Acta Odontologica Scandinavica, 2008; 66: 65–72

informa
healthcare

ORIGINAL ARTICLE

Comparison of the effectiveness of fissure sealants in Finland, Sweden, and Greece

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Abstract

Objective. To evaluate the effectiveness of sealant treatment in preventing dental restorations due to caries in a practice-based research network in Finland, Sweden, and Greece. ***Material and methods.*** Times of tooth emergence, sealing treatment, and dental caries were compiled from the dental charts of 4735 subjects born in 1970–72 in Finland and in 1980–82 in Finland, Sweden, and Greece. Survival time between tooth emergence and placement of first restoration was measured and estimated using survival analysis methodology. ***Results.*** At the end of follow-up (7–10+ years), 30–40% of sealed molars and 60–80% of non-sealed molars were restored. Early sealant placement compared to late sealing did not result in significantly higher survival of 1st molars. The strategy of sealing the 1st molars only in high caries risk subjects was as effective as sealing all the molars and premolars routinely without caries risk determination. ***Conclusions.*** The sealing of all molar fissures proved to be no more effective than sealing risk fissures of subjects. Early sealing did not result in any better outcome than late sealing. The effectiveness of sealant treatment in preventing dental restorations is dependent on the caries risk of individuals and caries prevalence of the country.

Key Words: *Fissure sealants, practice-based research, survival analysis*

Introduction

The scientific literature concerning the use of pit and fissure sealants is vast. The Cochrane review covered as many as 2301 articles, but only 4 could be analyzed scientifically [1]. Many authors have examined the retention of sealants and compared the effectiveness of different types and generations of sealants [2] applying meta-analysis methods [3]. The split mouth design has been used in most clinical trials. In a recent systematic review of sealant effectiveness, it is suggested that the caries preventive effect of sealants can be assessed by comparing sealed teeth with untreated control teeth of the individual as his/her own control [4]. In a consensus statement, the European Academy of Paediatric Dentistry summarized recommendations for sealant use in individual care programs in which the caries risk assessment of the individual strongly influences who benefits from fissure sealants [5].

Knowing what works in clinical trials is the basis for evidence-based dentistry (EBD), which should be implemented with knowledge of how these treatments work in clinical practice, i.e. EBD research should be completed with a practice-based dentistry (PBD) approach [6] using scientific methods in clinical practice [7]. As part of this PBD protocol, we have previously applied survival analysis methodology in determining dental health [8]. Survival analysis is suitable in the sense that it does not need the determination of dental health as the mean of the study cohorts, but the individuals are followed as long as their information is available. Tooth-specific survival analysis from the time of tooth emergence until the stage it becomes carious and needs restoration is a practical and accurate system for health determination in practice [8,9].

Survival analysis requires independent data for significance testing. Therefore, tooth-specific comparisons between sealed and non-sealed individual

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(Received 13 June 2007; accepted 17 January 2008)

ISSN 0001-6357 print/ISSN 1502-3850 online
DOI: 10.1080/00016350801926933

teeth [10], on the one hand, and subject-specific comparisons including all teeth surfaces in sealed versus non-sealed individuals [11], on the other, mostly satisfy this independence requirement. On the subject level, either all permanent 1st molars were sealed or none were sealed when comparisons between the subjects were performed [11]. Comparisons between sealed and non-sealed individual teeth are the basis for analysis of the effectiveness of sealant treatment in preventing caries in individual tooth fissures which are independent of the same tooth fissure in another subject. Comparison of the subjects with either sealed or non-sealed all 1st molars provides a model in assessing the subject-specific effectiveness of sealants. Two such approaches take into account the tooth-specific and mouth-specific interdependency problems.

The aim of this study was to analyze the effect of fissure sealant treatment in preventing dental caries and restorative treatment in children in a practice-based network of three European countries in two birth cohorts. The study includes comparisons between early sealing versus late sealing and sealed 1st molars versus non-sealed 1st molars (at individual tooth level and subject level) in caries prevention. Our hypotheses are the following: 1) sealant treatment prevents and/or delays caries attack on sealed tooth surfaces compared with their non-sealed counterparts in other subjects and 2) early sealing is more effective than late sealing. The subject-specific approach hypothesizes that: 3) subjects with all their 1st molar fissures sealed have less need for restorative treatment than non-sealed subjects using the same restorative criteria.

