

Review Article

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The impact of stopping or reducing the level of fluoride in public water supplies on dental fluorosis: a systematic review

<https://doi.org/10.1515/reveh-2019-0059>

Received August 2, 2019; accepted April 15, 2020; published online June 29, 2020

Abstract

Objective: The increased availability of fluoride and concern over the impact of fluorosis, have led to guidance suggesting a decrease or cease in the optimal concentration of fluoride in water fluoridation schemes. To date there have been no systematic reviews looking at both impact of fluoride reduction and total cessation. This review aimed to examine the impact of stopping or reducing the level of fluoride in public water supplies on dental fluorosis.

Content: Multiple databases were searched (MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials and the Web of Science). Two reviewers independently screened sources, extracted data and assessed study quality. Results were synthesised qualitatively and quantitatively. The main outcome measure was the prevalence of dental fluorosis.

Summary: Six studies of cross-sectional design were included. Two studies were scored as evidence level B (moderate) and the remaining four publications were evidence level C (poor). Meta-analysis indicated fluorosis prevalence was significantly decreased following either a reduction in the concentration of fluoride or cessation of adding fluoride to the water supply (OR:6.68; 95% CI:2.48 to 18.00).

Outlook: The evidence suggests a significant decrease in the prevalence of fluorosis post cessation or reduction in the concentration of fluoride added to the water supply. However, this work demonstrates that when studies are

subject to current expectations of methodological and experimental rigour, there is limited evidence with low methodological quality to determine the effect of stopping or reducing the concentration of fluoride in the water supply on dental fluorosis.

Keywords: dental fluorosis; fluoridation; public health; systematic review.

Introduction

Systematic reviews have acknowledged the benefits of water fluoridation as a whole population approach to caries prevention and the only side effect reported of this population approach is dental fluorosis [1–3]. Although water fluoridation has proved a successful approach to caries prevention, over time a number of countries have reviewed their fluoridation policy in light of alternative means of fluoride delivery. A previous review reported water fluoridation had ceased in 13 countries between 1956 and 2003 [4]. Findings reported mixed results but pointed more to an increase in caries prevalence post-cessation [4]. However, that review was focused on dental caries as the outcome measure and did not examine the impact of cessation on dental fluorosis.

In some countries rather than cease fluoridation completely, the level of fluoride added to the water has been adjusted downwards. The main reason reported for this approach is that traditional levels of water fluoridation [(at a concentration of 0.8–1 ppm F (parts per million) fluoride (F))] maybe too high given increasing exposure to other sources of fluoride, leading to an increased prevalence of fluorosis [5,6]. For example the US Public Health Services recommended lowering fluoride levels in public water supplies from the previously agreed range of 0.7 to 1.2 ppm to a level of 0.7 ppm [5]. In Europe, Ireland has lowered the fluoride concentration in the water from 1.0 ppm to a new range 0.6–0.8 ppm, with a target concentration of 0.7 ppm in 2007 [7]. In Asia, authorities in

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Hong Kong have reduced the fluoride concentration in their public water supply twice, from 1 to 0.7 ppm in 1978 and then a further reduction to 0.5 ppm in 1988 [8–10]. In Southeast Asia, Singapore has taken similar action by reducing the concentration of fluoride in drinking water twice from 0.7 to 0.6 ppm in 1992 and further to 0.5 ppm in 2008 [11]. In 2005, the Malaysian Ministry of Health reduced the fluoride level in the public water supply from 0.7 ppm to a target concentration of 0.5 ppm [6].

Taking into account the importance of understanding the risk of fluorosis due to the use of fluoride in caries prevention, this study aims to review the impact of stopping or reducing the fluoride level in the water on dental fluorosis. In this review the terms cessation and reduction are used. Cessation refers to stopping the addition of fluoride to the public water supply. Reduction implies a downward change in the concentration at which the water is fluoridated.

Methods

Search strategy

Detailed search strategies were developed combining controlled vocabulary and free text terms for each database searched. In collaboration with a professional dental subject librarian, the search covered research published from their starting date to 1st February 2019 from the following databases; MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials (CENTRAL) and the Web of Science. The detail of each search strategy and the keywords used are shown in (Supplementary material 1). The literature searched was restricted to English language publications. The reference lists of published systematic reviews of water fluoridation and water fluoridation cessation were checked and eligible papers were also hand searched.

