FLUORIDE AND DENTAL CARIES: SECOND THOUGHTS IN VIEW OF RECENT EVIDENCE FROM GERMANY

SUMMARY: After seventy years of controversial discussion, the reports by Dean et al. that purported to demonstrate an inverse relationship between the prevalence of tooth decay in children and the fluoride content of drinking water are still cited as strong evidence for a significant anti-caries effect of fluoride, despite their many shortcomings. In addition, major hypotheses for possible cariostatic mechanisms of fluoride action have been found to be seriously flawed. Sociodemographic factors, as presented here from a part of Germany, appear to be better predictors of caries in children than the fluoride content of water supplies, raising the question: How much does fluoride really help to prevent or reduce tooth decay, especially among the most socially deprived and less advantaged?

Keywords: Childhood caries; Dental caries epidemiology; Fluoroapatite; Fluoride and dental caries; Mayen-Koblenz Area; Oral enzymes; Sociodemographic variables; Water fluoridation.

In 1939–1940, when organized dentistry celebrated its first centennial, H Trendley Dean of the US Public Health Service, after conducting surveys of dental fluorosis in relation to fluoride levels in drinking water, reported finding an impressive inverse relationship between the fluoride content in water supplies and the prevalence of dental caries in children. These studies, supplemented by examinations of children in 21 cities as well as reports from fluoridation trials initiated in 1945, have become the subject of controversial analysis and discussions.[1-4] Despite their weaknesses, these early studies are still widely cited to support claims for the effectiveness of water fluoridation to prevent dental caries, even though it has become increasingly difficult to attribute the almost world-wide caries decline in developed nations to the anticipated beneficial anti-caries effects of fluoridated water.[3] Similarly, there are indications that the anti-caries effectiveness of fluoridated dental products may have been overrated.[5]

The failure to find epidemiological evidence in support of any single means of fluoride application has been mainly attributed to the widespread availability of fluoride-containing products including fluoride-containing toothpastes and mouthwashes, fluoride-impregnated tooth-picks and dental floss, fluoride in tea, fluoride tablets, fluoridated table salt, and topical fluoride application by dentists.[6] There is growing evidence, however, that nonfluoride variables such as significant improvements in nutrition, health education, and socioeconomic standards may play a major role in caries prevention, along with the increased use of antibiotics and better oral hygiene.[1,6-8]

Adequate evaluation of the many possible factors is difficult because the tool often used in dental epidemiology, i.e., the mean number of decayed, missing or filled primary or permanent teeth (dmft or DMFT) or tooth surfaces involved (dmfs or DMFS) per “child” or per 100 “children” *examined*, can be misleading and is subject to serious bias for reasons such as the following:

(1) There are variable numbers of caries-free children in study groups, and the number of carious teeth in children with caries experience may or may not actually differ appreciably between groups. Thus the observation that about 75 percent of caries defects develop in about 25 percent of children at high risk[9] could obscure the presence of a *large* or a *small* number of children with caries-free teeth. For

example, a mean overall DMFT score of 2.0 per child (among 100 children examined) could mean 50 of the children are caries-free, and 50 have a mean DMFT score of 4.0 per child. It could also mean that 100 children have a mean DMFT score of 2.0 per child, and none are caries-free.

(2) The dmf and DMF scores are also influenced by the number of erupted teeth, for which there is biological, environmental, dietary, and genetic variability among children, often especially between boys and girls of the same age. Some researchers also point to evidence that excessive exposure to fluoride can cause a delay in tooth eruption.[3,4]

(3) Inter- or intra-examiner variability may also account for considerable differences in the diagnosis of actually decayed teeth in the same mouth, hence the need for “calibrated” examiners in dental surveys.

(4) Even so, the examiner calibration issue has no bearing on the number of missing or filled teeth, since a non-calibrated dental practitioner has already decided in the past – rightly or wrongly – whether or not a tooth was to be filled or extracted.

(5) As pointed out in a recent report discussed near the end of this editorial, it is also difficult to distinguish between restorative fillings for treatment of cavities and prophylactic (sealant) fillings of pits and fissures where no underlying decay was present or diagnosed.