Material and methods

This study is part of the EUDENT research network project in which the dental health of subjects ($n = 4735$) was followed annually from age 5 to age 12+ over the course of 20 years [12]. Age cohorts of boys and girls born in 1970–72 in Finland ($n = 1441$) and Sweden ($n = 609$), and in 1980–82 in Finland ($n = 1494$), Sweden ($n = 632$), and Greece ($n = 559$) were followed. The data for this study were collected from the file records of Public Health Centres in Finland and Sweden as well as from private practice offices ($n = 328$) and health centers ($n = 231$) in Greece. Ethics Committees of Oulu University and the health centers involved granted permission for this retrospective study.

The interval between examinations varied between 6 and 18 months during the entire follow-up of several years, and was the only recruitment criteria for participation in the study. In Finland and Sweden, all children and adolescents from birth until 19 years of age received dental care in municipal dental clinics free of charge. In Greece, dental care in private practice has a regular fee and in health centers a nominal fee.

Timing of the emergence of permanent molars, placement of the fissure sealant, dental caries and restorative procedures were recorded and digitalized from the paper dental records. The ages of subjects were recorded with an accuracy of one day, and the dates of examination with an accuracy of one month. If the observation intervals were longer than 18 months, the subject was excluded.

Because the time of the eruption of 1st permanent molars varies and caries does not occur in unerupted teeth, the tooth emergence was taken as zero point of the analysis. The emergence of the tooth and the onset of the caries process was interval censored as having occurred at the first examination following the event [13,14]. If the sound tooth was attacked by dental caries (or was restored because of caries) at first examination after the eruption, it was interval censored. This resulted in that in the first examination after tooth eruption some of the 1st molars were registered as both erupted and affected by caries. Previously this was termed a "post-eruptive step" [8]. Most teeth were sound at the end of the follow-up, and carious stages of these teeth were hence right-censored.

If fissures were sealed within the first 12 months after tooth emergence, this was identified as "early sealing". All other sealant placements were identified as "late sealing". Resealing procedures were not recorded. Dental caries was recorded at the stage when dentists made the decision to restore the lesion. Restorations due to fractures were excluded.

In Finland in the 1980s, dentists examined schoolchildren annually and treated those with diagnosed problems. Standard preventive procedures included fluoride varnish application, oral hygiene instructions and dietary counseling once in one to two years. Caries, extending into dentin, was restored. Enamel caries was followed or treated by preventive methods including the sealing of occlusal fissures. Application of sealants was performed by dentists and the fissures of the 1st and 2nd permanent molars were sealed. The criterion for restorative treatment due to caries was the decision of the dentist to restore the lesion, normally when caries had reached dentin.

In Sweden, the preventive program was similar, including topical applications of fluoride varnishes and diet counseling. For fissure sealing, clinical and microbiological caries risk evaluation was used and only the high caries risk molars were sealed.

In Greece, a regular recall system was provided in private pediatric clinics and basically the decision to restore the lesion was the same as in Finland and in Sweden: dentin caries. The same dentists who worked in private practice also served in public health centers on a part-time basis and the treatment criteria and the recall interval in the public and

private practices were the same. Sealants were placed on 'molars at risk for caries' based on individual selective criteria (i.e. previous caries experience, deep fissure anatomy, etc.). Sealants were applied only after the parents' consent had been obtained; therefore, parent's subjective evaluation on cost effectiveness is another factor to be considered. Applying these criteria, approximately 40% of the 1st molars from private practice and 20% from the health center were sealed, while the respective values for 2nd molars were 60% and 30%. Regarding caries diagnostics, tooth surfaces were considered carious when there was a definite caries diagnosis at the dentin level. If a surface was diagnosed as questionable, a sealant was placed or replaced.

The data were entered into the computer and SAS statistical software [15] was used for analysis of tooth survival individually for each tooth applying the Kaplan-Meier method. Survival time was defined as the time elapsed between eruption of the tooth and placement of the restoration due to caries. Survival times of fissures were measured: at tooth level (sealed versus non-sealed tooth) and at subject level [all-sealed subjects (all four 1st molars sealed) versus non-sealed subjects (none of their 1st molars sealed)]. Separate analyses were done from these two data sets. Dentine caries lesions, also increasing the independence problems, were restored immediately when diagnosed trying to eliminate this variable.

