Prevalence of Enamel Fluorosis in 12-year-Olds in two Swiss Cantons

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Summary The neighbouring cantons Basel-Stadt and Basel-Landschaft had introduced different fluoridation schemes for caries prevention: Basel-Stadt provided drinking water fluoridated at 0.8–1 ppm F since 1962, while Basel-Landschaft introduced fluoridated domestic salt (250 ppm F since 1983). Representative samples of 12-year-old schoolchildren (6th-graders) were studied to evaluate the prevalence of (I) dental fluorosis (FOP) using the Thylstrup-Fejerskov (TF) index, (II) non fluoride-associated enamel opacities (non-FOP), and (III) hypoplasia of the incisors. Standardised frontal colour photographs were taken and assessed by four examiners after projection.

Of 373 schoolchildren studied in 1999 in Basel-Stadt 119 (31.9%) showed fluoride-associated enamel opacities, i.e. 66 (17.7%) a very mild form (TF score 1), 47 (12.6%) a mild form (TF score 2), five scored TF3 and one TF5. In addition, non-FOP were diagnosed in 115 (30.8%) and hypoplasia in 47 (12.6%) children. Among the 448 children evaluated in 2001 in Basel-Landschaft 143 (31.9%) showed FOP, namely 74 (16.5%) scored TF1, 54 (12.2%) scored TF2, 12 (2.7%) scored TF3, and three (0.7%) scored TF5. Non-FOP were found among 93 (20.8%) and hypoplasia among 56 (12.5%) children.

Thus, in spite of different fluoridation schemes in the two cantons, the prevalences of FOP were identical. Most fluoride-associated enamel opacities were mild or very mild. They did not represent an aesthetic problem and certainly not a public health concern.

Introduction

Based on the pioneering work of Dean (1934, 1942) a relationship between fluoridated drinking water, enamel fluorosis and reduced caries prevalence has been documented. However, when using fluoride for caries prevention, one must also consider the occurrence of enamel fluorosis.

Enamel fluorosis is a developmental disorder of dental enamel resulting from chronic overuse of fluoride during early childhood, i.e. during enamel formation (for a review: Aoba & Fejerskof 2002). Fluorosis is associated with increased hypomineralization and increased enamel porosity. In mild forms, it appears as chalky white lines in the enamel, which is usually symmetrical in contra-lateral teeth following the pathways of the perikymata. In severe forms the whole tooth surface is characterised by pitting and mottled yellow, brown, black discolouration (Thylstrup & Fejerskov 1978). Other extrinsic and/or intrinsic factors can also lead to similar changes in the enamel. However, these factors have only been vaguely identified.

The differentiation of enamel fluorosis and enamel opacities not caused by fluoride is important for assessing the prevalence and thus the undesirable side effects of fluoride use in caries prophylaxis. To assess clinical appearance, indices as described by Dean 1934, Thylstrup & Fejerskov 1978 were used from the beginning. However, other indices were also used, which presents difficulty in the comparison of the results.

The use of fluoride in various prevention products used over the past 50 years has been the most important contribution in decreasing caries prevalence in Switzerland, Europe and worldwide (Marthaler et al. 2005, 1996, Petersson & Bratthall

1996, Kumar & Moss 2008). However, in the same period an increase in mild forms of enamel fluorosis has been observed in several populations in the USA an in Europe (Fomon et al. 2000, Whelton et al. 2004).

The neighbouring Swiss cantons of Basel-Stadt and Basel- Landschaft have utilized different measures of systemic fluoride. In 1962, Basel-Stadt introduced water fluoridation (0.8–1 ppm F). In 1983, the canton of Basel-Landschaft decided to use 250 ppm F in domestic salt. These two neighbouring cantons also took different pathways in their respective measures toward school dental healthcare. The yearly dental examinations of all school-aged children in Basel-Stadt were centralised and carried out at two school dental clinic locations in Basel and Riehen. For any further treatment, parents were free to choose between the school dental clinic and a private dentist. In the canton of Basel-Landschaft, the yearly examination as well as any treatment were performed in private practice. In addition, prophylaxis assistants visited Kindergarten and primary classes twice yearly to provide lessons about oral health, fluoridation, and healthy snacks.