(6) The m or M and the f or F parts of the index also reflect not only availability of dental care as judged, for example, by the dentist/population ratio, but also socioeconomic status in regard to health education, diet, personal dental care, and ability to pay for treatment. Interestingly, this view, along with a tendency of some dentists to overtreat, is now being used to explain an increased caries prevalence found in some studies.[10]

Epidemiology often shows a correlation between two variables under investigation, but in itself it cannot prove a cause-and-effect relationship. Therefore, various hypotheses have been advanced to explain possible anti-caries effects of fluoride. These include inhibition of certain cariogenic bacteria and the formation at the enamel surface of a layer of fluorapatite, claimed to offer more resistance to acids causing tooth decay than the usually prevailing hydroxyapatite mineral.

Both hypotheses have failed the test of time, yet researchers have been resourceful in coming up with new replacements, of which only a few can be discussed here. Thus, as reviewed recently by Clinch, the early-proposed questionable impact of fluoride on cariogenic oral bacteria lacks confirmation.[11] The fluoroapatite argument, since its inception in the 19th century, has undergone a number of modifications. The fluorine content of fluorapatite is about 3.8%, which roughly corresponds to the amount of fluoride found in bones and teeth by early “indirect” analytical methods. Towards the end of the 19th century, when more reliable methods of F analysis became available, fluoride was reclassified from a supposed major component of teeth to a rather small fraction amounting to 0.1% at most.[12] In 1938, Armstrong and Brekhus claimed that, even though the overall amounts are low, sound dental enamel contained more fluoride than carious enamel (0.0111% vs. 0.0069%).[13] While it was generally taken for granted that the samples were "from the same mouths,"[14] it took 25 years before the principal author of the original report revised his previous conclusions: the difference was "due in major part to the higher mean age, amounting to 16 years, of the persons who supplied the sound teeth." This is significant because the fluoride content of hard tissues increases with age. In the follow-up investigation by the same author, enamel fluoride of sound or carious third molars was not found to be different in persons of comparable age.[15]

Still, the fluorapatite hypothesis was not discarded even after only minute amounts of fluoride were found to be present in dental enamel, but it was modified by the claim that a protective layer is formed at the surface. Another few decades had to pass until, in November of last year, a group of researchers at Saarland University, Germany, reported their discovery that such a layer is formed only on a nanometer scale and thus may not offer much protection against dental caries and may be worn off easily during normal eating while chewing food.[16] Nevertheless, convinced of a "clearly demonstrated cariostatic effect of fluoride compounds in various forms of applications" (their references again include the controversial studies of Dean et al.), the authors of this work promise further investigation of the action of fluoride on dental enamel.

How hard it is for some authors to accept negative evidence concerning Dean's early work and the paradigm resulting from it of fluoride's effectiveness to reduce tooth decay is also seen in a recent report on dental examinations of first-grade schoolchildren in Germany.[17] The drinking water of several communities in the Mayen-Koblenz-Kreis area (MYK) of West Germany's "Eifel," a landscape of low mountains, accumulates elevated natural levels of fluoride as it passes through strata of former volcanic activity. This particular geology offered an opportunity to repeat in Germany what Dean had done in the USA. In February and March 1977, Johannes Einwag, a graduate student in the dental department of the University of Bonn, examined children (ages 3 to 6, and 13 to 14 years) in seven communities in the area to relate the caries prevalence to the fluoride content of the water. Additional examinations were conducted in September of that year "in order to get statistically significant results," without any indication of how many children in which community or communities thus had the disadvantage of higher dental age.[18] The results, as presented in his doctoral thesis, indicated that the children in *one* community in the area, Polch (0.1 ppm F), had about 40 percent more decayed, missing and filled tooth surfaces (dmfs/DMFS) than children in the *six* fluoride communities in the area (0.9 to 1.6 ppm F).

This difference may or may not be due to different fluoride exposure. Especially in Polch, more primary teeth had been extracted ("m" being 19.5 or 15.9 percent of the dmfs among 5 or 6 year old children) because, according to Einwag, some dentists were apparently not inclined to treat (fill) carious primary teeth. Each extracted tooth enters the dmfs index as four or five surfaces and may thus lead to an overestimation of the caries prevalence. Similarly, the permanent teeth of 13 and 14 year-old children in Polch had received a slightly more intense dental treatment as indicated by the M + F contribution to the DMFS index: 51% as opposed to about 41% of the DMFS of the children in the other communities.

