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Patterns and Distribution of Dental Caries and Dental Fluorosis in Areas with Varying Degrees of Fluoride Ion Concentration in Drinking Water.

KEYWORDS: dental caries, dental fluorosis, TSIF, water fluoride level

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ABSTRACT *In the present times the relationship between water fluoride ion concentration, dental caries and dental fluorosis in not as clear as it was in the past. Also, the patterns and distribution of dental caries and dental fluorosis has been changing in the recent times. Data needs to be comprehensively re assessed in order to have preventive strategies balancing the burden of both the conditions. A community based epidemiological study was thus designed to assess the patterns and distribution of dental caries and dental fluorosis in areas with varying levels of water fluoride ion concentration in drinking water supply. A total of 2401 school children were examined, dental caries prevalence was 38% with a mean DMF(S) of 1.2±0.79. Occlusal caries was most common with a mean score o f 2.53± 1.3. Fluorosis prevalence was 45%. TSIF scores in the category of 1 – 3 were the most common encountered. No relation was observed between water fluoride levels and the prevalence of dental caries. At water fluoride level ranging from 0.3 ppm to 5.2 ppm the most common form of fluorosis to be observed was in the TSIF scores ranging from 1 –3*

Introduction

The relation between fluoride concentration in drinking water and dental caries may have existed throughout the history but was scientifically reported only at the beginning of the last century. [1] The epidemiology of enamel fluorosis and its relation to dental caries has a rich history dating back to 1900s. It serves as an illustration of the power of epidemiology to uncover important health relations and to establish the safety and efficacy of specific interventions well in advance of an understanding of the underlying mechanisms of action.

If enamel fluorosis were the sole oral health outcome associated with the presence of fluoride ion in drinking water, the history of its discovery would have been little more than an interesting epidemiologic footnote. However, the additional observation by early researchers that the presence of fluoride ion in drinking water was also associated with a markedly lower prevalence of dental caries added greatly to the importance of these early investigations which demonstrated that a 60% reduction in caries prevalence among populations served by water supplies containing naturally occurring fluoride in a concentration of approximately 1ppm. Of particular interest was the further observation that at this fluoride concentration, virtually no clinically noticeable enamel fluorosis was observed. [2] It was these observations that led to the concept of an "optimal" drinking water fluoride concentration, which has served as the basis for artificial water fluoridation. [3, 4] The observation that the fluoride ion was associated with a decreased prevalence of dental caries led to the development of numerous other products containing fluoride which were intended to be ingested, applied topically to the teeth, or both. These products have had a direct impact on the current prevalence of both caries and enamel fluorosis. [5, 6, and 7] However, during this same period, the prevalence of enamel fluorosis has also increased markedly in both optimally fluoridated and non-fluoridated areas. [1, 6] There is always a need to assess the prevalence of dental fluorosis and dental caries in relation to water fluoride levels so as to revaluate the strategies in caries prevention and the use of fluoride products. The study was thus undertaken with an aim of assessing the prevalence of dental caries and dental fluorosis in relation to varying levels of water fluoride ion concentration.

Methods

Study Design:

A community based, cross sectional, descriptive epidemiological study was designed to assess the prevalence and severity of dental caries and enamel fluorosis among 12 year old school children residing in areas with varying levels of fluoride in drinking water of Prakasam district in Andhra Pradesh (AP).

The age group included in this study corresponds to the WHO index age group for global monitoring of dental caries. Prakasam district in AP was considered to be the area of study as it is a known fluoride endemic area.

Ethical Clearance:

The ethics committee of Narayana Dental College and Hospital, Nellore approved the study design; permission was obtained from the Regional Educational Authorities to conduct the study in the schools of their jurisdiction. Cooperation of the School authorities was solicited before starting the study and informed consent was obtained by the parents/ guardians of the school children before the start of the study.

Study Procedure

Sample Size:

The sample size for the study was calculated on a finite population of 48,000 twelve year old children at an estimated prevalence of dental fluorosis of 50%. The calculated sample size was 2287 with 95% confidence level at 2% precision. An additional 5% was added to compensate for sample loss if any. The final sample thus accounted was 2401, 12 year old school children.