In 1979, De Crousaz (1982) carried out a preliminary study showing a 38% prevalence of enamel fluorosis of schoolchildren in Basel-Stadt. These results launched a political debate on the continuation of water fluoridation claiming that this value was too high, which showed signs of fluoride overuse. This value was actually higher than the 13–28% collected later in other Swiss cantons using fluoridated salt (Steiner & Menghini 1984, Steiner et al. 1995). The goal of this study was to determine the prevalences of enamel opacities from systemically administered fluoride and enamel opacities not caused by the use of fluoride in 12-year-old schoolchildren in the two cantons of Basel-Stadt and Basel-Landschaft.

Materials and Methods

Study Participants

The Departments of Education and of Health of both cantons granted permission to study the prevalence of enamel fluorosis in schoolchildren. Parents of children were informed by a letter (written in 8 languages) about the goal and purpose of the study.

All schoolchildren in Basel-Stadt were examined orally by the school dental service each year. In the 1998/99 school year, 22 randomly selected 6th-grade classes were additionally chosen on examination day for the fluorosis study as long as the parents had not disagreed. Thus, 443 pupils aged 11–13 years (average 11.9 years) were chosen to participate in the fluorosis study among the 1,504 6th-graders of the canton.

In 2001, in the canton of Basel-Landschaft an epidemiological study to assess the overall caries prevalence was carried out (Waltimo et al. in preparation). Oral health data was collected in a representative sample of 29 randomly selected 6th-grade classes within 18 communities. These schoolchildren (11–13 years, average 12.2 years) totalling 533 from 2,929 were included in the fluorosis study.

Clinical Procedure

Prior to clinical examination, a prophylaxis assistant instructed pupils in oral hygiene and supervised them in brushing their teeth together. Following the collection of data, the front teeth were photographed using a sterile, non-reflective plastic lip and cheek retractor (Spandex Sterile by Hager & Werken, Duisburg). Participants were instructed to bite their teeth together, placing incisal edge to incisal edge. Teeth were then dried for ten seconds using compressed air. Participants were further instructed not to swallow and refrain from touching the teeth with their tongue so as not to re-moisten them. With these conditions in place, two to four photographs holding the camera perpendicular to the front teeth were taken.

Two shots focused on the maxillary central incisor and two shots on the upper lateral incisor. All images were taken using the same Nikon F601 AF camera with an AF micro Nikkor 105 mm 1:2.8 D lens and a Nikon SB21 speedlight macro ring flash (Nikon AG Switzerland, Zürich). All exposures were taken using AGFA Chrome RSX 100 film from the same charge (Agfa – Gevaert NV/SA, Dübendorf). The developed slides were initially assessed on a light table with respect to focus and sharpness of the image. Two shots were chosen as the better quality images. The slides were then placed in two parallel slide projectors and viewed simultaneously so as to compare two images of the same participant.

Slide Assessment and Diagnosis

A few days after completion of the clinical study, slides were projected onto a white background at a 10-meter distance using a pair of Leica P2000 slide projectors (Leica Camera AG, Nidau) viewed by four examiners simultaneously. Each examiner judged the four maxillary incisors (12–22) and the four mandibular incisors (32–42) accordingly: fluoride-associated opacities (FOP), non-fluoride-associated opacities (non-FOP) and hypoplasia. The examiners compiled their findings in a continuous list. The FOP were assessed according to the Thylstrup Fejerskov Index (1978). All other opacities were not assigned to the fluoride-related opacities. Here, various diagnoses on the same tooth were possible. Hypoplasia was only counted when it reached to the dentin. The TF index was preferred over the WHO recommended Dean index (Dean 1934) so that data from Switzerland could be compared (De Crousaz 1982, Steiner & Menghini 1984, Steiner et al. 1995).

The highest value found on single tooth diagnosis was transferred as a result to the overall diagnosis per participant. Teeth that were covered with plaque, orthodontic appliances, overlapped, missing, or less than 50% erupted were excluded. Participants were totally excluded if teeth 11 and 21 could not be assessed or if at least four incisors could not be judged.

