Review

Caries Research

Caries Res 2016;50:9–16
DOI: 10.1159/000442713

Received: January 25, 2015
Accepted after revision: August 10, 2015
Published online: January 12, 2016

Caries Epidemiology and Community Dentistry: Chances for Future Improvements in Caries Risk Groups. Outcomes of the ORCA Saturday Afternoon Symposium, Greifswald, 2014. Part 1

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Key Words
Caries decline · Community dentistry · Prevalence · Prevention · Socio-economic status

Abstract
This paper reviews the first part of the outcomes of the ORCA Saturday Afternoon Symposium 2014 dealing with 'caries epidemiology and community dentistry: chances for future improvements in caries risk groups'. After the caries decline in many countries, there are remaining pockets of higher caries levels, mostly in the primary dentition and/or linked to a low socio-economic status (SES). The review into the evidence of caries-preventive measures clearly points to the use of fluorides, especially toothbrushing with fluoridated toothpaste and collective measures such as water fluoridation. In contrast to several unsuccessful high-risk approaches, community and public health programmes seem to be able to ensure a population-wide access and compliance in risk groups. Their simple and evidence-based measures mostly combine regular plaque removal and fluoride applications via toothbrushing, at least for children and adolescents. For the future, the common risk factor approach which addresses associations between oral health, social deprivation, diet, hygiene, smoking, alcohol use and stress should lead to combined efforts with other community health and education specialists. Further engagement with public policy, community leaders and administration is needed in order to strengthen healthy choices and behaviour, e.g. in 'healthy' schools and kindergartens. It seems advisable that these population programmes also aim at improving upstream factors.

The Caries Decline

The substantial decline of caries prevalence in countries with high social and economic development is well documented in children [Davies et al., 1997; Whelton, 2004; Dye et al., 2007; Petersen 2010]. By the end of the 20th century, caries prevalence and incidence had declined dramatically in many parts of the world, such as North America, Western Europe, Australia, New Zealand and Japan [Whelton, 2004]. More recently this decline has been carried on into adulthood, with military recruits in Australia, Denmark, England, Wales, Germany, Norway, Sweden and the USA showing caries reductions ranging from 18 to 66% in recent years [Menghini et al., 2001; Marthaler, 2004].

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Scandinavia had very high caries levels after World War II, which triggered organized preventive strategies and resulted in a marked caries reduction during the last three decades. Since 1972, the Health and Medicines Authority in Denmark has published a yearly database reporting the dental health of Danish children and demonstrating a marked fall in caries prevalence for all 2- to 18-year-olds. For example in 1980/81, 15-year-olds had a mean DMFS of 13.2 which in 2014 was reduced to 1.6 [Danish Health and Medicines Authority, 2015]. Among Danish adults utilizing oral health care delivered by private dental practitioners, dental status and dental caries experience were improved from 2000 to 2008. The continued improvement in oral health shows the positive changes that have been observed among children are maintained into adulthood [Vilstrup et al., 2010].

Similarly, New Zealand had one of the highest levels of oral disease in the Western world in 1976. In the 2009 national survey large improvements in oral health have occurred for children since the 1980s, with the proportion of 12- to 13-year-olds who were caries free almost doubling between 1988 (28.5%) and 2009 (51.6%) and the average lifetime experience of dental decay in the permanent teeth (DMFT) decreasing from 2.4 to 1.3 teeth. In people aged 20–24 and 35–44 years the lifetime experience of dental decay had almost halved [Ministry of Health, 2010].

After a late start, Germany structured legislation for community prevention and individualized prevention for children and adolescents in 1989 [SGB V, 1989]. Over the next 20 years, regular representative surveys reported a national caries decline for children and adolescents, e.g. a decline of 90% in 12-year-olds [DAJ, 2010] and now even for adults aged 35–44 years, with a reduction of 2 DMFT [IDZ, 2006]. Thus, the caries reductions in children and adolescents can persist in adulthood as described earlier in the USA [Liu et al., 2014] and Sweden [Hugoson et al., 2005].