Sampling Procedure:

The required numbers of school children were drawn from across the district through stratified cluster random sampling procedure with stratification based on basic demographic characteristics viz, rural urban distribution, public vs. private schools etc. the entire district is divided into three administrative divisions, a proportionate number of mandals from each administrative division were randomly included in the sampling frame. A list of schools for each included mandal was obtained by the office of the Directorate of Education. A proportionate number of schools from each mandal were randomly included as sampling units. Each of the schools was visited by the investigator with prior permission of the head master and children fulfilling the inclusion/ exclusion criteria were examined till the desired sample size was obtained.

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Inclusion Criteria:
- Children with informed consent, who were the continuous residents of the area of examination (born and brought up in the area of examination).
- Children with a history of same source of drinking water since birth.
- Children with a full complement of permanent dentition

Collection of Water Samples:
Water samples were collected by the investigator himself in graduated plastic containers from each area of examination after ascertaining the source. The following precautions as directed by the Water Analysis Department of Guntur Medical College were observed by the investigator while collecting the water samples

Plastic bottles with a graduations and clear labels mentioning the date and area code were used for collecting water.

Only fresh water supplied by the respective municipalities or the freshly drawn bore well water was collected.

Only water which was used for drinking was collected from the taps directly after turning on the taps for a few moments till a steady flow was observed.

After collection, water samples were to the laboratory on a daily basis for fluoride analysis. After obtaining the results of analysis, all the areas were grouped into below optimal, optimal and above optimal Fluoride levels in drinking water as per the recommendations of the WHO. [8]

Infection control:
Strict protocol for infection control was observed constantly through out the data collection period. The instruments were autoclaved daily and necessary cold sterilization was performed in the field during the clinical examination.

Clinical Examination:
Type III examination was performed using mouth mirrors, explorers and air syringe under adequate illumination. Data was recorded on a specially prepared proforma containing basic demography, dental caries experience using DMF(S) index of Klein, Palmar and Knutson (1938), Extent and severity of Enamel Fluorosis using Tooth Surface Index for Fluorosis (TSIF) of Horowitz et al (1984). The investigator was trained in recording the indices used in this study, and was calibrated prior to the main study.

Statistical analysis:
Data were analyzed using Statistical Package for Social Sciences (SPSS version 12.0 Inc., Chicago II, USA).

Results
A total of 4305 children were clinically examined by the investigator himself. However, the necessary data was recorded among 2401 school children upon satisfying the inclusion / exclusion criteria. The final survey forms thus amenable for statistical analysis were 2401.

Analysis of the socio demographic characteristics as presented in Table No 1 revealed that there was a slightly higher representation from boys 57% and a proportionate representation of children form the urban and rural background. Analysis of the SES revealed that majority of the children belonged to Upper poor class 50.7%. Analysis of BMI for age of the children revealed that a maximum number of children 76.5% belonged to underweight category. Water fluoride analysis revealed that the concentration of fluoride ion in the drinking water of the studied school children ranged from 0.3 ppm to 5.2 ppm. The areas of examination were segregated into below optimal, optimal and above optimal fluoride areas as per the recommendations of the WHO as shown in Table - 1.

Table - 1: Socio Demographic Characteristics of the School Children

Socio Demographic Characteristics	n	%
Gender		
Male	1368	57
Female	1033	43
Geographic Location		
Rural	1672	69.6
Urban	729	30.4
Socio Economic Status		
High	2	0.1
Upper Middle	461	19.2
Lower Middle	720	30
Upper Poor	1218	50.7
Lower poor	0	0
Body Mass Index for Age		
Under Weight	1836	76.5
Normal	514	21.4
Over Weight	51	2.1
Water Fluoride Level		
Below optimal	942	39.2
Optimal	779	32.4
Above optimal	680	28.3

n = 2401

Number of children with dental caries was 917 accounting to a prevalence of 38.19%, with a mean DMF(S) of 1.12 ± 0.79. Analysis revealed that the distribution of dental caries was not significantly associated with any of the socio demographic characteristics studied including the water fluoride levels as shown in Table - 2.

Table - 2: Prevalence of Dental Caries and its Association with Socio Demographic Characteristics.