Inter-examiner Calibration

In order to make relative comparisons to the Zürich and Glarus studies (Weber 1997, quoted in Menghini 2005) the four examiners first viewed 50 reference slides together, then a further 100 slides with a known diagnosis were individually evaluated. Any differences in individual evaluation were jointly discussed in order to reach a consensus consistent with the Zürich and Glarus study. Only after a consensus was reached, the examiners evaluated slides first from Basel-Stadt, later from Basel-Landschaft without jointly discussing the findings. The overall diagnosis of each examiner was then compared against the others. Discrepancies were re-evaluated in a further meeting to achieve a consensus of the examiners (in analogy to Weber 1997, quoted in Menghini 2005).

Statistics

To assess inter- and intra-examiner reliability the Kappa statistics was used (Hunt 1986) and interpreted as follows: Kappa <0.4 = poor; 0.4–0.75 = moderate to good; >0.75 = very good.

Kappa values between examiners were: for Basel-Stadt with respect to FOP 0.72–0.83, non-FOP 0.53–0.68, and hypoplasia 0.51–0.62; for Basel-Landschaft with respect to FOP 0.68–0.74,

non-FOP 0.58–0.73, and for hypoplasia 0.59–0.76. Intra-rater Kappa values lay between 0.65 and 0.84.

Differences in fluorosis prevalence were analysed with the Chi-Square test for a significance of $p<0.05$.

Results

Participation

In Basel-Stadt, 16 parents of 443 pupils declined their child's participation and another 14 were absent on examination day. Photos were taken of the remaining 413 test persons. Of these, another 40 were excluded due to 24 wearing orthodontic appliances and another 16 missing either one of the central incisors or lacking four anterior incisors needed for assessment (Tab. I). The remaining 373 sixth-graders participated in the study.

In Basel-Landschaft, 448 from 533 originally summoned pupils were investigated and photographic slides were produced. Of the 85 unevaluated participants, five had no slides made; 63 wore orthodontic appliances and the remaining 17 were excluded because of only one central incisor present or lacking four anterior incisors.

Fluoride-related Opacities (FOP)

In Basel-Stadt, 119 from 373 (31.9%) participants were diagnosed with FOP; in Basel-Landschaft, 143 from 448 (31.9%) (Tab. II). From these data, about 90% of the cases actually showed very light to mild forms (TF grade 1 and 2). The most affected teeth were the upper central incisors (Basel-Stadt 30.0%, Basel-Landschaft 30.8% of participants), followed by upper front laterals (Basel-Stadt 24.0%, Basel-Landschaft 23.9%). To a lesser degree, the lower front incisors showed FOP (Basel-Stadt 11.3%, Basel-Landschaft 7.0%) compared to the lower front laterals (Basel-Stadt 9.8%, Basel-Landschaft 6.6%).

In Basel-Landschaft, 83 of the evaluated 448 participants came from the communities of Allschwil and Binningen with fluoridated (0.8–1.0 ppm) drinking water and from the communities of Oberdorf and Wenslingen with naturally elevated (0.7 and 0.6 ppm) fluoride levels in drinking water. Fluorosis in this group of participants was 37.3%, above the 30.7% of total canton without these four communities. However, this difference is statistically not significant (Chi-square test: $p>0.05$). But for fluorosis grade 2, the prevalence difference did reach a statistical significance (Tab. II).

Non-Fluoride Related Opacities (Non-FOP)

In the canton of Basel-Stadt, 115 (30.8%) of 373 sixth-graders were diagnosed with non fluoride-related opacities. Of these, seven also showed FOP and 15 showed hypoplasia. Of 448 participants in the canton of Basel-Landschaft, 93 (20.8%) showed non-FOP. This difference to Basel-Stadt is statistically significant. Additionally, ten of this group also showed signs of FOP and 13 hypoplasia. The distribution of the non-FOP followed a similar pattern to the fluoride-induced opacities on individual teeth except where the lateral incisor tended to show a higher incidence.

Hypoplasia

Enamel hypoplasia was indicated in 47 (12.6%) of the 373 examined participants in Basel-Stadt and 56 (12.5%) of 448 participants in Basel-Landschaft. In most cases (90% in BL) the lower central incisors were affected.