Table I. The representative sample of subjects born in 1970–72 in Finland and in Sweden and in 1980–82 in Finland, Sweden, and in Greece

Country	Gender	1970–72 *n*	1980–82 *n*	Total *n*
FINLAND	Boys	694	734	1428
	Girls	747	760	1507
GREECE	Boys	–	267	267
	Girls	–	292	292
SWEDEN	Boys	312	335	647
	Girls	297	297	594
Total		2050	2685	4735

Because of the interdependence problem, the percentage of survival probability was estimated separately for each tooth from emergence to sealant treatment/restoration using the Kaplan-Meier method [16]. Survival curves for homologous teeth on the left and right sides were found to be similar and were combined in the figures but not in the statistical analysis, in which the child was the unit of analysis. The significance of the differences between the survival curves for each tooth in each group was compared by means of the log-rank test, and a *p*-value of <0.05 was taken to indicate statistical significance.

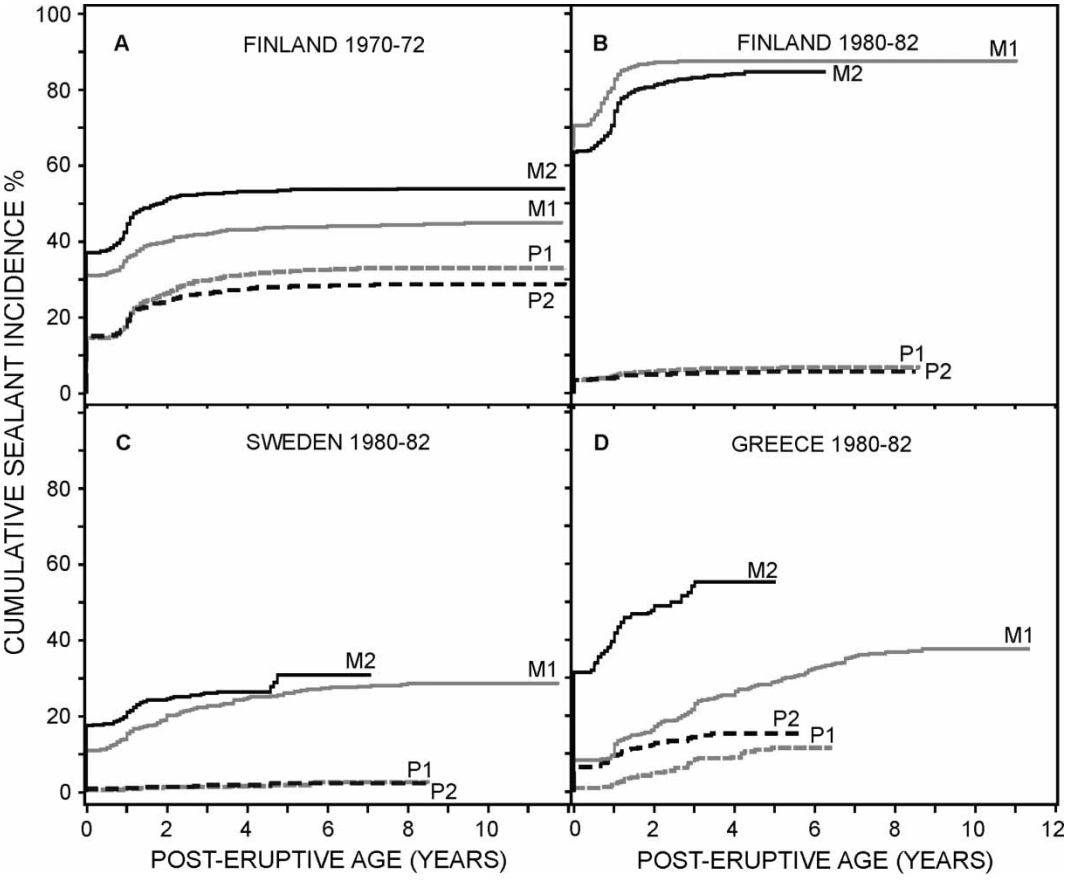

Figure 1. Cumulative sealant incidence (%) of permanent 1st (M1) and 2nd (M2) molars and 1st (P1) and 2nd (P2) premolars in Finland, Sweden, and Greece.

Results

The distribution of participants according to country, gender, and year of birth is given in Table I. In the 1970 cohort in Finland, half of the molars and 20–30% of the premolars were sealed (Figure 1A). In Sweden, very few teeth were sealed in that cohort and therefore no comparisons between sealed and non-sealed teeth/subjects could be performed. In Greece, the 1970 cohort was unavailable.