Study selection

All study designs were included in the review. Studies with a historical comparison (pre and post study with no control group); studies with a control group and any studies that compared fluorosis prevalence across multiple age groups that correlated with the change in fluoride level during enamel development were also included.

The review looked at both the permanent or temporary cessation of fluoride in the water supply in at least one of the study areas. The intervention had to be in place at least for 12 months to allow a meaningful effect of the intervention on fluorosis. Areas with a natural fluoride level of less than 0.3 ppm were regarded as “non-fluoridated”. Exposure to other sources of fluoride (e. g. fluoridated toothpaste) were not considered as these were assumed to be similar across fluoridated and non-fluoridated communities. If no specific information was available for other sources of fluoride, any studies conducted after 1975 in industrialised countries were assumed to have been conducted in the presence of fluoridated toothpaste use in the communities involved.

Outcome measure

The primary outcomes were changes in the prevalence of dental fluorosis. Dental fluorosis was measured as the percentage of children affected by fluorosis using the following indices; Dean’s Fluorosis Index, Tooth Surface Index of Fluorosis (TSIF), Thylstrup and Fejerskov (TF) Index and Developmental Defects of Enamel (DDE). The percentage of fluorosis prevalence was based on the index used in the individual studies. Subjects were defined as having fluorosis with a DDE, TSIF, TF score greater than zero or Dean’s classification of ‘questionable’ or greater.

Data extraction

Titles and abstracts were initially screened by NAMN and initial exclusions were agreed with IGC. For studies appearing to meet the inclusion criteria or for which there were insufficient data in the title and abstract to make a clear decision, full text articles were obtained. Two reviewers assessed all full text articles independently and disagreement was resolved by discussion. Three reviewers (NAMN, IGC and BLC) were involved in the data extraction exercise. Reviewers were paired for designated articles using data extraction forms. Any disagreements were resolved by discussion. The data extraction forms were piloted on three papers and necessary amendments were made before their use to screen all papers. Each study included in this review was assessed using a validity assessment checklist (a validity score and level of evidence) as used in the York Review [1,12].

Data synthesis

Qualitative analysis: The percentage prevalence of fluorosis, was used to determine the impact of fluoride level change. The percentage change in fluorosis prevalence was calculated as the difference between post-intervention and pre-intervention (post-pre). Data from fluorosis studies that compared children in different age groups that were exposed to different fluoride levels were extracted based on their exposure to fluoride level during the period of enamel development. The baseline prevalence data were extracted from the groups that were exposed to the old fluoride concentration and the ‘after’ prevalence data were extracted from the group that were exposed to the new fluoride level after reduction occurred. The data were compiled and presented in a descriptive table (Table 1).

Quantitative analysis: The meta-analysis for fluorosis was divided into three parts. The first analysis combined individual studies on the effect of reducing fluoride level and fluorosis. The second analysis combined individual studies on the effect of stopping fluoridation and fluorosis. A third analysis combined studies from both interventions (stopping or reducing) fluoride level for pooled estimates of effect across time points. Data were analysed using (STATA Version 13).

Assessment of heterogeneity: The I^2 score and chi-square analyses were used to test for differences between studies (heterogeneity). This test was used to assess whether the observed variability in study results (measure of effect) was greater than that expected to occur by chance. The test of heterogeneity was significant (I^2 : towards 100%, chi-square: $p < 0.05$), therefore random-effect models were used.

Table 1: Summary of studies after the cessation of fluoridation or reduction in fluoride levels in the water on dental fluorosis.

