D_eS_a>0$), called Group $>0_{FV}$ (301, 52%). In the same way the control groups in the three caries risk areas were pooled then called Group 0_C (76, 42% of controls) and Group $>0_C$ (105, 58%) respectively according to their caries status on the approximal surfaces at baseline.

Four bitewing radiographs each from baseline and at the end of the study were taken by the ordinary dentists at the different public dental clinics and these dentists were given prior appropriate education in the standardised method by two oral radiologists. The films were then scored and analysed blindly by the author, according to Gröndahl *et al*. (1977) using a light desk and a magnifying viewer. Permanent approximal surfaces from the distal surface of the canines to and including the mesial surface of the second molars were scored as follows: 0, caries free; 1, caries lesion in the outer half of the enamel; 2, caries lesion more than half way through the enamel but not passing the enamel-dentin junction; 3, caries lesion extending into the dentin but not more than half way through to the pulp; 4, caries lesion more than half way through the dentin to the pulp; 5, restored surface. Every approximal surface was followed and analysed during the 3-years trial concerning caries increment which was divided into caries incidence and caries progression. The approximal caries incidence was defined as an approximal caries-free surface that turned into an enamel or dentin lesion or into a filling (0→1-5) while approximal caries progression was defined as an approximal enamel lesion that turned into a dentin lesion or a filling (1-2→3-5). The progression rate on the approximal surfaces was expressed as the percentage of the enamel lesions in the outer half of the enamel (score 1) or in the inner half of the enamel (score 2) at baseline that had progressed into the inner half of the enamel (score 2) or into the dentin (score 3-4) or into fillings (score 5) after three years.

The ethics committees at the Universities of Gothenburg and Lund gave their approval prior to the start of the study in accordance with the Declaration of Helsinki (Dnr L 569-97). All the adolescents volunteered after they and their parents had given informed, written consent. The study was designed in 1997 and was performed before the "Consort Statement" was introduced.

All the data were recorded in a Microsoft Access database and then processed using SAS statistical computer software. Descriptive statistics, such as means, standard deviations and frequency distributions, were calculated at both site and subject levels. Comparisons between groups were made using unpaired t-tests or, when comparisons included more than two groups, one-way analysis of variance, ANOVA. The ANOVA tests were then followed by Newman-Keuls multiple comparison tests in order to test pair wise differences. For some parameters and comparisons, a 95% confidence interval was used. No tests were performed on site-level data. In the tests of significance, differences giving $p<0.05$ were considered statistically significant.

Results

Figure 1 shows the total caries increment on approximal surfaces expressed as the total approximal caries incidence (0→1-5) and approximal caries progression (1-2→3-5) after three years with and without fluoride varnish application at school. There were statistically significant differences relating to the approximal caries incidence between those that were caries free at baseline ($DFS_a+D_eS_a = 0$), called Group 0_{FV}, and received fluoride varnish applications for three years and all other groups, i.e. those who had approximal caries at baseline and received fluoride varnish applications and those in the control groups with or without approximal caries at baseline ($p<0.001$). Group 0_{FV} developed a mean of 0.13 (SD 0.54) new caries lesions on the approximal surfaces that were only enamel lesions and no dentin lesions or fillings during the three-year period.

In addition, in Group $>0_{FV}$ and Group $>0_C$, 0.34 (1.00) and 0.70 (1.13) approximal enamel lesions respectively progressed to dentin lesions or fillings ($p<0.001$). As a result, the total caries increment on the approximal surfaces for the adolescents in the fluoride varnish group who were not caries free at baseline was more than 1.6 approximal surfaces and, for the corresponding adolescents in the control group, more than 3.3 approximal surfaces compared with 0.13 and 0.79 for those caries-free adolescents with and without fluoride varnish applications at school.

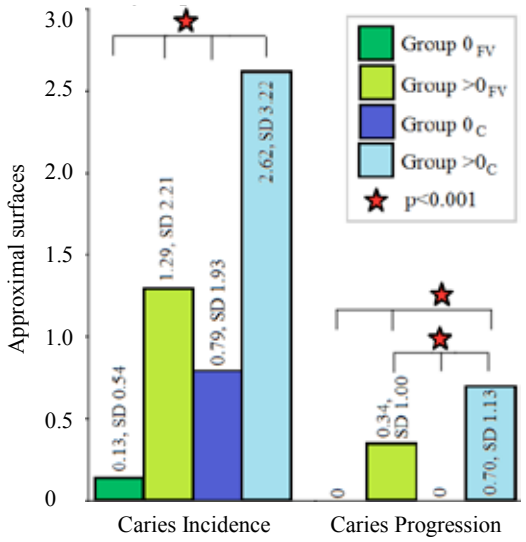

Figure 1. *Approximal caries increment expressed as caries incidence and caries progression on approximal surfaces after three years with or without fluoride varnish application at school in all risk areas combined for the different groups.*

Note: With each column, the mean and SD values are given. The left part of the figure shows approximal caries incidence, i.e. 0→1-5 and the right part shows approximal caries progression, i.e. 1-2→3-5.

