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Caries prevalence of 11.5 year-olds between 1989 and 2001 in a province of North-Eastern Greece

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Objective & Design: To compare cross-sectional caries prevalence data of 11.5 year old children over a 13 year period (1989-2001) and to evaluate the maximum effect of the applied preventive programme (sealants to 1st molars and 6-year health education) on DMFT values during the last five years. ***Participants:*** Using the records of a Public Health Centre (PHC) in NE Greece, a number (153-250) of children aged 11.5-years were selected from each calendar year, constituting 11 study groups (totalling 2,217 children), stratified by area of residency. ***Method:*** Annual oral health education sessions provided in 1990, a year after the PHC was established. Light-cured fissure sealants were systematically mass introduced in 1996. The same dentist completed all DMFT records in the dental clinic during the children's routine visits. DMFT was analysed using two Poisson and two Binomial models for both data from all years, and for the last five years. The models had as factors: "Time" (year of examination of the study group), "Residency" (semi urban, rural lowland, rural highland), number of "Sealed 1st molars" and "Sealed posterior teeth". ***Results*:** All the factors were highly statistically significant ($p<0.001$). Dental health was found to be good (DMFT=0), improving progressively year by year (range 12-50%). The mean DMFT decreased steadily from 4.5 (in 1989) to 1.81 (in 2001). The Significant Caries index was almost halved (from 8.08 to 4.23). ***Conclusion***: An important improvement in the caries status of 11.5 year-olds since 1989 has been demonstrated, irrespective of the residency. The systematic application of fissure sealants to all 1st molars, parallel to the cumulative effect of the 6-year health education programme per child, played a significant role in reducing disparities in disease prevalence, despite the difficulty of improving rates of decline when the caries levels are relatively low.

Key words: Caries prevalence, children, fissure sealants, poisson distribution public health center

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Introduction

In Greece, over the last 15 years, the caries experience of children and adolescents has followed the steadily declining trend (Demertzi and Topitsoglou, 2002; Chatzistavrou, *et al.,* 2000; Mamai-Homata, *et al*., 1997; Marthaler, 1996; Vadiakas, *et al*., 1996) as exhibited in most European countries. Generally, the decline in caries levels is likely to be attributable to the synergistic effects of improved plaque control (particularly through self-care), topical use of fluorides (mainly fluoride toothpastes), well-organized preventive programmes for children and adolescents (in school or Public Health based services) (Axelsson, 2000; Bratthall, *et al*., 1996) and to the general improvement in living standards (Holst, *et al.,* 2001).

With the decline in caries prevalence, the percentage of caries free children has increased, while the percentage with high or very high DMFT scores has decreased. According to Böhning*, et al., (1999)* the distribution of the DMFT data has changed from being symmetrical to being highly skewed to the right, requiring new models for statistical analysis (Lewsey, *et al*., 2000).

Although the primary health care system was established in Greece in 1987, only limited information exists on the effectiveness of the preventive programmes implemented by dental Public Health Centers (PHC). In one county of N.E. Greece a PHC had systematically collected data on DMFT and related factors (health education, individual training in tooth brushing, fluoride and sealant application) for all children up to the present date.

The objective of this study was to asses the cross-sectional caries data of 11.5 year old children over a 13 year period (1989-2001) and to evaluate the effects of the applied preventive programme (six years of health education per child and sealing of 1st molars) on caries indices, according to the year of examination and the residency.

Participants and Methods

The total number of subjects (2,217) comprised 11 separate groups (153-250 children each) aged 11.5-years (Table1). The records of 1,118 males (50.4%) and 1,099 females (49.5%) were part of a study conducted in the Public Health Center (PHC) of Nestos province. During a 13-year period from 1989 to 2001 (excepting 1990 and 1991), 11 examinations of children aged 11.5 years took place, usually at the beginning of each calendar year. The children lived either in semi-urban environment (n=1,005, 45%) or rural environments, nine lowland (n=635, 29%) and five highland villages (n=577, 26%). The children of immigrants, refugees and repatriated Greeks were excluded from the study, as well as the children of one village, with naturally fluoridated water (0.68 ppmF). In

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total, the records of 20% of the children living in the area were excluded from the study.