Exceptions and Pockets

However, the impressive data on the caries decline are just one side of the coin. There are a considerable number of exceptions to this trend, with pockets of remaining caries which should be addressed for further preventive approaches.

The use of the rather crude caries diagnostic criteria such as the DMFS/T index which only counts caries at the defect or filling level overlooks initial lesions. Especially in children, adolescents and young adults, many lesions are non-cavitated and, therefore, many surveys underestimate the real caries burden [Nyvad et al., 1999]. In addition, most survey and school examinations do not utilize radiographs as a diagnostic tool, which results in an underestimation of caries on approximal surfaces, even for dentinal caries [Lillehagen et al., 2007].

Besides the diagnostic lag, the caries decline seems to be greater in the permanent dentition than in the primary dentition. Children exhibit a clearly higher caries burden in the first 5–6 years of the primary dentition than in the first 6 years of the permanent dentition, as comparative European data on caries levels in 5- and 12-year-olds reveal [Bolin, 1997]. Similarly, German national surveys show a caries decline of 70% in the young permanent dentition over a 15-year period compared to only 35% in the primary dentition [DAJ, 2010]. Thus, German dentists encounter about 4 times more carious lesions in the deciduous dentition than the permanent dentition for children up to the age of 12.

Future caries-preventive approaches are needed for the primary dentition, especially in early childhood, as international studies report a high or even rising prevalence of early childhood caries [Jin et al., 2003; Postma et al., 2008; Treuner and Splieth, 2013]. Early childhood caries is clearly linked to socio-economic status and still persists after the caries decline. A recent review which examined 43 countries that had at least three data points on the caries experience of 12-year-old children during 3 or more time periods from pre-1980 to 2010 found the disease had changed from a disease of affluence to a disease of deprivation. No significant improvement in caries experience in the populations at a lower economic and human development level had occurred [Do, 2012]. A recent review further confirms that low socio-economic position is associated with a higher risk of caries lesions or caries experience, with this association being stronger in developed countries [Schwendicke et al., 2015].

In Germany, where adolescents attend schools with different educational levels at a young age, caries prevalence varies significantly according to the educational level: already at the school entry examination, first graders who will enter the 'Gymnasium' (highest school form) 4 years later exhibit only half the caries levels of other children. Children of academic fathers almost completely enter the 'Gymnasium', while only 42% of other children are selected for this school form [Schmoeckel et al., 2015]. Consequently, the caries levels in 10th grade are twice as high for 'other schools' compared to the 'Gymnasium', the rate for treatment needed (DT >0) is 3 times higher.

Thus, educational/socio-economic status and caries levels of children are highly linked, which is confirmed in all German national surveys [IDZ, 2006].

In many countries, the socio-economic status is also linked to ethnicity. The NIH surveys consistently present varying caries rates for the different ethnic groups [Liu et al., 2014]. Also in New Zealand, significant disparities still exist in the oral health status and related behaviour for children and adolescents, particularly for those of Māori and/or Pacific ethnicity. They were less likely to have accessed oral health services in the previous year, to have caries-free primary teeth or to meet toothbrushing recommendations than non-Māori children. Most of these differences might not be linked to ethnicity but to the underlying socio-economic difference. As children and adolescents in the most deprived areas in New Zealand in general were less likely to meet toothbrushing recommendations and had more missing primary teeth due to decay than those in the least deprived areas [Ministry of Health, 2010]. Similarly in Germany, the clear differences in caries levels between Arabian/Asian and Eastern European children and the native German population mostly mirror the variation in the socio-economic background [Korden, 2014].

Reasons for the Decline

The caries decline is a significant achievement brought about by numerous public health measures, such as community water fluoridation, improved oral hygiene including widespread use of fluoridated toothpaste, and better disease management, along with improved living conditions [Spencer et al., 1996; Petersen, 2010]. The preventive measures which led to the caries decline have been well documented and examined. Systematic reviews and expert views on the effectiveness of caries preventive measures [Bratthall et al., 1996; Marinho et al., 2002a, b; Santos et al., 2013] clearly agree on the strong evidence for caries reductions via fluoride exposure. Summarizing earlier investigations, Kay and Locker [1998] stated that oral health programmes which did not use fluorides failed to achieve significant caries reductions. As recently as 2012, the reason cited for such differing levels of decay between Vietnam and Australia is the total lack of population preventive programmes in Vietnam, namely, water fluoridation and the use of fluoride-containing toothpastes [Do, 2012]. Given the well-documented effectiveness of water fluoridation and the timely use of fluoridated toothpaste [CDC, 2001; MRC, 2002; NHMRC, 2007], the lack of these programmes may be one of the main reasons observed for the differences in DMFT of 12-year-olds between 43 countries of different social and economic development [Do, 2012].