In the 1980 cohort in Finland, sealing all molar teeth as early as possible after tooth emergence became a routine, and resulted in 80–90% of all molars being sealed (Figure 1B). In Sweden, the recommendation was to place a sealant only in caries risk subjects, and this resulted in 20–30% of molars and a low percentage of premolars being sealed (Figure 1C). In Greece, the prevalence of sealant placement for 1st molars was at the same level as in Sweden, but 2nd molars were sealed twice as often as the 1st molars and a relatively high percentage of premolars were also sealed (Figure 1D).

No differences were noted between the survival curves of boys and girls in any country or left and right sides, therefore the data were combined in the pictures. The curves for all molar teeth were similar, and therefore maxillary 1st molars were chosen to represent the survival curves in the pictures.

When the survival times between tooth eruption and placement of a restoration due to caries were compared between sealed (early or late) and non-sealed teeth, the results can be summarized as follows: sealing of any 1st molar resulted in a significant reduction ($p < 0.05$) of restoration placement in these teeth compared to their unsealed counterparts (Figure 2A–D). Approximately 30–40% of sealant treated molars were restored after 7–10+ years of follow-up in all these countries. The caries preventive effect of sealant placement was significant in Finland and in Greece (Figure 2A, B, D) where nearly 80% of non-sealed molars were restored at the end of follow-up. Sealing on the year of tooth emergence (early sealing) was not significantly ($p > 0.05$) more effective than sealing later on (late sealing) and the outcome was similar in all countries (Figure 2).

Results at the subject level show that subjects with all their 1st molars sealed had fewer restorations than non-sealed subjects did, and the difference was significant ($p < 0.05$) between sealed/non-sealed subjects in Finland in the 1970 cohort and in Greece in the 1980 cohort, whereas the difference was