Authors	Country/Area	Age (years)	Pre-Survey/F level (ppm)	Post-survey/F level (ppm)	Year change in F level	% Prevalence (pre)	% Prevalence (post)	Index	Teeth examined	Study design
<i>Studies on cessation of fluoridation</i>										
Buzalaf et al., 2004 [14]	Jau, Sao Paulo, Brazil	9–14	n/a	not stated	1991–1999	7.4	18.6	TF	Maxillary central incisors	^a Single-point CS survey
Wei and Wei, 2002 [13]	Gongzhou, China	15	0.7 1982	0 1990	1983	85.3	21.0	Deans	Not stated	^b CS with historical control
Clark et al., 2006 [15]	Comox & Campbell River, Canada	6–9	0.7–0.8 93/94	0 2002/03	1992	58.6	24.4	TF	All erupted teeth	^b CS with historical control
<i>Studies on reduction in fluoride levels</i>										
Evans and Stamm, 1991 [10]	Hong Kong	7–12	n/a	1986	1978	88.0	77.0	Deans	Upper right maxillary incisors	^a Single-point CS survey
Wong et al., 2014 [8]	Hong Kong	12	1 1983	0.7 2010	1988	89.3	42.1	DDE	Maxillary incisors	^b CS with historical control
Mohd Nor et al., 2018 [6]	Malaysia (Negeri Sembilan) [F]	9–12	1 n/a	0.5 2015	2005	44.6	39.3	Deans	Maxillary central incisors	^a Single-point CS survey with a control group
	Kelantan [NF]		0.7 n/a	0.5 2015	–	4.7	6.5			

CS, Cross-sectional, F, fluoridated, NF, non-fluoridated, DDE, Developmental Defects of Enamel, TF, Thylstrup and Fejerskov (TF) Index.

^aSingle point-cross sectional survey comparing fluorosis across different birth cohorts that exposed to different fluoride level due to change in fluoride exposure from water.^bStudy that has pre and post (cessation/reduction) data in one or more populations (no control group).

Results

Search results

A total of 385 studies were identified in the database searches and 110 records were excluded as duplicates. A further 264 records were excluded after titles and abstracts were screened. In total, 14 full text articles were screened for eligibility. Eight records were excluded following data extraction as irrelevant or unsuitable. A total of six publications were included in the review (Figure 1).

Publication date and reasons for change in fluoride level

The year of fluoridation cessation ranged from 1983 to 1999. The year of reducing fluoride level ranged from 1978 to 2005. All publications focused on children, aged between 7 and 15 years. Several studies reported reasons for water fluoridation cessation and the reasons varied across studies. These included observed increases in dental fluorosis [13] and a public vote in favour of cessation [15]. Reasons for reduction of fluoride level in the water were

related to an increased prevalence of fluorosis [6], the relationship between water intake and climatic conditions [8–10] and technical issues [14].

Qualitative synthesis on studies reporting the impact on change in fluoridation status on the prevalence of fluorosis

Six publications met the inclusion criteria for fluorosis outcome [6,8,10,13–15]. Three publications reported on cessation [13–15] and three publications were from areas where the level of fluoride in the water supply had been reduced [6,8,10]. Two studies were scored as evidence level B (moderate) [6,8] and the remaining publications were evidence level C (poor) [10,13–15].

Fluoridation cessation and dental fluorosis

Three publications, reported data on cessation of water fluoridation on fluorosis [13–15]. These studies were all cross-sectional in nature. These three studies with historical controls were conducted in China, Canada and Brazil and one study was a single point survey that compared