Discussion

The assessment of enamel fluorosis using the TF index (Thylstrup & Fejerskov 1978) is not easy due to the lack of a "questionable" category, which is in contrast to the Dean index (Dean 1934). The largest discrepancies between examiners lie in their distinction between TF grade 0 (normal) and TF grade 1 (very mild form). This difference had a crucial influence on the overall diagnosis. An attempt to correct the questionable slides was made by joint assessment and deciding on a realistic outcome. However, the joint consideration may have lead to a more sensitive assessment, which tended towards a higher prevalence of fluorosis. Also, the evaluation of enlarged slides on the projection screen probably increased the sensitivity, which would lead to a higher prevalence than if the slides had been viewed on a light box or evaluated *in vivo*.

Tab. I Sample size and involvement

Canton	Total population of 6th-grade classes	Summoned pupils	Photographed pupils	Evaluated slide pairs	Average age
BS 1999	1504	443	413	373 (84.2%)	11.9
BL 2001	2929	533	528	448 (84.1%)	12.2

Tab. II Enamel fluorosis and distribution grades (TF index)

Canton	Evaluated participants	Fluorosis total	TF-grade 1	TF-grade 2	TF-grade 3	TF-grade 4	TF-grade 5
BS	373	119 (31.9%)	66 (17.7%)	47 (12.6%)	5 (1.3%)	–	1 (0.3%)
BL total	448	143 (31.9%)	74 (16.5%)	54 (12.1%)	12 (2.7%)	–	3 (0.7%)
Four communities BL*)	83	31 (37.3%)	13 (15.7%)	16[a)] (19.3%)	2 (2.4%)	–	–
BL without four communities	365	112 (30.7%)	61 (16.7%)	38[a)] (10.4%)	10 (2.7%)	–	3 (0.8%)

*) Allschwil and Binningen with fluoridated drinking water (0.8–1 ppm F) from Basel, Oberdorf (0.7 ppm F) and Wenslingen (0.6 ppm F) with naturally raised F content in drinking water. Fluoridated salt is available for purchase in all four communities.

a) Statistically significant difference ($p<0.05$).

Since carrying out these studies (1999/2001) the reproducibility of data collection and examiner influence have been well documented in several publications (Burt et al. 2003, Cochran et al. 2004a, Tavener et al. 2007, Steiner et al. 2010). Thus, details of the documentation procedure, such as drying time and photo angles, do influence the result (Cochran et al. 2004a).

The prevalence of a 32% enamel fluorosis in Basel-Stadt is below De Crousaz's (1982) determined value of 38%; it is, however, probably not statistically significant due to the uncertainty of the percentages. In addition to the above-mentioned methodology, differences could also be attributed to the introduction of children's toothpaste with a reduced fluoride content (250 ppm F), which was introduced in Switzerland in 1986. Somewhat unexpected is the same high fluorosis prevalence (32%) in the canton of Basel-Landschaft. This value breaks down to 30.7% seen in an exclusive F-salt supply and 37.3% ($p>0.05$) with a "double supply".

In about the same period of time, schoolchildren in the cantons of Zurich and Glarus showed a prevalence of 21% and 22% (Menghini 2005). A prevalence of 32% is also above the median value of 21% among several studies in Switzerland (Steiner et al. 2010, Tab. V). A comparison of international studies in areas without water fluoridation showing a prevalence from 8%–82% (median 24.5%), the Basel values represent a midfield range. Compared to publications from regions with water fluoridation in which a prevalence of 22%–89% (median 42.5%) is reported, Basel-Stadt lies in the lower range (Steiner et al. 2010 Tab. V, Cochran et al. 2004b, Whelton et al. 2004, Momeni et al. 2007).

The severity of fluorosis observed corresponded to about 90% (Basel-Stadt 95%, Basel-Landschaft 89.5%) to the TF grades 1 and 2. These mild and very mild forms are usually not perceived as aesthetically disturbing (Whelton et al. 2004, Chankanka et al. 2010). It can be concluded that the relatively small number of adolescents with a more prominent enamel fluorosis in both cantons does not indicate a general oversupply of fluoride. Subsequently an attempt was made to determine where participants with TF grade 3 and higher had been living during their first three years of life. Four out of six Basel-Stadt pupils had lived in Basel-Stadt since birth, one came with 3½ and another with 4½ years of age. The lack of a thorough fluoride history unfortunately does not allow for detailed conclusions to be drawn.