Socio Demographic Characteristic	Children without caries		Children with caries		χ^2	OR (95% CI	P value
	n	%	n	%			
Gender							
Male	860	62.9	508	37.1	0.235	1	0.118
Female	624	60.4	409	39.6		1.11	
Geographic Location							
Rural	1045	62.5	627	37.5	0.294	1	1.56
Urban	439	60.2	290	39.8		1.1	
Socio Economic Status							
High	2	100	0	0	2.36	1	0.501
Upper Middle	284	61.6	177	38.4		1.12	
Lower Middle	436	63.3	264	36.7		1.01	
Upper poor	742	60.9	476	39.1		1.2	
Body Mass Index							

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Under Weight	1146	62.4	690	37.6	2.35	1	0.308
Normal	311	60.5	203	39.5		1.2	
Over Weight	27	52.9	24	47.1		1.6	
Water Fluoride Level							
Below Optimal	588	62.4	354	37.6	0.921	1	0.631
Optimal	486	62.4	293	37.6		1	
Above Optimal	410	60.3	270	39.7		1.1	

Children without caries = 1484
Children with caries = 917

An additional assessment of caries findings was conducted for mean DMF(S) scores by tooth surface type among the affected school children in relation to their water fluoride levels as shown in Table - 3. It was found that the most commonly affected surfaces were the Occlusal ones with a mean score of 2.53 ±1.3 followed by the Approximal surfaces, the least to be affected were the Smooth surfaces with a mean of 1.58 ± 0.79.

Table - 3: Surface Distribution of Dental caries

Surface	n	mean± SD	range
Occlusal	901	2.53 ± 1.3	1 to 8
Approximal	78	1.6 ±1.1	1 to 6
Bucco lingual	185	1.58 ±0.79	1 to 4

Number and percentage of children affected by surface type lesions in relation to water fluoride level indicated that there was a statistically significant difference in the severity of Bucco lingual lesions in relation of water fluoride level, but no such trend was observed for Occlusal and Approximal lesions as shown in Tables – 4.

Table - 4: Distribution of Dental Caries in relation to Water Fluoride Levels

Occlusal caries	DMF(S) < 3		DMFS> 3		
Water Fluoride Level	No	%	No	%	P value
Below Optimal	268	29.7	79	8.7	0.161
Optimal	223	24.75	63	6.9	
Above Optimal	192	21.3	76	8.4	
Bucco lingual caries	DMF(S) < 2		DMFS > 2		
Below Optimal	63	46.7	7	3.78	0.048
Optimal	51	27.5	9	4.86	
Above Optimal	54	29.18	1	0	
Approximal caries	DMF(S) < 3		DMFS> 3		
Below Optimal	36	46.1	4	5.1	0.161
Optimal	15	19.23	2	2.5	
Above Optimal	19	24.35	2	2.5	

The number of children with dental fluorosis (≥ one tooth surface affected) was 1085 accounting to a prevalence of 45% Analyses of dental fluorosis prevalence was carried out by multiple logistic regression analysis by enter method to yield respective Odds Ratio (OR) explaining the relative contribution of each of the socio demographic parameters investigated in this study. It was found that males had an OR of 1.53 (95% C I 1.24 – 1.53) compared to females. Children from a rural back ground were more commonly affected with fluorosis at an OR of 11.24 (95% C I 7.84 –16) compared to their urban counterparts. Children from the lower SES were found to be significantly associated with dental fluorosis. Body mass index was found to be statistically significantly associated with the occurrence of dental fluorosis.The level of fluoride in water was also strongly related to the occurrence of dental fluorosis with the residents from optimal fluoride areas having an OR of 4.79 and those from above optimal fluoride areas with an OR of 9.85, as shown in Table -5.

Table - 5: Prevalence of Dental Fluorosis regressed over various socio Demographic Characteristics.