Different opinions exist regarding all the reasons for the decline, but daily use of fluoridated toothpaste was considered to be the most important single factor [Bratthall et al., 1996]. Daily brushing with fluoride toothpaste seems to be easier to achieve than the regular use of fluoride supplements. Kay and Locker [1998] also point out that 'there is no evidence that oral health promotion per se affects caries rates'. Thus, the effectiveness of purely informational or motivational presentations should be questioned.

During the introduction of fluorides in preventive dentistry, almost any fluoride application resulted in significant caries reductions. Even 2 applications of fluoride gels, fluids or varnishes per year resulted in up to 60% reduction of caries incidence [Brambilla et al., 1997; van Rijkom et al., 1998; Marinho et al., 2002a, b, 2003]. Fluoridated domestic salt, the cheapest measure of all, has been recommended in Switzerland (83% market share since 2000) and Germany (53% market share in 2002) [Marthaler, 2003]. In these two countries, fluoridated salt has largely replaced fluoride supplements, whose public value, important in some countries decades ago, is not warranted any more [Burt, 1999]. In other countries, there is some debate as to the effectiveness of fluoridated water when other preventive measures are successfully implemented. For instance, in Kuopio/Finland water fluoridation was stopped in 1992, with the DMFS of 15-year-olds being 4.0. In spite of discontinued water fluoridation, no indication of an increasing trend of caries could be found in Kuopio, and 15-year-olds had a DMFS 3.2 in 1995 [Seppä et al., 1998].

The advantage of community water fluoridation is that it reaches even the least advantaged sections of the population. However, recent studies have given conflicting results, with some stating that there is insufficient evidence to establish the effectiveness of water fluoridation in adults [McDonagh et al., 2000; Yeung, 2008]. This is not in agreement with the systematic review by Griffin et al. [2007] that included cross-sectional studies and showed a mean reduction in caries in adults of 27%. Further evidence is available from a nationally representative sample of Australians adults, where the caries-preventive effects of water fluoridation were at least as great in adults born before as after the widespread implementation of water fluoridation [Slade et al., 2013]. If the risk for caries is high, however, water fluoridation alone cannot provide

sufficient protection against caries [Hausen, 2004], and fluoride in itself does not account for the entire decline.

In Denmark, however, where the decline is most marked, the reduction in caries prevalence among children is also closely related to the following: (1) the organization of the public dental health service in 1972 for all children from birth to 18-year-olds [Friis-Hasché, 1994] and (2) advances in the understanding of the aetiology of dental caries, highlighting the appropriateness of non-operative caries treatment instead of the traditional operative approach [Thylstrup et al., 1994].

The high DMFS of Danish 15-year-olds in 1980/81 can be seen as a result of a radical operative strategy: since Black published his concept 'extension for prevention', this principle was unchallenged for nearly a century and still used in the 1970s. In addition, approximal lesions were filled often at a non-cavitated stage [Bille et al., 1982]. For a long time, the 'extension for prevention' concept has been questioned [Osborne et al., 1998]. Further, the former routine drilling and filling of pits and fissures has become rare because of the extensive use of sealants. In 2003, Danish 15-year-olds had a mean of 3.1 sealed surfaces [Ekstrand et al., 2007], and caries research progress has prompted strategies based on arresting active initial lesions by non-operative treatments [Thylstrup et al., 1994, 1997]. Therefore, although Danish children nowadays have a very low DMFS it should be borne in mind that these children – in contrast to children in the 1980s – have a number of sealed surfaces as well as surfaces with active non-cavitated or inactive lesions. For this reason, the question may be raised whether the second part of the caries decline is not based on a change of treatment concept of the practicing dentists, allowing initial lesions to be arrested or sealed instead of placing a 'preventive' filling.

