Periodontal and dental conditions of a school population in a volcanic region of Tanzania with highly fluoridated community drinking water

Jaume Miranda-Rius[1,2], Lluís Brunet-Llobet[2,3], Eduard Lahor-Soler[1,2], Ombeni Mrina[4], Elias I Mashala[5], Michael J Mahande[6]

1. Department of Odontostomatology. Faculty of Medicine and Health Sciences. University of Barcelona, Barcelona, Spain.
2. Hospital Dentistry, Clinical Orthodontics & Periodontal Medicine Research Group (HDECORPEMrg), Institut de Recerca Sant Joan de Déu (IRSJD), Barcelona, Spain.
3. Department of Pediatric Dentistry. Hospital Sant Joan de Déu. University of Barcelona, Barcelona, Spain.
4. Dental & Oral Department, Soweto General Hospital, Arusha, United Republic of Tanzania.
5. Department of Orthopedic Surgery and Traumatology, Mount Meru Regional Hospital, Arusha, United Republic of Tanzania.
6. Department of Epidemiology and Biostatistics. Institute of Public Health. Kilimanjaro Christian Medical University College (KCMU College), Moshi, United Republic of Tanzania.

Abstract

Introduction: Dental fluorosis is endemic in the Rift Valley in Africa, especially around volcanic areas, due to the high fluoride content in daily drinking water.

Objective: This study evaluates the oral health status and types of occlusion in a school population, and to assess the possible association between dental fluorosis and other pathologies such as decay, gingivitis and periodontitis.

Material and methods: An observational study of 581 individuals recruited from a public secondary school in Arusha, Northern Tanzania was undertaken. The indices used were: the Silness & Löe Plaque Index, the Community Periodontal Index and the Decayed/Missing/Filled index. Descriptive statistical analyses were performed and a chi-square test was used to assess the associations between independent variables.

Results: Almost all the school children evaluated (96.73%) presented Angle class I dental occlusion, and 75.22% presented some degree of dental fluorosis. Most of the population (511, 87.95%) showed bleeding on probing. A moderate/high degree of some dental pathology (DMF score) was recorded in 14.46%. The association between dental fluorosis, gingival bleeding and tooth decay indicated a higher concentration of pathology in groups with more severe fluorosis ($p<0.05$).

Conclusion: In this large population sample, both tooth decay and gingivitis were significantly associated with moderate or severe dental fluorosis.

Keywords: Dental fluorosis; caries; periodontal disease; occlusion; community water fluoridation; socio-economic status.

Corresponding author:
Jaume Miranda-Rius,
Department of Odontostomatology,
Faculty of Medicine and Health Sciences,
University of Barcelona

Feixa Llarga, s/n, 08907 L'Hospitalet de Llobregat,
Barcelona, Catalonia, Spain
Tel: +34 934 024 269   Fax: +34 934 035 558
e-mail: jmiranda-rius@ub.edu

Introduction

Dental fluorosis is endemic to the Rift Valley in Africa, especially in volcanic areas, and it has been attributed to the high fluoride content in daily drinking water. In some parts of Tanzania, and particularly in the Arusha region (close to a dormant stratovolcano named Mount Meru), dental fluorosis is considered a health problem[1-4]. Although the World Health Organization (WHO) guidelines for drinking water quality recommend that fluoride concentration in the water supply should be between 0.5

and 1 mg/l,[5] the fluoride content of the drinking water in Arusha is approximately 3.6mg/l.[3]

The Kaloleni Secondary School is a publicly-funded center located in a low-income neighborhood in the city of Arusha, where students and their families have access only to the public water supply. For these reasons, the school is an ideal setting for the study of dental fluorosis in Northern Tanzania.

Dental caries remains the world's most prevalent disease, affecting billions of people, especially children.[6-10] Although the number of decayed, missing and filled teeth has fallen in many countries over the last three decades, a growing number of studies have observed increases in these rates in a small section of the population, above all among lower socioeconomic groups.[10-14] Numerous studies have attempted to correlate caries with dental fluorosis and have reported changes in the risk of decay depending on the degree of severity of the condition.[15-23]

Fewer studies have explored the association between dental fluorosis with periodontitis. The role of some of the etiological factors of periodontal disease such as age, gender, ethnicity, socio-economic status, lifestyle, smoking and oral hygiene has been studied in some populations in India[24,25] but the effect of fluoride on periodontal tissue remains controversial, even though its association with tooth decay is well established.[26] The epidemiological data regarding the periodontal status of individuals living in areas with highly fluoridated water are inconsistent. As regards malocclusion, few recent investigations have analyzed and classified dental occlusion in school populations in northern Tanzania.[27-29]

The objectives of the study were, on the one hand, to evaluate the oral health status and types of occlusion in this population, and to assess the possible association between dental fluorosis and other pathologies such as decay, gingivitis and periodontitis.