During the children's annual routine visits, the same dentist in the PHC dental clinic examined them using mirror, blunt probe and dental light, after supervised tooth brushing. The first group was examined in 1989, about one year after the establishment of the PHC. The DMFT were recorded by scoring only visible cavities or lesions with an apparent colour change (extension into dentin) (WHO, 1987). Radiographic analysis was not used. Data collected from patient records of PHCs has proven to be both trustworthy and useful in epidemiological studies (Hausen, *et al*., 2001). A total of 15 pupils from the 2001 group was re-examined one week after the examinations; the intraexaminer agreement was good (Kappa=0.98)

In 1990 the PHC implemented an annual preventive programme of health education and individual training in tooth brushing (Figure1). Fissure sealants on sound occlusal surfaces of permanent posterior teeth were introduced in 1996 for mass systematic application to all children. Every newly erupted posterior tooth was sealed using light-cured sealants on an annual basis. Lost sealants were not replaced.

Each child followed the health education programme for six years (6^{th} to 12^{th} year of age), although for the first four groups (1989, 1992, 1993, 1994) the duration of this programme was shorter (Table 1).

Data management and statistical analysis

Descriptive statistics per year and per residency type were calculated for: caries prevalence of permanent teeth, i.e. DMFT, its components and distribution (DMFT=0, 1-3, ≥4); care index (FT/DMFT%); number of fissure sealants used in mass application, particularly to 1^{st} permanent molars and to all posterior permanent teeth; Significant Caries index (SiC) per year (DMFT of one third of the population with the highest caries scores) (Bratthall, 2000).

General Linear Models (GLMs) (SAS system, software GENMOD). The effect of the various independent

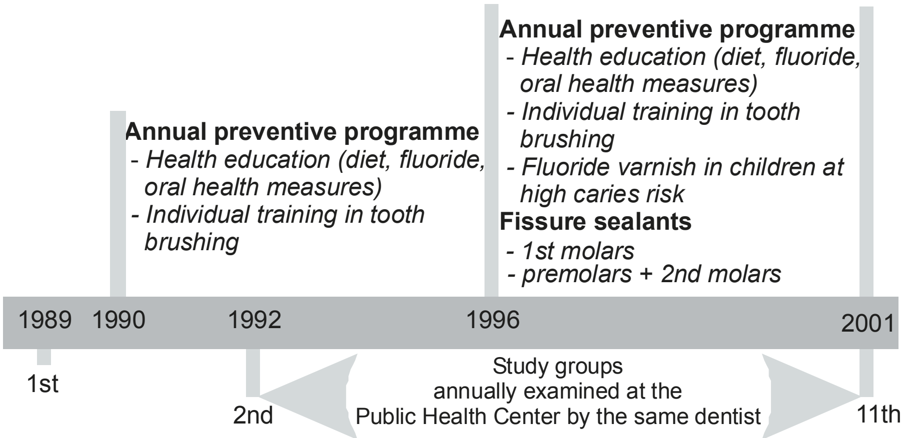

Figure 1. *Flow chart of the study. Eleven study groups of 11.5-year-old children examined between 1989 and 2001. The groups 6th (1996) to 11th (2001) were subjected to the full preventive programme (6yrs health education and mass application of sealants).*

Table 1. Eleven groups of children examined per residency type over a 13-year period (mean age 11.5 years).

Year of group examination	*Years of implemented programme/child*	*"Residency"* Semi urban n (%)	Rural lowland n (%)	Rural highland n (%)	*Total* n (%)
1989	0 health edu.	105 (44)	72 (30)	63 (26)	240 (11)
1992	3 »	110 (44)	63 (25)	77 (31)	250 (11)
1993	4 »	101 (44)	57 (25)	71 (31)	229 (10)
1994	5 »	91 (39)	74 (32)	66 (29)	231 (10)
1995	6 »	81 (41)	63 (32)	55 (28)	199 (9)
1996	6 » + sealants	93 (48)	52 (27)	47 (25)	192 (9)
1997	6 » + »	94 (50)	50 (26)	46 (24)	190 (9)
1998	6 » + »	82 (46)	54 (30)	44 (24)	180 (8)
1999	6 » + »	78 (51)	39 (25)	36 (24)	153(7)
2000	6 » + »	86 (47)	55 (30)	41 (23)	182 (8)
2001	6 » + »	84 (49)	56 (33)	31 (18)	171 (8)
Grand Total		*1005 (45)*	*635 (29)*	*577 (26)*	*2217(100)*

factors (covariates) on DMFT outcomes (response) was estimated using two Poisson log linear and two Binomial models. The alfa level in all tests was set at 0.05.