High-Risk Strategies

The Academic Way

A literature review for preventive programmes in caries risk children has revealed a rather frustrating picture for a long time. Bader et al. [2001] stated in their systematic review that the strength of evidence for the efficacy of fluoride varnish programmes was fair, but insufficient for all other methods. For instance, 3–4 varnish applications per year resulted in a 37% reduction of the caries increment in children in a deprived area [Zimmer et al., 1999]. Exemplary of the difficulties of intensive prevention is the study by Hausen et al. [2000]. Their analysis of the effects of counselling, F-varnish, F-lozenges, sealants and chlorhexidine use showed only minor caries reductions compared to basic prevention (counselling, 1× F-varnish/year). Pieper [1990] also could not compensate for the high caries activity following professional tooth cleaning compared to children grouped as low risk, who received only 2 topical fluoride applications per year. The risk group still had twice the caries levels of the low-risk group. Thus, the risk identified at the group level was correct, but the effort to close the gap for the high-risk group was not successful. Marthaler [1975] had previously proposed selective intensive prevention in schoolchildren, but 20 years later had to admit that no highly effective preventive programmes are known for children at high caries risk due to low compliance [Marthaler, 1995].

A more recent concept, 'proportionate universalism', was introduced which proposes that to reduce the steepness of the social gradient in health, interventions must be universal, but with a scale and intensity that is proportionate to the level of disadvantage faced [Marmot, 2010]. This concept was used in the 'child smile' programme in Scotland (43,470 children examined). However, they found that identifying a maximum number of children at increased risk through a directed population approach was difficult, particularly when the intervention was clinically based, e.g. with increased fluoride applications, as it did not address the underlying determinants of inequality [Brewster et al., 2013]. At the Scottish level only 50% of those targeted were actually considered to be at increased risk. This study concluded that developing a method to reach all or most individuals at increased risk, defined by either caries experience or deprivation, is difficult using a directed population approach at a group level. MEDLINE-based reviews conclude that several methods have been developed for the identification of high-risk groups or children, which are unfortunately mostly based on past caries experience [Twetman and Fontana, 2009], but it is difficult to implement targeted, effective programmes [Kay and Locker, 1998; Tickle, 2002]. Wider debate is required on how best to reach those most at need to improve health and reduce inequalities.

The Public Health Approach

A closer look reveals that community or school dental programmes, which have difficulties presenting their results in MEDLINE-listed publications, have developed several successful methods for further caries reductions: Brunner-Strepp [2001] achieved very low caries prevalence by weekly supervised brushing with Elmex® fluid at

school and low caries prevalence in children at high caries risk with 4 professional applications of Elmex® fluid in comparison to a control group. Even in a community with a very low caries level in Solothurn, Switzerland (0.77 DMFT, 12-year-olds), where the use of fluoride toothpaste and fluoride salt is high (>90 and 80%, respectively), Guindy et al. [2000] found a correlation between caries prevalence and the number of group prevention inputs (instruction, brushing with higher concentrated fluorides). Trummler and Weiss [2000] linked the very low caries level in St. Gallen, Switzerland (0.75 DMFT, 12-year-olds) to the school dentistry act of 1982 which obliged kindergarten and school teachers to take an active role in caries prevention, e.g. brushing with a fluoride gel at school twice every month for grades 1–6, which resulted in about 20 fluoride applications/year.

A very successful Danish dental health programme was in force as a demonstration project from 1987 to 2005 in the Nexö Public Dental Health Service [Thylstrup et al., 1997]. Nexö is a low socio-economic area of Denmark whose caries prevalence was high at that time. The new and scientifically based 'Nexö Method' consisted of a non-operative caries treatment programme with the following components:

- Access from 8 months of age to 98 % of children, highlighting the early education of parents using principles of motivational interviewing. The aim was to establish adequate habits from the very beginning instead of changing inadequate ones later.
- Risk-specific non-operative caries treatment and recalls.
- Stressing effective plaque control in plaque stagnation areas + F application = toothbrushing training at each regular visit, carried out by dental assistants.
- Focus on eruption periods of molar teeth, stressing cross-brushing technique.