Methods
We performed a cross-sectional study at the Kaloleni secondary school as part of the KiliBarnaDental Project, a health promotion intervention carried out in Arusha, northern Tanzania during the 2015-2016 school year. The sample in this observational study comprised 581 individuals.

Study area
The epidemiological characteristics of the sample are representative of the Kaloleni neighborhood, which has a population of 11,651 inhabitants of low socio-economic status. The World Bank Country classification defines the United Republic of Tanzania as a low–income economy.[30] Arusha and its area of influence has a population of approximately one million inhabitants, and mean per capita annual income is 499USD.

We stress that our study was part of a non-for-profit project which was previously approved by the health authorities of Arusha City Council. Permission was obtained from the regional health authorities to conduct the study (Ethical clearance certificate, Ref. No. CD / E.10/39/131) and parents of the prospective students were asked to give their consent. The assessments were carried out consecutively by two examiners who had been trained in the use of the measurement system before the recording of the data. Finally, for each participant we wrote a report indicating his/her diagnostic and therapeutic needs.

Study population
The homogenous sampling in this study was crucial in order to minimize the effect of other confounding factors such as socioeconomic status, sugar intake, and tooth brushing. In fact, the students included were all of low socioeconomic status, ate the basic local diet without refined sugar, and only occasionally brushed their teeth. The study population was made up of healthy individuals without toxic habits, who only used the public water supply for drinking and/or cooking. According to the Arusha Urban Water Supply and Sanitation Authority (AUWSA), the water consumed by this population had a fluoride concentration of 3.6 mg/l.[31,32]

Measurements
The indices used were: the Silness & Loe Index (PI) to evaluate oral hygiene.[33] Assessment of Periodontal status was done using Community Periodontal Index (CPI) modified (Gingival bleeding and periodontal pockets) by the World Health Organization (WHO) Oral Health Assessment Form, 2013.[34] The Decayed, Missing, Filled (DMF)[35] index to determine the prevalence of tooth decay and dental treatment needs, and the Thylstrup-Fejerskov Index (TF)[36] to establish the degree of fluorosis. Finally, the index of restoration (IR%) (IR%=[F/DMF] x100) was also calculated to evaluate the presence and

distribution of dental treatments. With regard to occlusion, the discrepancy (diastemas/crowding), overbite, overjet, crossbite and the Angle class were recorded. The probing depth for the CPITN index was measured with a WHO periodontal probe (550B ES, LM Dental, Parainen, Finland).

The assessments were carried out consecutively by two examiners, OM and EIM, who had been trained and calibrated in the use of the measurement system before the recording of the data.

Statistical analysis

Statistical analyses were performed using Stata version 13.1 (Stata Corp, College Station, TX). Data were cleaned, checked for discrepancies in value labels, missing values and range checks to enhance consistence. Descriptive statistics were summarized using frequencies and proportions for categorical variables while means and standard deviation were used for normally distributed continuous variables. Chi-square tests were used to determine the associations between a set of independent variables and the outcome of interest. A p-value of less than 0.05 (two-tailed) was considered statistically significant.

Results

The characteristics of the study participants (n=581) are summarized in Table 1. The mean (SD) age of the participants was 15.69 (1.45 SD) years. Most were aged over 15 (314, 54.04%) and slightly more than half (298, 51.29%) were male.

The assessment of dental occlusion indicated that 96.73% of the population evaluated had an occlusion of Angle class I. Angle classes II and III were observed in 2.75% and 0.52% of cases respectively (Table 2). With regard to overjet, the population was classified into three categories: edge-to-edge bite (0- 1mm) 49.57%; normal (2-3mm) 45.95%, and increased (> 3mm) 4.47%. As for overbite, 52.84% of the population were edge-to-edge (0-1mm), 46.47% normal (2-3mm), and 0.69% increased (> 3mm). No diastemas were observed in 93.29% of the population (Table 2).