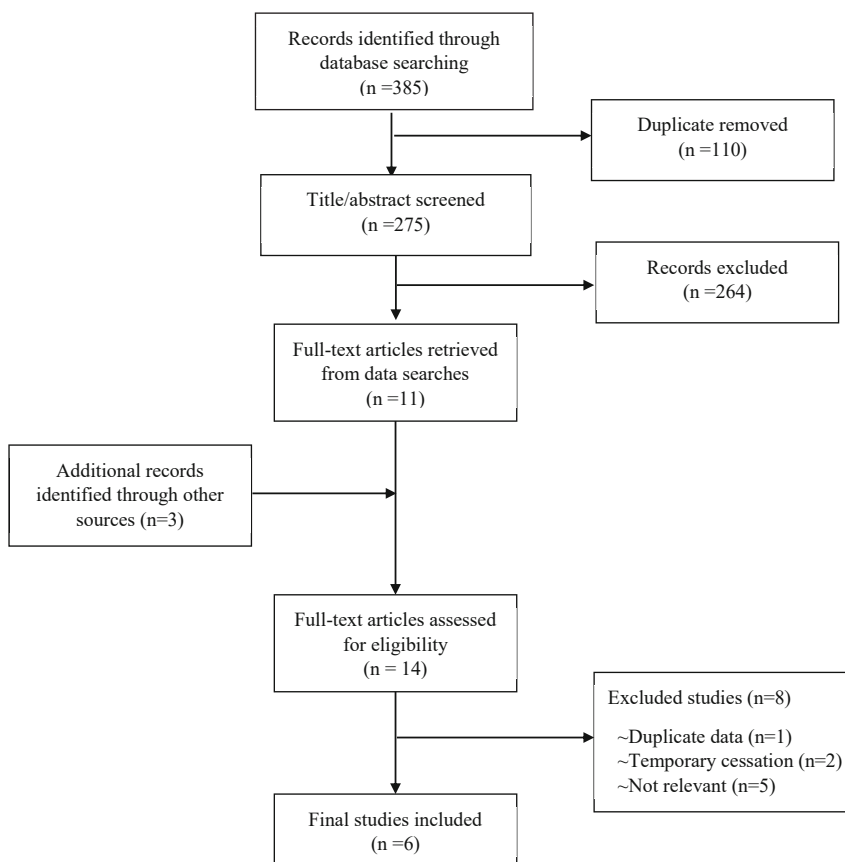


Figure 1: Flowchart for studies inclusion and exclusion.

multiple birth cohorts that were exposed to different fluoride levels during tooth development. Pre-cessation fluoride concentration was 0.7–0.8 ppm in China [13] and Brazil [14] and 1 ppm in Canada [15]. Three studies reported a decrease in fluorosis prevalence following the cessation of water fluoridation. However, a Brazilian study reported an increase in fluorosis prevalence post-cessation. The study in Canada used the TF index and reported the presence of fluorosis on (a) all teeth and (b) maxillary anterior teeth alone [15]. For both of these outcome measures, fluorosis prevalence decreased following the cessation of water fluoridation. When all teeth are included the reported decrease was greater than when considering only the anterior teeth (58.6 vs 24.4%).

The study in Brazil used the TF Index to measure fluorosis on maxillary central incisors. In comparison to other studies included in the review, only this study reported an increase in fluorosis prevalence after 7 years of water fluoridation cessation [14].

The Chinese study reported on fluorosis prevalence using Dean's Index [13]. Results demonstrated a decrease in fluorosis prevalence following the cessation of water fluoridation (85.3–21.0%). However, these findings should be interpreted with caution because while the number of affected individuals was described by the separate categories in Dean's Index in the pre-cessation survey, for the post-cessation survey, results were not broken down by level of severity. It is therefore unclear if the fluorosis prevalence reported post-cessation included the questionable category.

The impact of reducing fluoride level in the water supply on dental fluorosis

Initial screening indicated four publications with data on the effect of reducing the fluoride level in the water on fluorosis were studies conducted in Hong Kong and Malaysia [6,8–10]. However, two publications on the Hong Kong studies [9,10] were linked papers whereby the first publication reported the prevalence of fluorosis among four districts and the later publication reported overall fluorosis data of the studied sample. To avoid data duplication, only overall fluorosis data were used in the analysis [10]. All studies were cross-sectional in nature. Of those three studies included in the analysis, one study [8] was a pre and post survey and another two studies [6,10] were a single point survey with multiple birth cohorts comparison (i. e. children with different age groups were compared based on different exposure to fluoride level in the water during tooth development).

The Hong Kong studies [8,10] had no control group and the Malaysian study used a non-fluoridated community as a control group [6]. Two publications used Dean's index and one study used the DDE index to report fluorosis prevalence. The Hong Kong studies were conducted post-1975, and assessed minor reductions in fluoride level (from 1 to 0.7–0.5 ppm).

All three studies examined fluorosis on anterior teeth. These included the upper right central incisor [10], maxillary incisors [8] and maxillary central incisors [6]. Two recent studies examined fluorosis with photographs for blind outcome assessment [6,8].

Quantitative synthesis to examine the relationship between change in fluoride level and fluorosis

Six studies met the inclusion criteria to be included in the meta-analysis [6,8,10,13–15]. The meta-analysis is presented in Figure 2. Results show that fluorosis prevalence was significantly decreased following reduction of fluoride level in the water supply. The reduction was greater in a study that used pre and post study design (OR:11.48) than a single point survey (different age groups comparison). On the other hand, fluorosis prevalence was decreased after water fluoridation cessation in two studies, but statistically not significant. The decrease was greater in the Chinese study (OR: 21.93) in comparison to the Canadian study (OR: 4.32).