Socio Demographic Characteristics	Children with Fluorosis		OR (95% CI)	Beta	SE of Beta	P value
	n	%				
Gender						
Female	405	39.2	1	0.428	0.106	0.001
Male	680	49.7	1.53(1.24-1.5)			
Geographic Location						
Urban	71	9.7	1	2.419	0.18	0.001
Rural	1014	60.6	11.24(7.84-16)			
Socio Economic Status						
Upper Middle	84	18.2	1.2	18.65		
Lower Middle	303	42.1	5.1	17.75		0.001
Upper Poor	698	57.3	6.1	17.92		0.001
Body Mass Index						
Over Weight	7	13.7	1			
Under Weight	935	50.9	0.96(0.35-2.6)	-0.03		0.001
Normal	143	27.8	0.78(0.31-2.3)	-0.141		0.001
Water Fluoride Level						
Below Optimal	178	18.9	1			
Optimal	359	46.1	4.79(3.7-6.1)	1.56	0.127	0.001
Above Optimal	548	80.6	9.85(7.5-12.8)	2.28	0.136	0.001

N =1085
Prevalence of dental fluorosis = 45%
Nagalkerke R^2 value = 0.156

Analysis of the severity of fluorosis revealed that 89.85% of surfaces examined were affected with fluorosis to varying degrees of severity amongst below optimal fluoride areas compared to 85.46% and 85.55% form optimal and above optimal fluoride areas. Scores in the categories of 1 – 3 which represent various degrees of whitish discoloration were the most commonly encountered scores in this study. Significantly 26.8% of surfaces recorded a score of 6 from above optimal fluoride areas.Surface specific distribution of fluorosis was analyzed in relation to water fluoride levels; it was found that occlusal surfaces were the most common to be fluorosis free while the buccal and the lingual surfaces had an almost similar distribution. Score 3 was the most commonly observed category on the occlusal surfaces and scores 2 and 3 being the most widespread amongst the buccal and lingual surfaces it is to be noted that the buccal and lingual surfaces had a similar distribution of different scores as shown in Table - 6.

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Table - 6: Surface distribution of TSIF scores in relation to water fluoride level

Water Fluoride Level	n	surfaces	% Distribution of TSIF scores (overall surfaces)						
			0	1	2	3	4	5	6
Below Optimal	178	12816	11.15	3.88	36.44	42.35	1.62	1.6	0.98
Optimal	359	25848	11.54	6.74	21.05	50.82	2.1	2.6	0.79
Above Optimal	548	39456	9.63	2.6	21.34	50.7	2.9	5.1	26.8
	% Distribution of TSIF Scores on Occlusal surfaces								
Below Optimal	178	2845	18.33	3.51	29.52	44.74	0	0.9	0.89
Optimal	359	5744	16.53	6.7	9.29	56.92	2.07	2.8	3.69
Above Optimal	548	8768	10.46	1.6	16.6	53.18	1.81	4.2	12.3
	% Distribution of TSIF Scores on Buccal surfaces								
Below Optimal	178	4984	8.46	3.97	40.38	41.31	1.4	3	1.3
Optimal	359	10052	9.11	7.91	21.64	51.53	3.66	3.3	1.57
Above Optimal	548	15344	9.98	2.7	23.9	44.44	3.8	4.9	10.9
	% Distribution of TSIF Scores on Lingual surfaces								
Below Optimal	178	4984	9.06	5.57	39.04	41.02	2.24	0.8	0.16
Optimal	359	10052	10.03	6.61	33.33	44.02	1.76	1.7	0.29
Above Optimal	548	15344	10.06	2.7	24.07	41.36	3.3	6.4	9.2

Prevalence of dental caries and dental fluorosis was plotted against the concentration of water fluoride ion it was observed that a there was a positive co relation between the water fluoride ion and the prevalence of fluorosis. As regards to dental caries no co relation was observed as depicted in Figure - 1. The point of intersection of both the curves was between fluoride ion concentrations of 0.6 ppm and 1.00 ppm.

Figure 1: The relation between dental caries and dental fluorosis

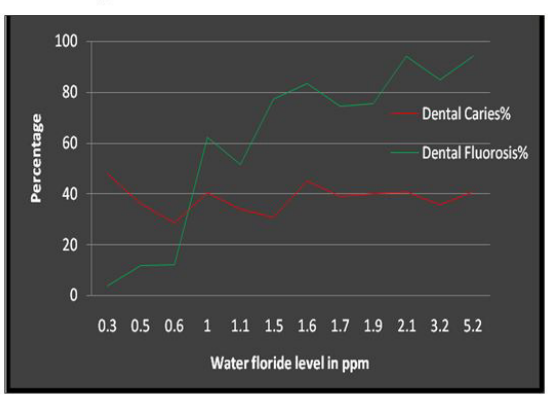

Figure 1: The relation between dental caries and dental fluorosis at varying levels of fluoride ion concenttration in drinking water