Table 1: Demographic characteristics (N=581)

Characteristics	n (%)
Age (mean + SD), years	15.69 (1.45)
Age category	
≤15 years	267 (45.96)
>15 years	314 (54.04)
Gender	
Female	283 (48.71)
Male	298 (51.29)

Table 2: Occlusion characteristics (N=581)

Occlusion	n (%)
Angle class I	562 (96.73)
Angle class II	16 (2.75)
Angle class III	3 (0.52)
Overjet	**n (%)**
Edge-to-edge 0-1mm	288 (49.57)
Normal 2-3mm	267 (45.95)
Increased ≥4mm	26 (4.47)
Overbite	**n (%)**
Edge-to-edge 0-1mm	307 (52.84)
Normal 2-3mm	270 (46.47)
Increased ≥4mm	4 (0.69)
Crossbite	**n (%)**
0mm	563 (96.90)
1mm	18 (3.10)
Diastemas	**n (%)**
0mm	542 (93.29)
1mm	39 (6.71)

The participants' periodontal status is displayed in Table 3. The majority of the participants (511, 87.95%) had a CPI of 1 (bleeding at probing), and only 1.90% had periodontal pathological pockets of 4-5mm in depth CPI of 2 (Table 3). As for the Plaque Index, 27.19% of the sample had values of bacterial plaque accumulation above 50%. Fluorosis was observed in 75.22% of the population: it was mild in 30.81%, moderate in 34.94% and severe in 9.47% (Table 4).

Table 3: Periodontal characteristics (N=581)

Community Periodontal Index (CPI)	n (%)	Plaque Index (PI)	n (%)
Score 0	59 (10.15)	<25%	68 (11.70%)
Score 1	511 (87.95)	25-50%	355 (61.10)
Score 2	11 (1.90)	50-75%	148 (25.47)
Score 3	0	>75%	10 (1.72
Score <2	570 (98.10)	Score ≤50%	423 (72.81)
Score ≥2	11 (1.90)	Score >50%	158 (27.19)

Score 0: No sign of disease; Score 1: Gingival bleeding after gentle probing; Score 2: Teeth with shallow pocket 4 to 5mm deep; Score 3: Teeth with deep pocket 6mm or more.

Table 4: Dental fluorosis distribution (N=581)

Dental fluorosis	n (%)
0 = No fluorosis	144 (24.78)
1 = Mild fluorosis	179 (30.81)
2 = Moderate fluorosis	203 (34.94)
3 = Severe fluorosis	55 (9.47)
Fluorosis Mean (SD)	1.29 (0.944)

No fluorosis (value 0)= score of 0 on the Thylstrup-Fejerskov(TF) Index
Mild fluorosis (1)= score of 1-3 on the Thylstrup-Fejerskov (TF) Index
Moderate fluorosis (2)= score of 4-5 on the Thylstrup-Fejerskov (TF) Index
Severe fluorosis (3)= score of 6-9 on the Thylstrup-Fejerskov (TF) Index

Regarding the prevalence of tooth decay and dental treatment needs (the DMF score), table 5 shows the distribution of decayed, missing and filled teeth and the percentage of individuals affected by the different pathologies.

The DMF scores indicated the following rates of pathology: zero (value = 0) in 54.56%, mild (value = 1-2) in 30.98% and moderate/high (value> 2) in 14.46% (Table 5).

Table 5: Dental characteristics of the study participants (N=581)

Criteria Index	n (%)	Criteria Index	n (%)
D (Decayed)		**DMF score**	
0	347 (59.72)	0	317 (54.56)
1	98 (16.87)	1	103 (17.73)
2	66 (11.36)	2	77 (13.25)
3	29 (4.99)	3	31 (5.34)
4	22 (3.79)	4	26 (4.48)
5	8 (1.38)	5	12 (2.07)
6	7 (1.20)	6	7 (1.20)
8	2 (0.34)	7	3 (0.52)
9	2 (0.34)	8	2 (0.34)
M (Missing)		9	1 (0.17)
0	552 (95.01)	10	1 (0.17)
1	22 (3.79)	13	1 (0.17)
2	5 (0.86)		
4	1 (0.17)		
5	1 (0.17)		
F (Filled)		**DMF score**	
0	563 (96.90)	0 (No pathology)	317 (54.56)
1	13 (2.24)	1-2	180 (30.98)
2	1 (0.17)	>2	84 (14.46)
3	2 (0.34)		
4	1 (0.17)		
5	1 (0.17)	**DMF** Mean (SD)	1.147 (1.666)

D: decayed; M: missing; F: filled; DMF: overall decayed, missing, and filled

Overall, our sample presented a DMF pathology rate per patient of 1.147. Both the overall DMF pathology rate and the rates for the individual D, M, and F values increased in line with the severity of fluorosis (Table 6). The index of restoration (IR%) of the study population was only 4.8%.