Model 1: Poisson log linear model using all years' data, with the following factors: "Time": 11 levels (the group examined in 1989 and the next 10 groups examined in the years 1992 to 2001), "Residency": three levels (semi urban, rural highland and rural lowland), "Sealed 1st molars" per child: five levels (#0 to 4). The response factor was DMFT: levels 17 (#0 to 16).

Model 2: Binomial model using all years' data with factors: "Time" and "Residency" as described above and "Sealed posterior teeth" per child: 17 levels (#0 to 16). As response, the binary variable "zero" was used, if DMFT=0 (caries free children) and "one", if DMFT>0 (caries present). The use of models 1 and 2 helped separate those factors that influence the magnitude of caries from factors influencing the presence or absence of caries.

Model 3: Poisson log linear model using the last five years' data. This model is the same as model 1 differing only in factor "Time" having five levels (groups examined from 1997 to 2001).

Model 4: Binomial model using the last five years' data. It is identical with model 2, apart from factor "Time" having five levels (1997-2001). The use of models 3 and 4 focused on the period of time in which the sealants applied would demonstrate their maximum effect, in association with the six year application of health education programme per child.

Two more factors were tested; the factor "Gender", and "Years of the implemented programme per child" (5 levels: 0 and 3 to 6 years). The factor "Gender" was dropped from all the models after testing its significance and the significance of all two-way interactions and as no statistically significant difference was found between males and females, their data were combined. The second factor was excluded from the model analysis, because it demonstrated multicollinearity, secondary to its incorporation in factor "Time".

Results

The fluoride concentration in the drinking water of all the villages involved was found to be less than 0.1 ppm F.

Descriptive statistics: The caries levels of all study groups, regardless of residency type, are presented in Table 2. Median and quartile ranges were chosen for Figure 2 as more illustrative than mean and standard deviations in view of the skewed data. In the examination of the 1st group (year 1989), carried out before the implementation of the preventive programme, the mean DMFT index was found to be 4.5 (+3.16). Subsequently, the mean gradually decreased significantly ($p<0.05$) showing a reduction of approximately 44% by 1996. The next five groups examined showed a continuing, albeit slower, decline in caries levels approximately 29% (Figure 3). In all data sets, the largest component of the DMFT was attributed to decayed teeth. Although the care index gradually increased, many teeth remained to be restored. The SiC index followed the general decline, but remained high (Figure 3). The application of fissure sealants rapidly increased from 1996 and after, covering the vast majority of both the pupils (74-96%) and their 1st molars (mean "Sealed 1st molars" 1.82 - 3.04 per child) (Table 2). The distribution of DMFT values revealed a decrease in the proportion of high caries children year by year (Figure 4). The corresponding increased proportion of cavity free children from 19% (mean percentage of the years 1989-1996) increased to 40% (mean percentage of the years 1997-2001).

Analysis of variance: Figure 2 shows that the median of each box lies at a different level, a fact that confirms the non-symmetric distribution of the dependent variable DMFT, with the exception of the 1989 group. The different distribution in each year complicated the choice of a single model that would fit the data for any year of examination. Since we do not have a large proportion of zeros in all years, the zero-inflated Poisson model (ZIP), as proposed by van den Broek (1995), is not appropriate.