The prevalence of non-FOP was determined to be 30.5% in Basel-Stadt and 20.8% in Basel-Landschaft. The cause of this difference can only be speculated on. The value for Basel-Stadt was higher than for schoolchildren in the cantons of Zurich and Glarus, where it was determined to be 17%–23% (Menghini 2005). As with fluorosis, the evaluation is dependent on the examiner (Steiner et al. 2010), so the prevalence could, for the reasons discussed above, tend to be high for both groups.

In summary it can be said that the 1999/2001 enamel fluorosis among youth in the cantons of Basel-Stadt and Basel-Landschaft is about 32%. This in comparison with recent data from Switzerland (Steiner et al. 2010) was rather high but lower than in the survey of 1979 (De Crousaz 1982). It poses neither an aesthetic problem nor one of public health. A decreasing trend (Steiner et al. 2010) was observed in recruits, which provides a nationwide scope, which could be extrapolated to mean that today's prevalence in both Basel-Stadt and Basel-Landschaft should be significantly lowered. This applies in particular to Basel-Stadt, where water fluoridation has been replaced since 2003 with fluoridated salt (Meyer et al. 2003). In 2015, a new survey could be useful when 12-year-olds in Basel have not enjoyed fluoridated drinking water since birth.

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Dedication

This article is dedicated to the memory of Dr. Peter Minnig who, until his unexpected death in August 2008, was a relentless promoter of children's oral health.

Résumé

Les deux cantons voisins Bâle-Ville et Bâle-Campagne avaient établi différentes méthodes de fluoration comme prophylaxie contre la carie: Bâle-Ville par la fluoration de l'eau potable (0,8–1 ppm F) dès 1962, et Bâle-Campagne par la fluoration du sel de table (250 ppm F) dès 1983.

Des sondages représentatifs auprès d'écoliers âgés de 12 ans ont été effectués en 1999 dans le canton de Bâle-Ville et en 2001 dans le canton de Bâle-Campagne, ayant pour but de déterminer la prévalence des opacités d'émail des incisives permanentes. Ces opacités ont été classées en opacités du type fluorose (FOP) à l'aide de l'indice de Thylstrup et Fejerskov (TF), en opacités non associées aux fluorures (Non-FOP) et en hypoplasies. Des diapositives standardisées des incisives ont été projetées sur un écran et jugées par quatre examinateurs.

Parmi les 373 écoliers examinés dans le canton de Bâle-Ville, 119 (31,9%) ont présenté des signes d'opacités du type fluorose d'émail; à savoir 66 (17,7%) de forme très légère (TF degré 1), 47 de forme moyenne (TF degré 2), cinq (1,3%) de forme modérée (TF degré 3) et un (0,3%) de forme grave (TF degré 5). En outre, 115 (30,8%) ont présenté des signes d'opacités non associées aux fluorures, et 47 (12,6%) ont présenté des hypoplasies.

Dans le canton de Bâle-Campagne, les chiffres relevés furent similaires: parmi les 448 écoliers évalués, 143 (31,9%) ont présenté une fluorose, dont 74 (16,5%) TF degré 1, 54 (12,1%) TF degré 2, 12 (2,7%) TF degré 3, et trois (0,7%) TF degré 5. Des opacités non associées aux fluorures ont été identifiées chez 93 (20,8%), et des hypoplasies chez 56 (12,5%) écoliers.

Malgré les schémas différents de fluoration dans les deux cantons suisses concernés, on a observé des prévalences similaires des opacités de type fluorose chez des écoliers âgés de 12 ans. La majorité des signes cliniques ont été faibles, voir même très faibles, et ne posaient aucun problème esthétique. En plus, toute source de problèmes de santé publique fut exclue par la même. Dans le canton de Bâle-Ville, une diminution de la prévalence a été constatée depuis la stipulation de 1979.

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