Table 6: Patient pathology rates (Decayed (D), Missing (M), Filled (F) and Overall DMF)

	No Fluorosis n=144	Mild Fluorosis n=179	Moderate Fluorosis n=203	Severe Fluorosis n=55
Decay (n)	71	153	210	87
Rate D/Patient	0.49	0.85	1.03	1.58
Missing (n)	12	7	15	7
Rate M/Patient	0.08	0.04	0.07	0.13
Filled (n)	2	5	11	12
Rate F/Patient	0.01	0.02	0.05	0.22
DMF (n)	85	165	236	106
Rate DMF/Patient	0.590	0.921	1.16	1.92

D: decay; M: missing; F: filled; DMF: overall decayed, missing, and filled; Pat: patients.

With regard to the accumulated distribution of the DMF score according to individuals and teeth affected, 83.52% of dental pathology was recorded in 27.67% of the school children examined (Table 7).

Factors such as age, Plaque Index (PI), CPI, and DMF score were significantly associated with dental fluorosis ($p<0.05$). However, there was no significant association between dental fluorosis and gender ($\chi2$; $p>0.05$) (Table 8).

Table 7: Accumulated percentages of DMF scores, according to patients and teeth affected.

		Patients			Teeth DMF	
DMF	n	%	Accumulated %	n	%	Accumulated %
13	1	0.17	0.17	13	2.08	2.08
12	0	0	0.17	0	0	2.08
11	0	0	0.17	0	0	2.08
10	1	0.17	0.34	10	1.60	3.68
9	1	0.17	0.51	9	1.44	5.12
8	2	0.34	0.85	16	2.56	7.68
7	3	0.51	1.36	21	3.36	11.04
6	7	1.20	2.56	42	6.72	17.76
5	12	2.06	4.62	60	9.60	27.36
4	26	4.47	9.09	104	16.64	44.0
3	31	5.33	14.42	93	14.38	58.88
2	77	13.25	27.67	154	24.64	83.52
1	103	17.73	45.40	103	16.48	100
0	317	54.60	100	0	0	100
Total	581	100		625	100	

Table 8: Factors associated with fluoride concentration (N=581)

	Total	No Fluorosis	Mild Fluorosis	Moderate Fluorosis	Severe Fluorosis	p- values*
Age						
≤15	267	56 (20.97)	92 (34.36)	104 (38.95)	15 (5.62)	0.002*
>15	314	88 (28.03)	87 (27.71)	99 (31.53)	40 (12.74)	
Gender						
Female	283	67 (23.67)	93 (32.86)	95 (33.57)	28 (9.89)	
Male	298	77 (25.84)	86 (28.86)	108 (36.24)	27 (9.06)	0.698*
CPI						
Score ≤2	570	142 (24.91)	170 (29.83)	203 (35.61)	55 (9.65)	0.044*
Score >2	11	2 (18.18)	9 (81.82)	0 (0)	0 (0)	
Plaque Index (PI)						
Score ≤50%	423	112 (26.48)	140 (33.10)	140 (33.10)	31 (7.33)	0.004*
Score >50%	158	32 (20.25)	39 (24.68)	63 (39.87)	24 (15.19)	
DMF score						
0 (No pathology)	317	97 (30.60)	97 (30.60)	99 (31.23)	24 (7.57)	
1-2	180	36 (20.00)	61 (33.89)	68 (37.78)	15 (8.33)	<0.001*
>2	84	11 (13.10)	21 (25.00)	36 (42.86)	16 (19.05)	

*p≤0.05 (Chi-square tests).

The association between missing, filled and overall DMF and dental fluorosis is shown in Table 9. There was a statistically significant association between fluorosis and decayed, missing, filled scores and overall DMF ($p<0.05$). The results showed that groups with more severe degrees of fluorosis had higher rates of dental pathology (Table 9). There was no significant association between dental pathology (DMF score) and the age of the study population ($p=0.876$) (Table 10).