Table 2. Mean DMFT and its components, percent (%) of children with sealed 1st molars and mean number of sealed 1st molars per child

Year of group examination	*DT X (sd)*	*MT X (sd)*	*FT X (sd)*	*DMFT X (sd)*	*Care index FT/DMFT %*	*Children with sealed 1st molars*	
						%	*X*
1989	3,45±*2,69*	0,18±*0,48*	0,87±*1,60*	4,5±*3,16*	19	0	0
1992	2,42±*2,16*	0,14±*0,45*	1,14±*1,72*	3,7±*2,79*	31	0,4	0
1993	1,90±*2,21*	0,08±*0,33*	1,09±*1,59*	3,07±*2,53*	36	0,4	0.02
1994	1,68±*2,00*	0,11±*0,38*	1,05±*1,62*	2,84±*2,43*	37	0,9	0.02
1995	1,17±*1,46*	0,06±*0,30*	0,73±*1,08*	1,96±*1,71*	37	32	0.6
1996	1,49±*1,85*	0,02±*0,14*	1,02±*1,49*	2,53±*2,40*	40	74	1.82
1997	1,16±*1,75*	0,06±*0,28*	0,73±*1,17*	1,95±*2,17*	37	78	2.24
1998	1,19±*1,77*	0,02±*0,15*	0,71±*1,25*	1,92±*2,26*	37	87	2.61
1999	1,04±*1,70*	0,04±*0,23*	0,75±*1,22*	1,82±*2,11*	41	93	2.81
2000	0,67±*1,24*	0,03±*0,19*	0,51±*0,96*	1,21±*1,64*	42	96	3.04
2001	1,01±*1,53*	0,02±*0,24*	0,78±*1,28*	1,81±*2,12*	43	89	2.78

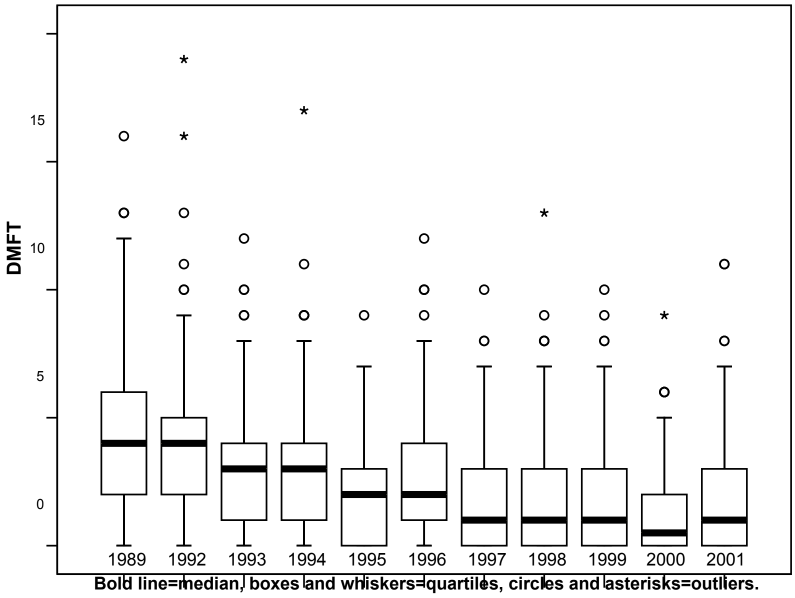

Figure 2. *Box plots of DMFT frequency distribution per year of examination (n=2,217)*

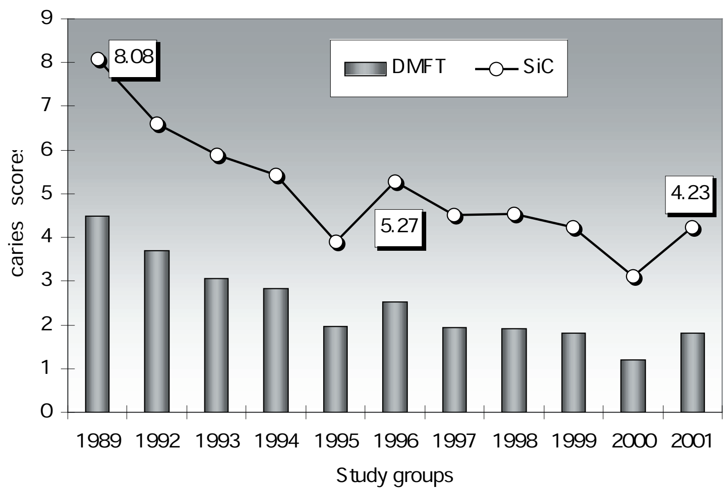

Figure 3. *Mean caries (DMFT) and Significant Caries (SiC) indices of the 11 study groups aged 11.5 years old, examined during the 13 year-observational period.*