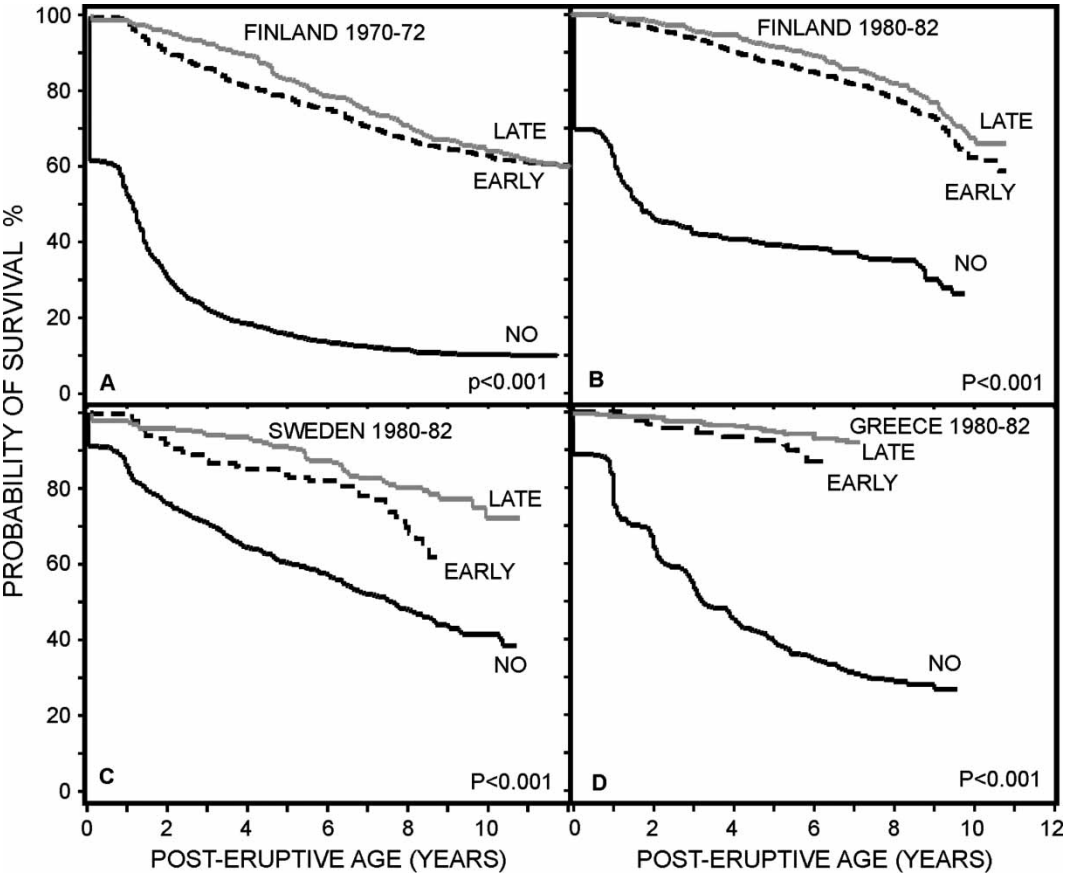

Figure 2. Survival curves of maxillary permanent 1st molars in subjects with early, late, or without any sealant treatment in Finland, Sweden, and Greece. The log-rank model *p*-value is listed between early/late sealed and non-sealed 1st molars.

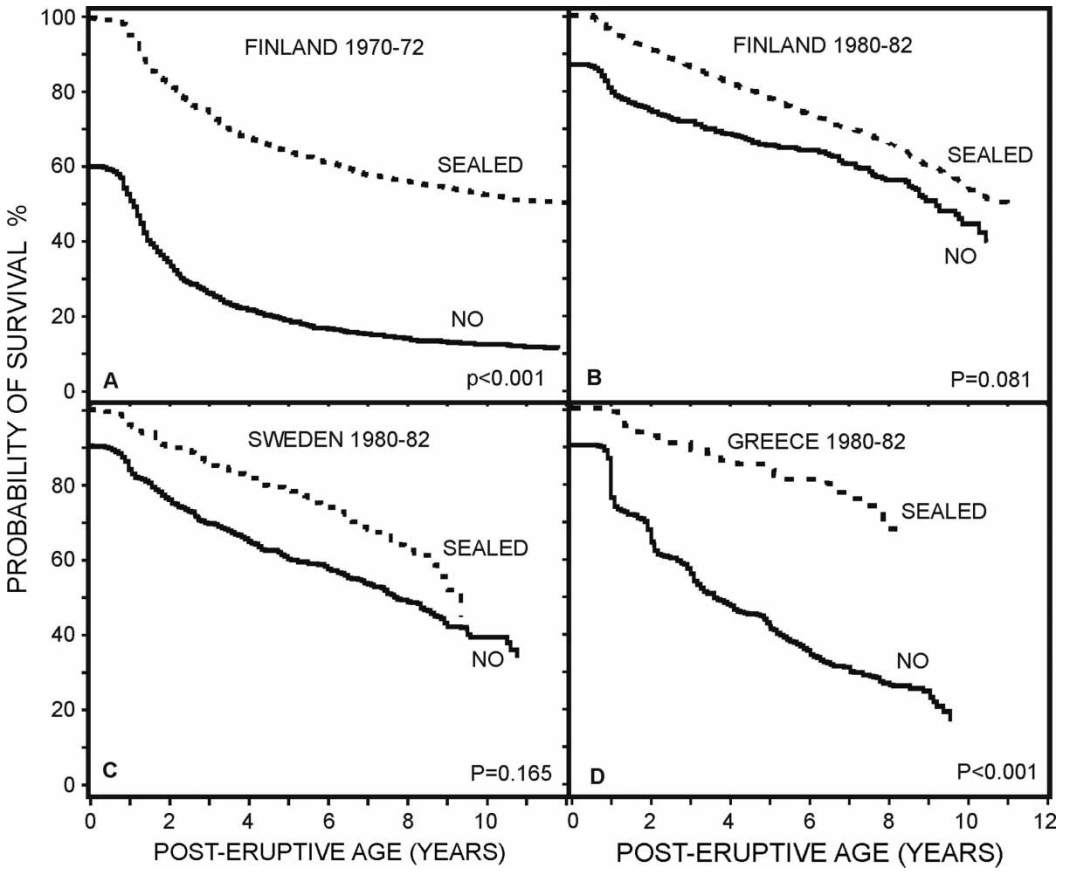

Figure 3. Survival curves of the maxillary permanent 1st molars in subjects with no sealant treatment in any of their 1st molars ("no") and in subjects with all their 1st molars sealed ("sealed") during the first post-eruptive year in Finland, Sweden, and Greece. The log-rank model *p*-value is listed between sealed and non-sealed 1st molars.

insignificant ($p > 0.05$) in Finland and in Sweden in the 1980 cohort (Figure 3).