Table 9: Dental pathology and dental fluorosis

	Total	No Fluorosis	Mild Fluorosis	Moderate Fluorosis	Severe Fluorosis	p-values*
D (Decayed)						
0	347 (59.72)	105 (72.92)	105 (58.66)	110 (54.19)	27 (49.09)	
1	98 (16.87)	20 (13.89)	32 (17.88)	37 (18.23)	9 (16.36)	
2	66 (11.36)	11 (7.64)	24 (13.41)	26 (12.81)	5 (9.09)	
3	29 (4.99)	4 (2.78)	7 (3.91)	13 (6.40)	5 (9.09)	<0.001*
4	22 (3.79)	3 (2.08)	7 (3.91)	10 (4.93)	2 (3.64)	
5	8 (1.38)	1 (0.69)	0 (0)	3 (1.48)	4 (7.27)	
6	7 (1.20)	0 (0)	4 (2.23)	3 (1.48)	0 (0)	
8	2 (0.34)	0 (0)	0 (0)	0 (0)	2 (3.64)	
9	2 (0.34)	0 (0)	0 (0)	1 (0.49)	1 (1.82)	
M (Missing)						
0	552 (95.01)	138 (95.83)	173 (96.65)	192 (94.58)	49 (89.09)	
1	22 (3.79)	2 (1.39)	5 (2.79)	10 (4.93)	5 (9.09)	0.033*
2	5 (0.86)	3 (2.08)	1 (0.56)	0 (0)	1 (1.82)	
4	1 (0.17)	1 (0.69)	0 (0)	0 (0)	0 (0)	
5	1 (0.17)	0 (0)	0 (0)	1 (0.49)	0 (0)	
F (Filled)						
0	563 (96.90)	142 (98.61)	174 (97.21)	197 (97.04)	50 (90.91)	
1	13 (2.24)	2 (1.39)	5 (2.79)	4 (1.97)	2 (3.64)	
2	1 (0.17)	0 (0)	0 (0)	1 (0.49)	0 (0)	0.044*
3	2 (0.34)	0 (0)	0 (0)	0 (0)	2 (3.64)	
4	1 (0.17)	0 (0)	0 (0)	0 (0)	1 (1.82)	
5	1 (0.17)	0 (0)	0 (0)	1 (0.49)	0 (0)	
DMF						
0	317 (54.56)	97 (67.36)	97 (54.19)	99 (48.77)	24 (43.64)	
1	103 (17.73)	20 (13.89)	35 (19.55)	41 (20.20)	7 (12.73)	
2	77 (13.25)	16 (11.11)	26 (14.53)	27 (13.30)	8 (14.55)	
3	31 (5.34)	4 (2.78)	8 (4.47)	15 (7.39)	4 (7.27)	
4	26 (4.48)	6 (4.17)	8 (4.47)	9 (4.43)	3 (5.45)	
5	12 (2.07)	1 (0.69)	1 (0.56)	7 (3.45)	3 (5.45)	0.001*
6	7 (1.20)	0 (0)	3 (1.68)	2 (0.99)	2 (3.64)	
7	3 (0.52)	0 (0)	1 (0.56)	1 (0.49)	1 (1.82)	
8	2 (0.34)	0 (0)	0 (0)	0 (0)	2 (3.64)	
9	1 (0.17)	0 (0)	0 (0)	1 (0.49)	0 (0)	
10	1 (0.17)	0 (0)	0 (0)	1 (0.49)	0 (0)	
13	1 (0.17)	0 (0)	0 (0)	0 (0)	1 (1.82)	

*$p \leq 0.05$ (Chi-square tests).

Table 10: Dental pathology and population age (N=581)

Criterion Index DMF index score	Total	≤15 years	>15 years	p-value*
0	317	147 (46.37)	170 (53.63)	
1	103	43 (41.75)	60 (58.25)	
2	77	40 (51.95)	37 (48.05)	
3	31	15 (48.39)	16 (51.61)	
4	26	12 (46.15)	14 (53.85)	
5	12	5 (41.67)	7 (58.33)	
6	7	2 (28.57)	5 (71.43)	0.876
7	3	2 (66.67)	1 (33.33)	
8	2	1 (50.00)	1 (50.00)	
9	1	0 (0)	1 (100)	
10	1	0 (0)	1 (100)	
11	0	0 (0)	0 (0)	
12	0	0 (0)	0 (0)	
13	1	0 (0)	1 (100)	