Discussion

The intent of this study was to assess the prevalence, severity and distribution dental caries and dental fluorosis among communities having below optimal, optimal and above optimal levels of fluoride in their drinking water. The debate about the relationship between the concentration of fluoride in drinking water and dental caries and fluorosis began with Dean's classical studies during the 1930s and1940s in the United States. A resurgence of interest has occurred during the past few decades. A large body of scientific literature is published from around the globe. Comparison with the available published literature must be interpreted cautiously because of different climatic conditions, patterns of water ingestion, dentifrice use, dietary habits, fluoride supplements, use of different criteria and indices, and a lack of uniformity in the collection of collected information.

This study was conducted in Prakasam district of Andhra Pradesh; the district occupies an area of 17626 sq. kms. It is also the largest in area among the coastal districts of Andhra Pradesh. The district lies between 15°30'16"N 79°80'E. It is located at an altitude 328 ft above sea level with a tropical climate. The district is a part of the Fluoride belt of India and is declared a known area for fluoride endimicity. [9] The age of studied subjects included in this study was 12 years as this age is considered an important age in the studies relating to the epidemiology of dental caries and dental fluorosis. [2]

It is prudent to realize before attempting to discuss the findings of this study that, unlike the situation during the beginning of the last the century, when fluoride in drinking water accounted for virtually all of the fluoride exposure in the general population, in the past recent years the number of intended and unintended sources of ingested fluoride has grown considerably. [10.11].This epidemiological study, being the first of its kind among the studied population apart from providing necessary information also serves as a baseline data for future research.

Analysis of water samples of the areas included in this study revealed a fluoride ion concentration ranging from 0.3 ppm to 5.2 ppm, based on the ion electrode method which is considered to be a highly sensitive method of fluoride ion estimation. As per the WHO recommendation, the areas were then classified as those belonging to below optimal, optimal and above optimal areas and all further interpretations were based on comparison on these lines.

The prevalence of dental caries among the school children in this study with was 38.19%, with a mean DMF(S) of 1.12 ± 0.9, the values are much lower to the reported national average of 52.5% and the average values for the state children at 53.1% [12] of the same age. A decreasing trend in dental caries experience has been reported in the literature across India with approximately 89% 80% and 82% in the 1980s and early 1990s to around 55% in the late 1990s and early 2000. [13] It can be said that this studied population thus has an approximately 14% less caries experience compared to their other counterparts. In an extensive review of studies conducted between 1979 and 1989, Newburn has found a difference of 15% to 35% in caries experience between fluoridated and non fluoride areas. The findings of this study are slightly less compared to the ones reported by Newburn. [14]

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Dental caries was found to be statistically insignificant among the variables incorporated in this study including Gender, SES, Geographic location, BMI for age, and also the Water fluoride level. A number of scientific reports have shown that the relationship between dental caries and water fluoride concentration is not as clear today as it has been in the past. [15, 16 and 17]The caries preventive effect of fluorides was first described in Dean's seminal studies during 1930s and 1940s, which showed an inverse relationship among high fluoride concentrations in drinking water, a high prevalence of fluorosis and a low prevalence and extent of dental caries, consequently one might in the present study have expected also to observe such a negative association. Residents of communities that once designated as non fluoride or suboptimal communities because of lack of optimal levels of fluoride in drinking water, often now, receive significant amounts of fluoride from other sources such as food and beverages procured from fluoride rich areas. Also, in the present investigation the area being of a tropical climate, water consumption could be higher compared to other areas. The small difference between caries experience among areas with different water fluoride ion concentration does not necessarily mean that water fluoride is less effective than it was in the past. Instead, it perhaps reflects the extensive role of the other sources of fluoride.