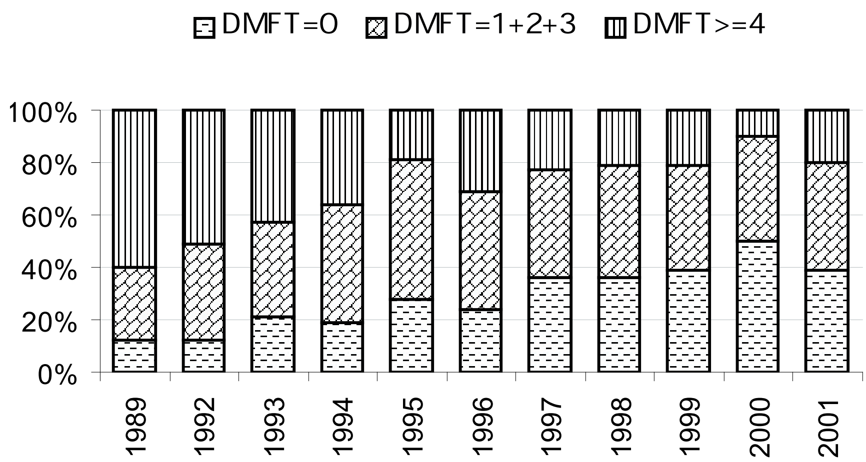

Figure 4. *Percentage of children distributed according to the magnitude of their DMFT index, per year of examination.*

Even if we did have zero inflation, our over-dispersed data could not be analysed (Ridout, *et al*., 2001). This is because these test statistics are very sensitive to anomalous cases in the data, as ours are, and incorrect inferences concerning the choice of the model may be drawn (Lee, *et al*., 2004).

In all the models we tested, the two-way interactions were dropped in the absence of any evidence of statistical significance. The Poisson *models 1 & 3* showed a good fit for all years' data (Deviance/DF =1.6579, Pearson Chi-Square/DF =1.7430, Log Likelihood =881.2514, DF=2200) and a perfect fit for last five years' data (Deviance/DF =1.1162, Pearson Chi-Square/DF =1.5154, Log Likelihood= -66.7100, DF=864) (Table 3). When the value of Deviance/DF is close to 1, it is an indication of a good fit (Byers, *et al*., 2003). The results allowed "Time" effect, "Residency" effect and "Sealed 1st molars" effect, to be assessed (p<0.001). When processing all years' DMFT data according to "Residency", children from highland villages were found to experience slightly worse dental status compared to those in lowland villages or semi urban environments (Figure 5).

Although the statistical models used demonstrate the statistical significance of the factors, a more visual interpretation of the results is useful. The histogram in Figure 6 presents the mean DMFT of the last five years' data and shows that with increasing numbers of sealed 1st molars per child, the DMFT drops dramatically, faster than it drops year by year (compare with Fig 3). With no sealed 1st molars, the mean DMFT value of the last five years' data is 4.7 (95% *CI* 4.4-4.9), i.e. more than 10 times the mean 0.38 (95% *CI* 0.24-0.51) for children with all their 1st molars sealed.

In the Binomial *models 2 & 4* the factor, number of "Sealed posterior teeth" per child was used (Table 4). When processing the data for the entire period of study, the Binomial *model 2* had a good fit (Deviance/DF =0.8668, Pearson Chi-Square/DF =1.1662, Log Likelihood= -948.2550, DF=2188) and all factors were highly significant (p<0.001). When analysing data for the last five years (1997-2001), *model 4* also produced a good fit (Deviance/DF =0.8848, Pearson Chi-Square/DF =1.1046, Log Likelihood= -377.3548, DF=853). The factors "Time" (p=0.0162) and "Sealed posterior teeth" per child were significant (p<0.0001), but the factor "Residency" had lost its effect only in the *model 4* (p=0.1129). It seemed that "Residency" had more to do with the magnitude (*models 1 & 3*) of the DMFT than with the absence or presence of caries (*models 2 & 4*). The Binomial models also provide evidence that the probability of being caries -free for the 2001 group was significantly greater than for the 1989 group, and, that the probability of being caries-free for the lowland group was significantly greater than for the highland group.