When all studies were combined, the pooled estimate of effect indicated a significant difference of fluorosis reduction (OR: 3.25, 95%CI: 1.34–7.85). However, results should be treated with caution because of high heterogeneity, lack of blinding and small numbers of studies included in the meta-analysis.

Discussion

All available reviews acknowledge that a randomised controlled trial is not feasible as a study design in evaluating the effectiveness of water fluoridation [1–3]. This explains the complexity of assessing such an intervention and why the majority of water fluoridation studies have been mostly cross sectional in nature. Taking into consideration the methodological limitations in assessing fluoridation, this review includes any published study. The aim was to appraise the available literature with the widest possible range of study designs. This study adapted criteria used in the York Review [12] with some modifications for

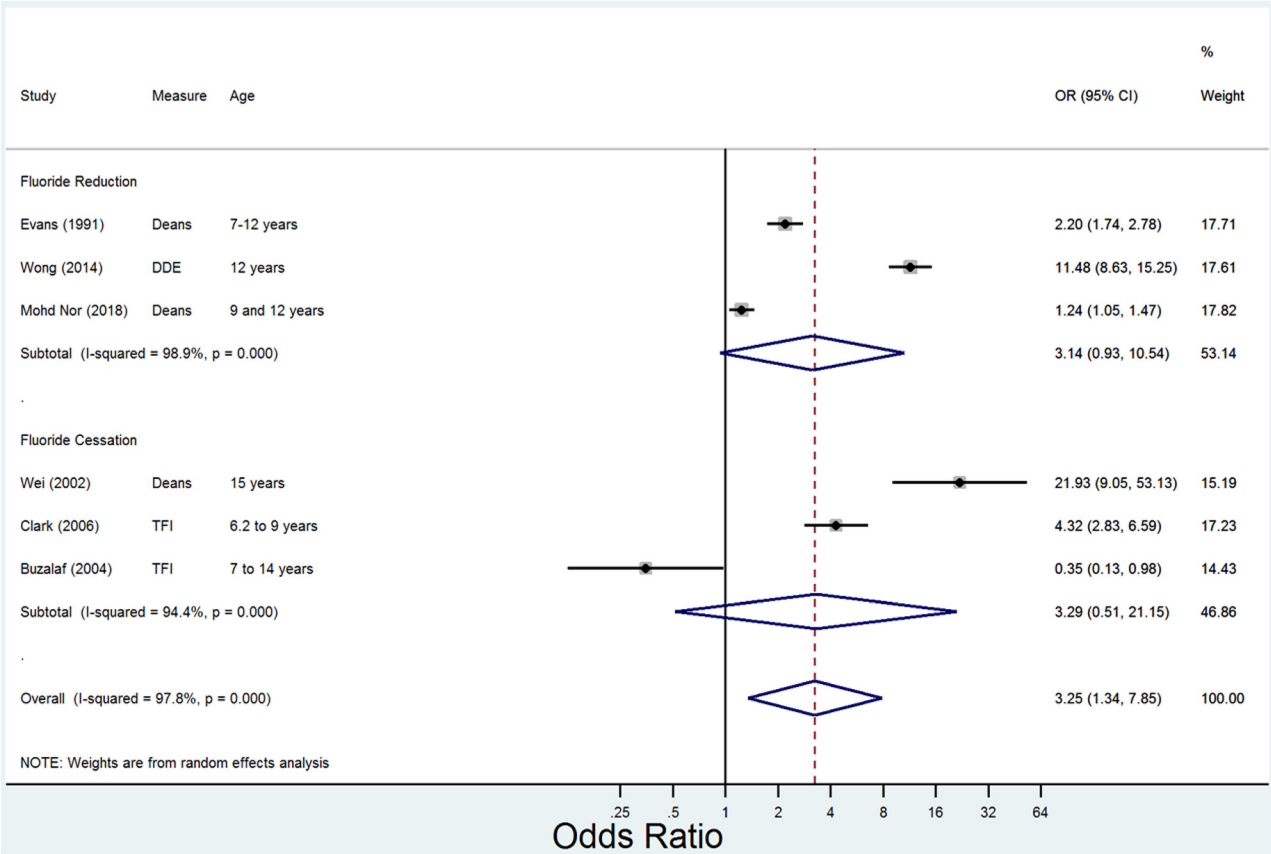


Figure 2: Meta-analysis on fluorosis.

study validity assessment. Similar to the York review, some of the included cross sectional studies were ‘upgraded’ as moderate quality (moderate risk of bias) when they had a concurrent control group, blinding of outcome assessment, and addressed and control confounding factors in the analysis. Taking these factors into account, four studies were rated as low quality and two studies were regarded as of moderate quality.