The *p*-values are listed showing significance differences between survival curves of sealed and non-sealed 1st molars at tooth level (Figure 2) and at subject level (Figure 3) in each country. The number of teeth/subjects participated in study and differentiated the amount of "failed" and censored" teeth/subjects are presented in Tables II and III. Odds ratios illustrate the instantaneous risk of 1st molars becoming cavitated (Tables II and III).

Discussion

The effectiveness of sealants is usually evaluated in clinical trials by comparing the caries prevention in sealed teeth with teeth that were not sealed in the same mouth. Once a sealant method is recognized, it could be considered unethical to deny patients its use and untreated control teeth are not acceptable [2]. Thus, evidence-based clinical trials in this mode are not ethically acceptable and not a sound way of estimating sealant treatment effectiveness nowadays. A double-blind trial with standardized placements of

Table II. The number of permanent 1st molars divided into failed (carious) and right-censored (healthy) groups at the end of follow-up. OR illustrates the instantaneous risk of 1st molars becoming cavitated at tooth level

	FINLAND 1970–72					FINLAND 1980–82			
Sealing status of 1st molar	Failed	Right-censored	Total	OR (95% CI)		Failed	Right-censored	Total	OR (95% CI)
Early	373	494	867	1.0	Early	548	1526	2074	1.0
Late	178	214	392	1.1 (0.9–1.4)	Late	122	380	502	0.9 (0.7–1.1)
No	1390	153	1543	12.0 (9.7–14.9)	No	244	120	364	5.7 (4.5–7.2)
	SWEDEN 1980–82					GREECE 1980–82			
	Failed	Right-Censored	Total	OR (95% CI)		Failed	Right-censored	Total	OR (95% CI)
Early	42	95	137	1.0	Early	14	77	91	1.0
Late	45	168	213	0.6 (0.4–1.0)	Late	30	261	291	0.6 (0.3–1.3)
No	469	440	909	2.4 (1.6–3.5)	No	492	225	717	12.0 (6.7–21.7)

Table III. The number of subjects divided into failed (carious) and right-censored (healthy) groups at the end of follow-up. (Sealed subjects = all four 1st molars sealed; non-sealed subjects = any of 1st molars sealed). OR illustrates the instantaneous risk of 1st molars becoming cavitated at subject level

	FINLAND 1970–72					FINLAND 1980–82			
Sealing status of subjects	Failed	Right-censored	Total	OR (95% CI)		Failed	Right-censored	Total	OR (95% CI)
Sealed subjects	604	320	924	1.0	Sealed subjects	1073	1435	2508	1.0
Non-sealed subjects	1378	220	1598	3.3 (2.7–4.0)	Non-sealed subjects	188	216	404	1.2 (0.9–1.4)
	SWEDEN 1980–82					GREECE 1980–82			
	Failed	Right-censored	Total	OR (95% CI)		Failed	Right-censored	Total	OR (95% CI)
Sealed subjects	78	114	192	1.0	Sealed subjects	35	79	114	1.0
Non-sealed subjects	497	563	1060	1.3 (0.9–1.8)	Non-sealed subjects	615	349	964	4.0 (2.6–6.0)

sealants and caries diagnostics with more than 4500 subjects over 10 years' follow-up would not be possible either. Therefore, practice-based networks for studying the effectiveness of treatment are needed urgently [6,7].

Survival analysis has an advantage over traditional statistical methods because it takes into account censored observations, which makes it especially suitable for a practice-based research protocol. High-risk individuals will tend to have a short survival, and the remaining will be of lower risk, giving a selection over time, whereas in clinical trials there is a sizable attrition rate over time and considerable information may be lost [17]. In this study, survival analysis was used to characterize the distribution of survival time on sealed/non-sealed teeth/subjects.

The survival of caries-free molar teeth was near the same level in Finland and Sweden in the 1970 cohort, even though the use of fissure sealants was common only in Finland. A similar observation is reported in Finland with younger age cohorts (born in 1990), where risk determination, and thereafter a reduced number of sealants, resulted in a similar outcome in effectiveness as routine sealant treatment [11]. With the use of fissure sealants, there is a possibility that dental health in molars reached the same level in Finland as that obtained in Sweden, where other preventive protocols were followed [18].

A marked decline in caries prevalence in primary and permanent dentition during the past three decades has been reported in both countries [19,20]. In the 1970 cohort in Finland, the prevalence of fissure caries in 1st molars was markedly higher than in the 1980 cohort, suggesting that the benefit of sealing fissures is more pronounced when caries prevalence is higher. This is supported by the findings in the 1980 cohort in Greece [21–24], where caries prevalence was about at the same level as in Finland in the 1970 cohort, and the sealant treatment has about the same effectiveness.