This strategy led to a remarkable decline in DMFS compared to the national mean [Ekstrand et al., 2003, 2005; Christiansen, 2011] (fig. 1), but over the years these treatment options have become well integrated in all Danish public dental health services, which were accompanied by a further caries decline in Danish children [Danish Health and Medicines Authority, 2014].

The Nexö programme was successfully tested on a group of children in Moscow from 1994 to 1996 including a randomized control group [Ekstrand et al., 2000]; 18 years after the 2.5-year intervention a follow-up study found a long-term positive effect of the Nexö programme implemented during childhood [Kuzmina et al., 2015].

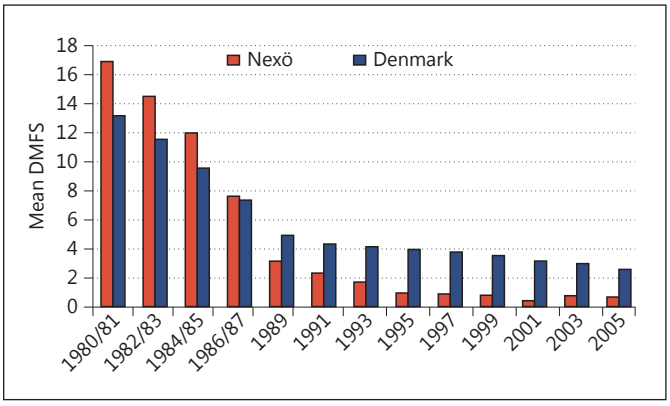

Fig. 1. Caries (mean DMFS of 15-year-olds) in Nexö and all of Denmark from 1980 to 2005 according to the Danish Health and Medicines Authority [2015].

Unfortunately, community programmes can rarely implement a randomized control group without intervention due to ethical reasons or simply as the programme cannot be implemented in half of the community. Other communities often differ in socio-economic structure or other parameters, which reduces the validity of strict scientific comparisons. Still, the Nexö programme was compared to all other Danish municipalities, and after the implementation of the above-mentioned programme caries values dropped from very high to the lowest in Denmark (fig. 1).

In order to implement the above-mentioned preventive measures, access to the children is necessary, especially when the compliance of the family is reduced and they are not eager to take part in even free-of-charge preventive programmes in private offices. A repeated outreach programme offers a better chance to reach children most in need of dental prevention, as shown by a study on the effect of school dental screening on dental attendance, which revealed much more visits at the dentist (73%) for children provided with a reply slip and a follow-up than for children without follow-up (42%) [Zarod and Lennon, 1992].

The structural elements of the Nexö and Swiss programmes were combined for the Community Dental Services in Greifswald, Germany, which are restricted to preventive measures in kindergartens and schools by federal laws. The combination of targeted brushing and fluoride use with toothpaste or gel was promoted in parent meetings and instructions and in the training of kindergarten educators and school teachers, as well as during the weekly or daily brushing in the institutions. The programme

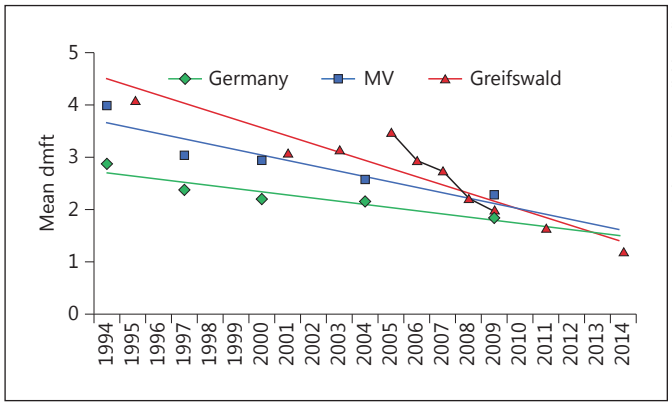

Fig. 2. Caries decline in first graders (6- to 7-year-olds) in Germany, Mecklenburg-Vorpommern and Greifswald from 1994 to 2014. MV = Mecklenburg-Vorpommern [DAJ, 2010; ÖGD, 2014].