Beginning in the mid-1970s, educational efforts have been in place to reduce dental caries in the Mayen-Koblenz area. Several health insurance companies initiated dental hygiene projects in the kindergartens and distributed toothbrushes and rinsing cups. In the 1980s, dentists of the area organized an initiative and provided instructions on dental hygiene in the kindergartens. Since summer of 1985, health insurance companies and local dentists formed the *Arbeitsgemeinschaft Jugendzahnpflege* and expanded their efforts to include primary schools in their prophylaxis programs. At the end of the 1990s annual dental examinations of first-grade pupils began, and since then they have revealed a steady decline in caries prevalence among first-graders, with those of the Mayen-Koblenz-Kreis area having better teeth than the children in Koblenz, a city with many socially deprived areas.[19,20] However, this overall decline in caries was not attributed primarily to expanded dental education but rather to increased fluoride use, even though shortly after the start of the examinations, no correlation could be found between the prevalence of dental caries and the fluoride content in the water.[20]

In a recent publication, this remarkable finding was analyzed by Reinhard Steinmeyer, a dentist with the MYK Health Authority and board member of the *Arbeitsgemeinschaft Jugendzahnpflege*. According to Steinmeyer, the expected beneficial dental effects of fluoride may be semi-additive until a state of "saturation" results, at which point no further benefit from additional fluoride is obtained. Thus the question arises whether the fluoride content of the drinking water in the MYK communities can still be shown to exert some anti-caries effect. But, in fact, such a connection does not appear to exist. The caries prevalence among 9,555 first-graders, aged 6 to 7 years, in all 63 schools of 48 communities in the area failed to show any correlation with water fluoride. On the other hand, sociodemographic factors (unemployment, migration, financial aid from social care institutions, etc.) were known for families of 7,563 children and were found to serve as better predictors of caries experience. In this subgroup the mean percentage of caries-free 6- and 7-year-old children decreased from 64.5% to 58.1% and 50.9% in the order of high, middle, and low socio-economic status.

In further detail, as can be seen from the following table, the percentage of children from families in the middle socio-economic group actually increased with increasing fluoride levels in the water, while the percentage in the high socio-economic group decreased. However, at no socioeconomic level was there evidence of a consistent pattern of increasing caries-free teeth with increasing water fluoride levels. On the other hand, lower socio-economic status was associated with a decreasing percentage of caries-free children, not with less fluoride in the water. Therefore, in the light of these and earlier findings, the question must be asked: Does fluoride in drinking water actually help reduce tooth decay to any significant extent, especially in poorer children or even in all children?

As cited above,[7,8] dental comparisons of selected communities while neglecting important nonfluoride factors can be misleading. Still, such weak evidence continues to be used to support claims of the effectiveness of fluoride to prevent dental caries. This reluctance to recognize that an overall reduction in tooth decay may not be due to fluoride in drinking water has been described as "tardive photopsia", in which those who adhere to an outdated and unverified belief are "slow to see the light."[21].

Table. Percent of children according to socioeconomic status in relation to water fluoride concentration, caries-free dentition, dmft, and DMFT of 7,563 children (data from Steinmeyer[17])

Socioeconomic status	Fluoride category				
	I (≤0.2 ppm)	I-II (ca. 0.3 ppm)	II (>0.3–<0.7 ppm)	II-III (ca. 0.7 ppm)	III (>0.7 ppm)
	Percent children by fluoride category[a]				
High		100.0	58.3	22.2	19.0
Middle	21.7		41.7	77.8	81.0
Low	78.3				
	Percent caries-free				
High		68.9	60.0	62.0	
Middle	57.9		60.6	57.8	
Low	50.9				
	dmft (only for teeth #3,4,5 in each quadrant)[b]				
High		0.90	1.22	0.94	
Middle	1.46		1.08	1.33	
Low	1.62				
	DMFT				
High		0.024	0.045	0.019	
Middle	0.097		0.028	0.048	
Low	0.053				

[a]Calculated from data of Steinmeyer.[17]
[b]Central and lateral incisors not counted as they tend to be shed in children of this age group.[17]

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