Table 1 shows the distribution for the enamel lesions in the outer half of the enamel of the approximal surfaces, score 1, and for the enamel lesions in the inner half of the enamel, score 2, among those adolescents in the fluoride varnish group and in the control group who had approximal caries at baseline. Among those who received fluoride varnish applications at school, 25% of the lesions in the outer half of the enamel progressed to the inner half while as many as 72% arrested and only 2% progressed to dentin lesions and 1% to fillings. In the control group which did not receive any fluoride varnish applications, 50% progressed to the inner half of the enamel and 38% arrested. For the enamel lesions in the inner half of the enamel, 88% and 56% respectively arrested in the test group and in the control group, while 12% and 44% respectively progressed to dentin lesions and fillings.

Table 1. Approximal enamel lesions, expressed as percentages, in the inner and outer halves of the enamel that had arrested or progressed after three years with and without a fluoride varnish programme at school

	Fluoride group	*Control group*
Individuals with approximal enamel lesions at baseline, n	298	103
Distribution of approximal enamel lesions at baseline, %:		
Score 1, outer half of the enamel	56	68
Score 2, the inner half of the enamel	44	32
Approximal caries progression, %:		
1→1	72	38
1→2	25	50
1→3-4	2	10
1→5	1	2
2→2	88	56
2→3-4	8	26
2→5	4	18

Discussion

The null hypothesis was rejected, as the caries prevalence at age 13 influenced the future approximal caries incidence in the different groups of adolescents both with and without the fluoride varnish programme at school. The adolescents with approximal caries lesions and/or fillings at baseline developed statistically significantly more caries compared with those individuals who were caries free on the approximal surfaces at baseline. This result was not unexpected, as there is strong evidence that baseline caries prevalence is the single best predictor of new caries lesions (Hausen, 1997; Mejàre *et al*., 2014). At the same time, the results of this study also revealed that adolescents who received fluoride varnish applications at school had a significantly lower approximal caries incidence compared with the control group, regardless of the caries prevalence at baseline on these surfaces, while the fluoride varnish group who was caries free at baseline had a negligible caries incidence. Consequently, the school-based fluoride varnish programme had the ability to prevent new approximal caries lesions to a great extent for adolescents at the caries-risk ages of 13 to 16 years when many approximal surfaces are at risk in terms of caries.

The null hypothesis was also rejected in terms of the progression rate of approximal enamel lesions, as the results revealed large differences between the fluoride varnish group and the control group, as twice as many lesions progressed without the fluoride programme at school. These figures underline the importance of a school-based fluoride varnish programme for adolescents at caries-risk ages, in addition to the regular use of fluoride toothpaste at home and caries prevention at the public dental clinics. A programme of this kind should be implemented at an early stage, when the approximal surfaces are still caries free, which also means free from enamel lesions as fluoride has a major impact when it comes to remineralisation at an early stage and keeping caries-free surfaces free from new lesions during high caries-risk periods. One important reason for implementing this programme on a population basis is the difficulty involved in selecting the individuals who will develop caries in the future. The Swedish Council on Technology Assessment in Health Care (2007), as well as Burt (1998), therefore suggested that caries prevention should be aimed on a population-basis at geographical target areas with a known high caries risk or at ages characterised by a relatively high risk of caries, provided there are cost-effective programmes. The ages of 13-16 years represent one such period during which many surfaces are at risk and these ages are also a risk period for caries development, as the intake of junk food and soft drinks is high. Epidemiological data also shows that more new caries lesions will develop in the low to medium caries-risk group of adolescents, as this group is much larger than the high caries-risk group, thereby supporting a population strategy instead of a high-risk strategy (Batchelor and Sheiham, 2006).

Moreover, the true caries prevalence is underestimated in official caries data, as enamel lesions are not included in these data (Nyvad and Heidmann, 1999; Sköld *et al*., 1995; Socialstyrelsen, 2015). This means that far more adolescents suffer from caries and will benefit from a school-based fluoride programme, if a population strategy is implemented.