Discussion

The objective of the study was to asses the cross-sectional caries data of 11.5 year old children over a 13 year period (1989-2001), within which a sub period between 1997-2001 has been distinguished, characterised by the mass application of sealants (78% to 96% of children, mean 2.24 to 3.04 of 1stmolars/child) and possibly the cumulative effect of the preventive programme applied, namely, health education and individual training in brushing the teeth. This was started in the year 1990, hence children aged 11.5 years then were only involved in the programme once; while 11.5 year olds after 1996 (mass application of sealants) had been involved in the programme on six occasions. Thus, from the year 1997 the children benefited from the maximum impact of the PHC efforts. Apart from 1st molars, sealants were also

Table 3. Type III analysis. Poisson log Linear with dependent variable DMFT and factors "Time", "Residency" and "Sealed 1st molars".

	Model 1 *All years' data*		*Model 3* *Last five years' data*	
Factors	*Degrees of freedom*	*p-value*	*Degrees of freedom*	*p-value*
Time	10	<0.0001	4	0.0007
Residency	2	<0.0001	2	0.0006
Sealed 1st molars	4	<0.0001	4	<0.0001

Table 4. Type III analysis. Binomial models (Y=0 or Y=1, if DMFT>0) and factors "Time", "Residency" and "Sealed posterior teeth".

	Model 2 *All years' data*		*Model 4* *Last five years' data*	
Factors	*Degrees of freedom*	*p-value*	*Degrees of freedom*	*p-value*
Time	10	<0.0001	4	0.0162
Residency	2	0.0004	2	0.1129
Sealed posterior teeth	17	<0.0001	4	0.001

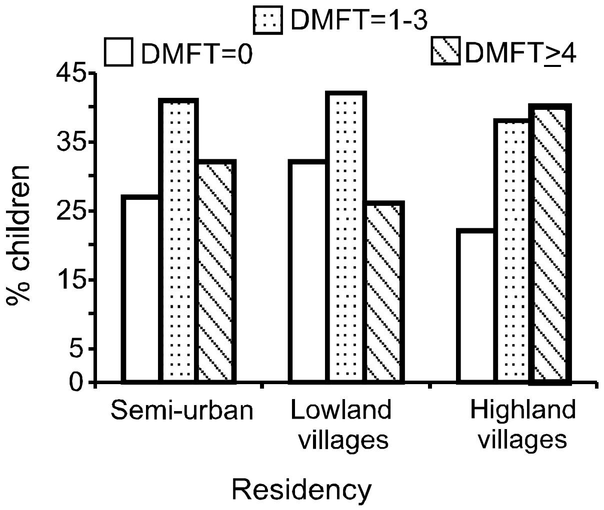

Figure 5. *Percentage of children distributed according to residency type in relation to their caries index (all years' data).*

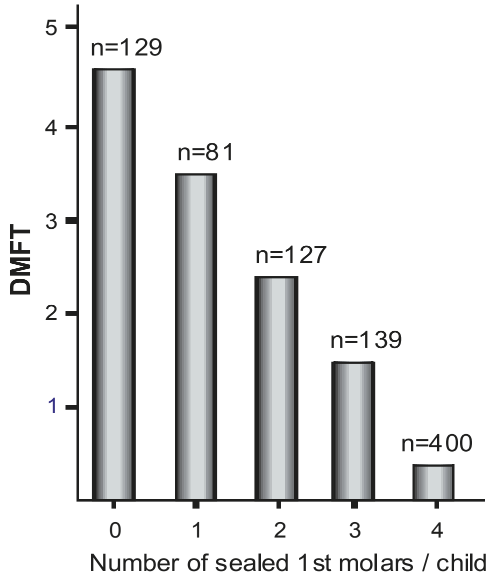

Figure 6. *Caries index of 11.5 year-old children in relation to the number of their 1st molars sealed (last five years' data).*

applied to premolars and 2nd molars, but these teeth contribute less to the caries index up to 11.5 years of age than 1st molars.