*$p≤0.05$ (Chi-square tests); Criterion index: DMF index score

Discussion

Fluoride may be consumed via drinking water, or via food and oral hygiene products. Interestingly, some studies carried out in Northern Tanzania have reported similar prevalence and severity of dental fluorosis in areas with substantially different concentrations of fluoride in drinking water, (e.g. Kibosho 0.2 mg/l versus Arusha 3.6 mg/l). Various studies have reported similar effects in populations that use "magadi", a potash (trona) salt, to cook certain foods.[37-41]

In order to be able to relate fluorosis and tooth decay, it is important to establish the effects of the fluoride ion on dental tissues (Figure 1). Fluoride participates in many aspects of the formation of calcium phosphate and has notable effects on the process, nature and properties of the mineral tissue formed. It is well known that fluoride reduces the volume of the crystal and increases the structural stability.[42]
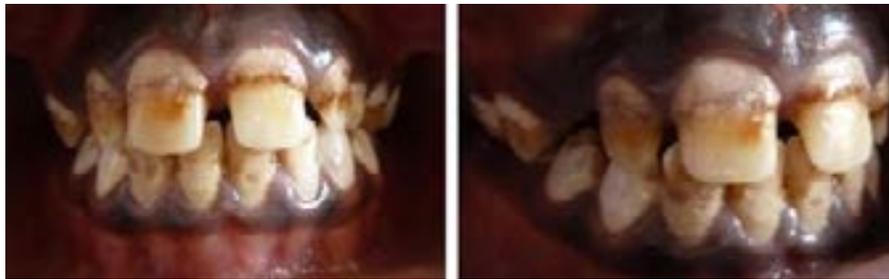

Figure 1. Severe dental fluorosis: In the enamel surfaces note the roughness, spots, and plaque accumulation.

In the process of enamel mineralization during amelogenesis, the fluoride ions are incorporated into the mineralized enamel, reducing its solubility as well as improving the interaction of the mineral-protein matrix. In contrast, an excess of fluoride leads to a defective formation of the enamel, thus slowing the maturation of the tissue.[43]

The critical period for the development of dental fluorosis in permanent dentition is the first six years of life. Many studies have assessed the prevalence of tooth decay both in populations that present high levels of fluorine and in others that present lower levels.[15-23] In 1994, a World Health Organization Expert Committee published

a consensus report on the role of fluoride in the promotion of oral health all over the world.[44]

Assessing the prevalence of caries in schoolchildren living in areas with different levels of fluoride, Sukhabogi et al.[17] observed the highest prevalence in the group in the low fluoride area, followed by the groups in the high and very high area. The lowest rates of decay were found in the medium fluoride area. Thus, an excess of fluoride related to severe dental fluorosis increases the risk of decay. However, Shanthi et al.[18] observed a higher prevalence of caries in population groups with suboptimal fluorine levels. Aimée et al.[19] conclude in their study that combined fluoride exposure through fluoridated water, food cooked with fluoridated water and twice daily brushing with conventional fluoride-containing toothpaste from an early age are recommended to control the progression of tooth decay.

Most cases of fluorosis are mild and tend to cause minimal aesthetic compromise, although in certain areas severe cases may be recorded. Discussing the rising prevalence of fluorosis over the past 50 years, Rozier et al,[20] conclude that the benefits of fluoride during the critical phases of enamel development outweigh the risks. Jackson et al.[21] reported that during the period of enamel formation fluorine concentrations of 1ppm in drinking water, or even lower, may cause mild fluorosis. However, infants who drink water with fluoride levels of 1 ppm present protection against decay compared to those who drink water with fluoride levels practically zero. The authors concluded that although mild fluorosis may cause slight aesthetic effects, the protective role of fluoride against caries should prevail.

Similarly, Molina-Frechero et al.[22] argue that exposure to different sources of fluoride is a risk factor for the development of fluorosis and a benefit for dental caries, and Iida & Kumar [23] observed that molars with fluorosis were more resistant to caries than those without. In contrast, our research shows that patients with more severe fluorosis present the highest rates of decayed, missing and filled teeth. Our study suggests that only mild fluorosis provides a certain protective effect against caries. Indeed, in areas with very high concentrations of fluorine, Sukhabogi et al.[17] observed a high prevalence of caries.