Dental caries in permanent dentition has become predominantly a disease of the pits and fissures this was clearly evident from this study. Caries was seen most commonly on the occlusal followed by the approximal and then the buccolingual surfaces these findings are in accordance to the studies reported in literature proving that fluorides provide their greatest relative protection to smooth surfaces. [18, 19 and 20,)

The prevalence of fluorosis as evidenced by a TSIF score of more than one on at least one tooth surface was 45% in this study; these findings are considerably higher when compared to the reported values for national and regional children of same age. [12] This study has found a maximum fluoride ion concentration of 5.2 ppm with a prevalence of nearly 45%, one study has reported a concentration of up till 7.9 ppm [13] while another has reported as high as 12 ppm in the other nearby areas of the state with 100% prevalence of fluorosis. [21] Recent literature from India has reported a prevalence of 49.26 %[22], and also 39 % to 100% prevalence in areas with different levles of water fluoride levels.[23] In addition a study has reported a fluorosis prevalenc of as high as 52.7% in an area with a fluoride level concentration of as low as 0.3 p p m, suggesting the influence of other sources of fluoride. [24]

Gender differences were observed in the prevalence of fluorosis in this study with males being more commonly affected compared to females at an OR of 1.53, these findings are in contrast to the reported findings [25,26], while another study [27] has reported that variable gender did not affect the occurrence of dental fluorosis. In this study it was observed that rural population was at a significantly higher risk of dental fluorosis compared to their urban counterparts. The possible role of dietary and other factors need to be explored in order to explain these differences. Recent literature has shown a higher prevalence among the males as high as 83 % among males vs 71% among females at the same water fluoride concentration.[22]

SES and BMI for age were studied in relation to dental fluorosis in this study and were found to be statistically significantly associated with the occurrence of dental fluorosis, these findings should be interpreted cautiously and further studies need to be conducted before drawing any logical conclusions. These findings should also be interpreted in the light of dental fluorosis and its nutritional status as both SES and BMI can be an indirect assessment of nutritional status.

Previous studies have demonstrated a direct relation between the fluoride concentration of drinking water and the prevalence and severity of dental fluorosis. The findings of this study are in agreement with earlier studies in that substantial increases in dental fluorosis occurred at above optimal fluoride levels with the condition being most pronounced at the highest level tested. A dose response relationship was found among the three water fluoride levels with an approximately 20% increase in the prevalence of dental fluorosis as the concentration increased from low to optimal level and nearly 40% increase as the concentration increased from optimal to high levels these findings are in accordance to those reported by Dean, Galagon et al. and Ben Chu et al. [28]

The distribution of TSIF scores among the different surfaces in relation to areas with different levels of fluoride was in consistent with the prevalence of fluorosis in that more severe scores were found in areas with higher levels of water fluoride level. The most common scores being TSIF - 2 and TSIF – 3 among the below optimal and optimal fluoride areas, where as TSIF – 6 and TSIF -7 were also observed among above optimal fluoride areas in accordance to the findings of Driscoll et al [29] where a parallel pattern of distribution between prevalence and severity was demonstrated.

TSIF scores of two and three were the most commonly observed scores amongst all the surfaces irrespective of the water fluoride level. Such a finding has not been reported in literature; hence further studies need to be conducted in order to explain this pattern of distribution. Occlusal surfaces were found to be the most common surface to be affected by fluorosis followed by the buccal and lingual surfaces where the severity and the pattern were almost similar. Such a distribution of fluorosis has been reported in literature by Murray and Shaw [30]

This study has revealed that as there is a dose response relationship between fluorosis and water fluoride level, some degree of fluorosis has occurred at even low levels of fluoride exposure, Therefore any level of water fluoridation will necessarily involve a trade off between obtaining desired caries reduction with an acceptable level of concomitant fluorosis, the optimal concentration for water fluoridation which has been commonly determined by the intersection of the caries and fluorosis lines plotted against water fluoride concentration together in one chart [31, 32]. In this study the point of intersection was between 0.6 ppm and 1.00 ppm at which point it was seen that maximum caries benefit with minimal concomitant fluorosis was observed. The major finding of this study is that caries levels were found statistically insignificantly when compared to its association with water fluoride levels though there is an over all lesser prevalence of the disease compared to the reported national and regional values. [13] Thus, the concern, at present is perhaps the higher prevalence of dental fluorosis though of a whitish discoloration within the TSIF scores of 1 and 3.

Current standards of water fluoride levels may have stood since the time of Dean, many things have changed since then and there is perhaps a need to redefine the standards. As stated by Leverett[32] "we need to acknowledge that fluoride is no different from many other chemicals deliberately introduced into our environment, in a sense that we should strive to maintain the lowest level capable of producing the desired therapeutic effect

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