Observing the DMFT scores over the period of 13 years, it might seem that the rate of reductions were greater prior to the introduction of the fissure sealants. For this reason the statistical models were used twice: once with all years' data *(model 1)* and once with the last five years' data *(model 3)*. Both models verified that the factor "Sealed 1st molars" remained statistically significant, something that is true even for the factor "Sealed posterior teeth" in binomial *models 2 and 4*. The study also revealed that while caries prevalence declined, a mean of 19% of the 11.5 year-old children still had high caries levels (DMFT>=4) during the 1997-2001 period, confirming the often quoted 80:20 rule (Pitts, *et al*., 2003). This is in accordance with other recent cross-sectional or longitudinal studies of children of the same age in other parts of the country (Demertzi & Topitsoglou, 2002; Chatzistavrou, *et al*., 2000; Mamai-Homata, *et al*., 1997).

The topical fluoride application measure was, unfortunately, not successful, being only provided to approximately 5% of children at high risk, due to the limited response from families in driving children to PHC. Dental health was found to have continuously improved year on year, with caries (cavity)-free children increasing by a factor of four. Systematic efforts by the PHC at both primary and secondary health care levels, mainly health education programmes and fissure sealants, respectively, have been important contributors to this improvement. Analogous results by other researchers have also been found (Axelsson, 2000; Bratthall, *et al*., 1996). Unfortunately, the lack of a control group without any preventive programme prevents further comparisons. Despite improvements in providing operative care for those with dental decay, significant groups remain within the population of 11.5 year-olds with cavities and needs for dental care and intensive prevention programmes, both home and clinic based. The importance of parents bringing their children to the PHC for treatment (fillings and topical application of fluoride) was stressed; however, the response was disappointing, especially from families in highland villages.

In contrast, sealants were routinely applied during the annual examination of each school class, avoiding any family responsibility. This allows the assertion that the most effective measure implemented by the PHC was the application of fissure sealants protecting the most vulnerable of all tooth surfaces (the occlusal) (García-Godoy, *et al*, 2004; Marthaler, 2004). The caries preventive potential of sealants has been proven in many studies and from a cost/effectiveness point of view their routine use is suggested as early as possible after eruption for caries susceptible teeth (molars) and children (with ≥1 caries lesion per year or with caries in deciduous teeth) (Locker, *et al*., 2003). This is why one of the objectives of the programme "Healthy people 2010" in the US is to increase the proportion of children who have received dental sealants on molar teeth from 23% (national %) to 50% (US PHS, 2000).

Concerning location of residency, in all years' data and in last five years' data, the factor "Residency" was found highly significant in affecting caries scores *(models 1 & 3)*, beyond the fact that the applied preventive programme was the same in the three residencies. This could be attributed to the complex nature of the factor "Residency", as it incorporates many socio-economic and demographic elements (Holst, *et al*., 2001; Axelsson, 2000). Perhaps, as Moyniham, *et al.,* (2003) suggested, in disadvantaged areas health education interventions and fluoride-based preventive programmes may be least effective, as they require personal involvement and consent.

According to the proposals for the year 2000, the goal for the caries index was <3 at age 12. This goal has almost been surpassed in the study area. The SiC index is still high (DMFT=4.23) and, according to the proposals made by Bratthall (2000), it should be less than three by the year 2015. To achieve this goal with young children entering primary school already showing signs of caries symptoms, the PHC should increase its efforts by starting programmes earlier in kindergarten and by implementing a complementary programme for those children at high-risk.

In conclusion, the level of caries across the 11.5 years-old study population has been reduced significantly over the 13-year period 1989-2001. The mass systematic application of sealants to all 1st molars, and, perhaps, the cumulative effect of the health education programme applied to each child for six years, played a significant role in reducing disparities in disease prevalence, despite the difficulty in improving rates of decline when the caries levels are relatively low. As the majority of caries -free children had had their 1st molars sealed early, and the statistical conclusions indicate the significant role of sealants to 1st molars in achieving this, it becomes apparent that Greek Public Health Centers with analogous caries level should, as a matter of course, incorporate sealants into their preventive programmes, in parallel with their health education efforts and fluoride treatment.

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