Finally, comparison of the index of restoration (IR%) in this school age population in Tanzania (4.8%) and in an equivalent population from southern Europe (67%) indicates the great difficulty patients in developing countries in obtaining dental treatment.[45]

Fluoride produces effects on bone tissue that can lead to skeletal fluorosis. The main sign of this metabolic alteration is osteosclerosis, mainly affecting the joints. The result is usually ligament calcification accompanied by osteopenia, osteoporosis and osteomalacia of varying degrees of severity.[46,47]

Skeletal fluorosis usually presents in individuals with a daily fluoride intake of 36-54 mg for at least 10 years.[46,48] Few studies have investigated the relationship between periodontal disease and fluoride intake. A lower prevalence of shallow pockets has been observed in study populations where the concentration of fluoride in drinking water ranged from 1.83 to 2.01 ppm, leading to the conclusion that fluoride in water was beneficial for periodontal tissues.[24,25] Similarly, Anurada et al. (2002) observed that increasing the concentration of fluoride reduced the prevalence of periodontal disease.[49] For their part, Megalamanegowdru (2012) reported that the severity of periodontal disease was inversely related to the fluoride concentration in drinking water.[50] However, Vandana & Reddyobserved (2007) observed that increasing the degree of fluorosis also increased the prevalence of periodontitis.[24] In our study, we found higher Plaque Index scores and a higher prevalence of bleeding on probing in patients with moderate fluorosis; this may be related with the development of rougher and more retentive dental surfaces when these teeth are affected by fluorosis. According to the CPI, periodontal pockets are not recorded in individuals younger than 15 years of age,[34] but in our group some students were above this threshold and so finally we decided to record these data.

Our study provides a description of the type of dental occlusion in the child and adolescent population in this area of Tanzania. Almost all the school children evaluated (96.73%) presented Angle class I dental occlusion. We have not found any previous studies of the dental relationship of the maxillary and mandibular arches in this country. In one study in the Nigerian population, some authors observed a predominance of Angle class II and III malocclusions with respect to type I.[51] In contrast, in another Nigerian population a predominance of Angle class I occlusion was observed.[52] Other studies have examined the differences between ethnic groups with re-

gard to craniofacial measurements and angles, which help to describe facial morphology.[53]

This study was part of an oral health project, which was previously evaluated and approved by the authorities of Arusha city council. In addition to the clinical examination of the students, we gave lectures/seminars to the entire school community, including teachers and administrative staff. The main themes of this oral education program were dental plaque, caries, periodontal disease, and oral hygiene instructions. We also provided dental hygiene material for conducting practical workshops in small groups. Finally, for each participant we wrote a report indicating his/her diagnostic and therapeutic needs. In these areas with high rates of fluorosis, economical strategies for reducing the level of fluoride in drinking water should be promoted. At present the only way to minimize endemic fluorosis is to use bottled water, even for cooking, and this represents a huge cost for families of low socio-economic status. It would be useful to assess the feasibility of innovative systems incorporating the use of osmosis membranes to facilitate the purification of water for household use.

Conclusion

In this broad population sample, both decay and gingivitis were associated with moderate/severe dental fluorosis. The introduction of oral education programs in schools may be an appropriate strategy for improving dental hygiene among the young and for reducing the incidence of future oral pathologies.

Author contributions

JMR and LBL conceived the ideas; OM and EIM collected the data; JMR, LBL, EIM, MJM, and ELS analysed the data; all the authors read and approved the final version of the manuscript.

Abbreviations

PI: Plaque Index; CPI: Community Periodontal Index; DMF Decayed, Missing, Filled Index; TF: Thylstrup-Fejerskov Index; (IR%): Index of Restoration; WHO: World Health Organization; SD: Standard Deviation.

Ethical considerations

Our study was reviewed and approved by the Arusha City Council prior to its commencement. Ethical clearance certificate, Ref. No. CD / E.10/39/131, was obtained from the Arusha Health and Ethics Committee. Written consent was obtained from all participants prior to oral diagnosis and interviews, after a full explanation of the study objectives. Confidentiality and privacy were guaranteed according to the birth registry protocol. All the parents/legal guardians of the participants were informed of the nature of the study and provided signed informed consent in advance. Hence our research was conducted in full accordance with the World Medical Association Declaration of Helsinki.

Conflicts of interest

The authors have no conflicts of interest to declare.

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