Color version available online

was mostly supported by the community preventive dental assistant for the institutions with the highest caries levels, kindergarten teachers also helped children with special needs, and teachers were responsible for the weekly brushing with fluoride gels.

Caries values in Greifswald also dropped from exceptionally high values to below the mean values in the federal state of Mecklenburg-Vorpommern and for the whole of Germany. Mean dmft values for first graders fell from 4.1 dmft to currently 1.2 dmft (fig. 2), 12 year-olds exhibit a mean DMFT of 0.5, and in 15-year-olds a caries decline of 70% was recorded while representative data in the federal state only decreased by 50% [ÖGD, 2014].

Maybe one of the scientifically best-documented studies of this approach is the randomized clinical trial by Hausen et al. [2007] on the 'non-invasive control of dental caries in children with active initial lesions' in Pori, Finland. By definition, school children with active initial lesions are categorized as high-risk individuals in a low caries population. In contrast to the failed high-risk attempt with most professional or pharmaceutical interventions [Hausen et al., 2000], this time a patient- and empowerment-centred approach was chosen which included toothbrushing with fluoridated toothpaste and special attention to erupting permanent teeth.

Over a 4-year period, the DMFS levels of the control group clearly progressed more than in the intervention group, and the prevented fraction was 44%. This mirrors the differences in caries development in Nexö and Greifswald compared to the mean national surveys after the implementation of the above-mentioned community programme.

Conclusions and Perspectives

After the caries decline, there are still individuals and groups with high caries levels, who are mostly defined by a low socio-economic status which may also be associated with a migration background or specific ethnicity.

As the caries decline has been mostly linked to the frequent use of fluorides, especially via toothbrushing with fluoridated toothpaste, many high-risk groups may have missed out on some of the opportunities of an increased frequency of fluoride exposure [Ministry of Health, 2010; Davidovich et al., 2013; Lintula et al., 2014]. It appears promising to use an aetiologically based approach to repeat the success of the caries decline with regular plaque removal and simultaneous fluoride applications (= toothbrushing) in these so-called high caries groups. Public health or community services offer a reliable setting to ensure adequate access and compliance for risk children and adolescents [Guindy et al., 2000; Ekstrand et al., 2003; Hausen et al., 2007; ÖGD, 2014]. The network of a community approach also tackles the influence of socio-political factors as the key determinants of health. Following the common risk factor approach, which is the wider socio-environmental milieu and low education levels, the associations between oral health, diet, hygiene, smoking, alcohol use, stress and trauma can be addressed in a collaborative strategy. Combined efforts with other health and education specialists, as well as community administration, could be useful in strengthening healthy choices and behaviour, e.g. in 'healthy' schools and kindergartens [Sheiham and Watt, 2000]. A 'setting approach' can improve the access to disadvantaged groups and compensate parental problems with compliance via health care professionals, educators and teachers.

Even the cost-benefit ratio for a setting or community approach seems to be favourable as preventive assistants or other auxiliaries deliver programme components, preventive measures can be integrated into kindergarten or school routines and larger groups are addressed, in contrast to a 1:1 ratio of a costly dental office [Kowash et al., 2000, 2006; Splieth and Flessa, 2008].

In conclusion, community dental health programmes manage to deliver the simple and evidence-based measures of regular plaque removal and fluoride applications via toothbrushing, and they are a successful strategy to extend the caries decline to groups of children and adolescents with persistent higher caries levels. In addition, the common risk factor approach can utilize the associa-

tions between oral health, social deprivation, diet, hygiene, smoking, alcohol use and stress for combined efforts with other health and education specialists, as well as community administration, to strengthen healthy choices and behaviour, e.g. in 'healthy' schools and kindergartens.

Author Contributions

All authors drafted the outline and wrote a chapter of the paper, as well as correcting and commenting on the other parts and revising the final document.

Disclosure Statement

No potential conflicts of interest exist in this study for any author.

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