Within each country, non-sealed molars were restored 1.5–3 times more frequently than their sealed counterparts in the 1980 cohorts, although there were large differences in the overall prevalence of caries between these countries [25]. Contrary to our hypothesis, early application of sealants did not result in a lower percentage of restorations compared to teeth that were sealed later. Determination of sealant effectiveness after data-mining could not be performed with early and late sealing and therefore we conducted that analysis using the chronological age as the timescale. Sealing premolars was found to be less effective than sealing molars in preventing dental caries. Premolars may be less prone to caries attack than molars. Korhonen et al. [9] analyzed the first caries attack on different teeth using Kaplan-Meier survival methods and pointed out that the first restorations due to caries of 1st and 2nd premolars were significantly lower than those of the 1st and 2nd molars during the first 4–5 post-eruptive years.

We also divided the subjects into two categories at the subject level: sealed subjects were those with all the 1st molars sealed during the 1st post-eruptive year and non-sealed were those without sealants in any of their 1st molars, but all teeth were restored when necessary in both cohorts. This grouping of subjects resulted in disappearance of the significant sealant effect on the 1st molars in Finland and Sweden in the 1980 cohort, whereas sealant application remained effective in Finland in the 1970 cohort and in Greece in the 1980 cohort.

Socio-economic status (SES) has an impact on caries level within a population but the difference in the economic sense should be eliminated in Finland and in Sweden since the dental public health centers serve the whole population on these age cohorts. Our inclusion criteria eliminated the non-attendees, normally having lower SES.

In Greece, patients visiting the private office for dental care came from the medium and high socio-economic groups. On the contrary, patients visiting the health center belonged mainly to the low

socio-economic group. This explains the difference in the survival curves between Greece and the Nordic countries.

In Greece, a regular recall system was provided in private pediatric clinics, and basically the decision to restore the lesion was the same as in Finland and in Sweden: dentin caries. The dentists working in the private practices also served in public health centers on a part-time basis. Therefore, the treatment criteria were the same as well as the accepted recall intervals. In both Greece and Sweden, sealants were placed on 'molars at risk for caries' based on individual selective criteria.

The criteria for restoration and decision to seal or not to seal should be nearly the same inside the countries but could not be analyzed by scientifically standardized ways between the countries. There are significant differences in diagnostic criteria between countries, where teaching at various universities may differ on when to restore early fissure caries. For this reason, we concentrated our efforts on describing the differences between the survival curves of sealed and non-sealed 1st molars primarily within the countries.

Experimental trials on pit and fissure sealants have shown much higher caries reduction rates: only 6% of sealed teeth became carious in the 10-year follow-up period [26], while 30% of the sealed and 80% of the unsealed became carious after 15 years of follow-up [27]. In the present study, the corresponding figures were 30–40% for the sealed and 60–80% for the non-sealed molars, indicating that sealant placement by the dental practitioner in everyday practice is not as effective as meticulous sealant placement by an experienced clinical researcher in a clinical trial; however, the preventive effect is still high in the practice-based conditions as well. On the other hand, all figures of carious attacks on molars are close to those reported in a recent trial with life-table analysis with a follow-up of 4 years [28]. In areas where children show high rates of pit and fissure caries, it is well established that sealants are highly effective in preventing the occurrence of such caries. However, it is surprising that caries reduction in non-sealed molars between the 1970 and 1980 cohorts in Finland and Sweden was more pronounced than that of sealed teeth, indicating that caries reduction is also obtained without the use of fissure sealants in these countries. The other explanation might be a change of diagnostic criteria for caries: caries extending to enamel was not restored any more in the early 1980s.

This practice-based study on sealant effectiveness in preventing dental caries in "field conditions" has established that sealant application is indeed an effective preventive measure in individual molars, but not in premolars. The strategy of sealing all molar fissures (in Finland) proved no more effective than sealing clinically evaluated risk fissures of subjects (in Sweden and Greece). The effectiveness of sealant treatment was dependent mainly on caries prevalence in each country, such that the higher the caries prevalence the higher the effect was. Contrary to our hypothesis, early sealing did not result in a better outcome than late sealing.

Acknowledgments

This study was supported through a research grant received from the European Union (Biomed contract BMH4-CT96-1541).

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