However, with this strategy, there are individuals who will stay caries free, regardless of the intervention, but, as long as the programme does not harm anyone, there are positive aspects when it comes to taking part in the same programme as one´s school friends. Moreover, from a democratic point of view, all adolescents should have the opportunity to take part in this programme at school. Furthermore, more and more adolescents in Sweden today have a migration background from countries outside Europe with a documented higher caries risk, and they could benefit from a school-based fluoride varnish programme.

An updated Cochrane review revealed a substantial effect on caries increment among children and adolescents as a result of fluoride varnish applications although there was considerable heterogeneity between the included studies (Marinho *et al*., 2013). One of the studies was performed at school during a period of 36 months on seven- to eight-year-olds and did not reveal any effect on caries increment after three fluoride varnish applications each year compared with no application (Milsom *et al*., 2011). This is in contrast to the present results. There could be several reasons for the absence of effect, such as focusing on occlusal surfaces instead of approximal surfaces, the diagnostic criterion of dentin caries instead of enamel caries, bitewing radiographs not being used for diagnosis and few tooth surfaces at risk. In the present study, more approximal surfaces were at risk, as the individuals were 13- to 16-years of age. Furthermore, the diagnostic criterion was enamel lesions, which is of great importance, as caries is a slowly progressing disease and, during three years, far more new enamel lesions will occur compared with dentin lesions. In addition, the effect of fluoride prevention is much greater on approximal surfaces compared with occlusal surfaces. Finally, the bitewing radiograph plays a fundamental role as a diagnostic tool for early approximal lesions (Lillehagen *et al.,* 2007).

Schools are suitable for health prevention, as adolescents go to school during the period when health-related behaviours, beliefs and attitudes are formed. The WHO supports health-promoting schools and schools are an obvious place for also promoting oral health. Jürgensen and Petersen (2013) stated that, among other things, exposure to adequate fluoride levels by using relevant fluoride vehicles at a time when lifelong oral-health behaviours are developed is an important part of school programmes to promote health and a healthy lifestyle. There are many positive side-effects to a population-based approach at school. Adolescents are more likely to attend school than a public dental clinic for the same fluoride programme. There is an opportunity to talk about dental health and support individuals to take responsibility for their dental health, while those in need of extended prevention can be selected for further intervention.

There is a wide variation in fluoride varnish application between two or three times a year and eight times a year and the results of the original study showed that eight times had a slightly better prevented fraction than twice a year at six-monthly intervals, but that such frequent applications of fluoride varnish were not cost effective. A comparison of cost effectiveness between two school-based fluoride programmes revealed that fluoride varnish applications twice a year at six-monthly intervals produced a better outcome at a lower cost than supervised fluoride mouth-rinsing on the first three and the last three schooldays during the school terms (Sköld *et al*., 2008). The cost of the prevention was then compared with the cost of fillings. The value of healthy teeth and good oral health may, however, be higher than the cost of a filling (Oscarson *et al*., 2007).

It is extremely interesting to see how an organised school-based fluoride programme works under field conditions when it is implemented on a broad scale. The Public Dental Service in the Västra Götaland Region with 1.6 million inhabitants implemented a school-based programme of this kind, with fluoride varnish applications every six months for all adolescents in the 6th to 9th grades. The reason for choosing fluoride varnish instead of supervised fluoride mouth-rinsing was the result of a cost analysis of these two fluoride programmes (Sköld *et al*., 2008). The programme has run since 2008 with good compliance, as more than 98% of all school classes take part. An evaluation of approximal caries increment and the cost effectiveness of this programme are reported in a study by Bergström *et al.* (2016). Adolescents who had taken part in a school-based fluoride varnish programme experienced it as positive and they regarded the school as an important health-promotion arena (Bergström *et al*., 2012). It is also important to highlight the role of the dental personnel working at school, as they are largely responsible for creating the atmosphere. A recent study by Hedman *et al*. (2013) showed the importance of the behaviour of the dental personnel, as the adolescents sometimes had a feeling of vulnerability in the application sessions.

One interesting question for future studies is to evaluate whether a population-based fluoride varnish programme in a school during the caries-risk ages of 13-16 years has any long-term effect on approximal caries prevalence in adulthood.

Conclusion

A school-based fluoride varnish programme inhibited new approximal lesions to a great extent and effectively kept approximal enamel lesions within the enamel among 13-16-year-olds. A programme of this kind should therefore be implemented when the approximal surfaces still are caries free in order to keep these surfaces free from caries and keep upcoming enamel lesions within the enamel.

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