Of all the included studies, only three studies [6,8,15] used analysis to control potential confounding factors. Future research should consider appropriate study design and better handling of confounders. If possible, a longitudinal study design is the ideal method to assess the effects of change of fluoride level in the water supply. If resources are limited, a study design with concurrent control (positive or negative control) is desirable [16]. All of the included studies reported outcomes in child populations only with ages ranging from 7 to 15 years.

Fluorosis occurs due to excessive exposure to fluoride during tooth development and the risk period is between birth and three years of life for anterior teeth and eight years of life for posterior teeth [17]. This may explain the use of a

single-point survey comparing multiple birth cohorts exposed to different fluoride levels during tooth development (i. e. exposure to fluoride levels vary at different age groups). Taking into account the value of birth cohort studies, it was deemed relevant to include this study design in the review. However, this study design was rated as lower quality in comparison to studies that fulfilled the ‘at least two points in time’ requirement. This design was also used in two studies that assessed short term unintended cessation of water fluoridation on fluorosis where the interruption of the fluoride provision occurred due to technical issues for a period of 11 months [18,19]. Results of these reported decreased fluorosis prevalence following short-term cessation. These studies were identified during data searching but excluded from this review as they did not meet the inclusion criteria (temporary cessation of fluoridation for less than 12 months).

In terms of fluorosis assessment, Dean’s, TF and DDE indices were the most commonly reported in the primary studies. Blinding of fluorosis assessment can be achieved using standardised photographs and this was mostly employed in more recent studies. This method also allows

archiving, remote assessment and data comparison across different time points. Although the photographic method has many advantages, the analysis is often restricted to maxillary central incisors which may result in an underestimation of the true fluorosis prevalence in the study population. Uniform diagnostic criteria and reporting techniques for fluorosis would improve the comparability of results across studies and aid in meta-analysis. Future research should consider this factor for higher quality data.

The results from the meta-analysis indicate a decrease in the prevalence of fluorosis after reducing or stopping fluoridation. However, these results should be treated with caution because of significant heterogeneity across studies, lack of examiner blinding, the small number of studies included in the meta-analysis and the use of different indices to measure fluorosis. The results are mainly derived from low quality primary studies in which only one study had a concurrent control group. Only a few recent studies tend to control for confounders [6,8,15] and used blind photographic assessment to score fluorosis [6,8].

Other possible confounders of particular relevance to fluorosis are temperature and altitude. People living in climates with a higher mean temperature drink more water, and may therefore be exposed to more total fluoride. Higher altitude has also been reported to be associated with the development of fluorosis, however the mechanism for this is unclear [1]. Future studies should consider this factor. More research is also needed to measure consumption of tap water within a population and how it is associated with fluorosis development.

Limitations

The limitation of the meta-analysis is the lack of data and different outcome assessment across studies. This reflects the lack of a standardized method when reporting fluorosis data. In addition, an analysis on the dose-response relationship between fluoride in the water and fluorosis could not be undertaken because of a lack of data. Another limitation is that the review only included four major electronic databases. Relevant works from non-English publications and some grey literature such as local reports may have been missed.

Conclusions

The evidence suggests a significant decrease in the prevalence of fluorosis post cessation or reduction in the concentration of fluoride added to the water supply. However,

this work demonstrates that when studies are subject to current expectations of methodological and experimental rigour, there is limited evidence with low methodological quality to determine the effect of stopping or reducing the concentration of fluoride in the water supply on dental fluorosis.

Acknowledgement: Assistance from the subject specialist librarians at Cardiff University is acknowledged gratefully.

Research funding: This work was funded by a scholarship from the Ministry of Education, Malaysia to support PhD studies undertaken by NAMN.

Competing interests: Authors state no conflicts of interest to declare.

Informed consent: Informed consent is not applicable.

Ethical approval: Ethical approval to conduct this study was approved by the Research Ethics Committee, School of Dentistry, Cardiff University (DSREC, 14/17a).

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- Supplementary material:** The online version of this article offers supplementary material (<https://doi.org/10.1515/reveh-2019-0059>).