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Systematic Review Article

Prevalence of dental caries and fluoride concentration of drinking water: A systematic review

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ABSTRACT

Background: The objective of this study was to systematically review prevalence of dental caries at different water fluoride levels and emphasize fluoride concentration of drinking water and prevalence of dental caries.

Materials and Methods: A comprehensive study was conducted using PubMed database. Inclusion criteria were predefined and some articles fulfilled these criteria. Study validity was assessed by some checklists. Surveys were conducted to determine prevalence of dental caries among individuals.

Results: The heterogeneity in the group of children with deciduous teeth in terms of the amount of fluoride in drinking water and social class was significant, and the results of the studies in all the subgroups could not be pooled. However, the heterogeneity of group 2 for subjects with permanent teeth in terms of the fluoride level in drinking water and social class was not significant, and the results of the studies in each subgroup could be pooled together.

Conclusion: The meta-regression showed that tooth type and social class had a significant association with the difference in the prevalence of dental caries. Therefore, these variables were the sources of heterogeneity, and the studies must be grouped and subgrouped based on these variables.

Key Words: Dental caries, fluoride, review, systematic, water

INTRODUCTION

Many studies have been conducted to explain the effects of water fluoridation in adults.[1] In an Australian National Survey of Adult Oral Health, the researchers investigated the effect of fluoridating drinking water on dental caries. The results showed that caries-preventive effects of water fluoridation were at least as great in adults born before fluoridation as after it.[2]

Broffitt *et al.* assessed caries incidence and risk factors for young adolescents at approximate ages of 9 and 13 years, and the results indicated that incidence of dental caries was low except for the occlusal surfaces of first molars.[3] In another study, a cross-sectional study was conducted in Vadodara District, in which 6 out of the 261 villages with high fluoride levels and 5 out of 1490 ones with normal fluoride levels in drinking water were selected. The results showed that the risk of dental fluorosis was higher in areas with high fluoride content in drinking

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water, but the rate of dental caries was low in the same area.[4] Another survey was conducted in 1989 to assess the effect of water fluoridation on reducing dental caries in the United States, Australia, Britain, Canada, Ireland, and New Zealand.[5] Griffin *et al.* reviewed the effectiveness of fluoride in preventing dental caries in adults.[6]

The rationale for this review is that although two relevant systematic reviews on water fluoridation and dental carries have been conducted so far by McDonagh *et al.* in 2000 (reviewing the safety and efficacy of fluoridation of drinking water)[7] and another by the Australian National Health and Medical Research Center in 2007 (reviewing the efficacy and safety of water fluoridation),[8] there is a lack of complete analysis and recently published articles have been missed in previous studies. In fact, what is already known is that there is a relation between the prevalence of dental caries and fluoride concentration of drinking water. However, this relation needs to be studied in a more comprehensive approach. In this regard, the current study takes a closer look in order to provide a broader view over the previous researches through a systematic review, considering all the effective confounders.

MATERIALS AND METHODS

Search strategy
The MEDLINE database was used in this research. The time scope covered the starting date of the database to December 2014. Further searches were carried out through bibliographies of the included studies and also previous systematic reviews, especially the studies by McDonagh *et al.*, hand-searched Index Medicus (from 1945 to 1963) and Excerpta Medica (from 1955 to 1973).

The full electronic search strategy for PubMed database included the following:
- Dental caries (Mesh), 37,309 records
- Dental caries, 49,043 records
- #1 or #2, 49,043 records
- Water (title/abstract), 530,698 records
- Drinking water (Mesh), 2575 records
- Water supply (Mesh), 28,670 records
- #4 or #5 or #6, 537451 records
- Fluorin* (title/abstract), 6 records
- Fluorin* (title/abstract), 17,703 records
- Flurid* (title/abstract), 157 records
- Fluorid* (title/abstract), 37,624 records

- Fluorine (Mesh), 6996 records
- Fluorides (Mesh), 31,459 records
- Fluoridation (Mesh), 5437 records
- #8 or #9 or #10 or #11 or #12 or #13 or #14, 69,990 records
- #3 and #7 and #15, 2367 records.

Inclusion criteria
The inclusion criteria considered in this study were related to dental caries and fluoride levels in drinking water. The following criteria were considered for studies: (1) being an original study, (2) studying humans, (3) being related to fluoride in drinking water supplies and dental caries, (4) at least one group of individuals being included in the study, and (5) reporting measurable outcomes in a group accompanied by the amount of fluoride in its drinking water supply.

Data extraction and assessment of study validity
The inclusion criteria were examined by at least two reviewers. The reviewers independently extracted data from the studies and assessed their validity. Furthermore, the third reviewer checked the results. The validity was assessed based on the STROBE checklist adapted for cross-sectional study designs and the checklist of Centre for Evidence-based Social Service adapted for before–after study designs.

Outcome measures
The number of teeth becoming decayed, missing, and filled (DMFT) was used to classify dental caries. Dental caries was defined in this review as any level more than 0 on DMFT. In addition, a meta-analysis was conducted for obtaining summary measure with 95% confidence interval (CI) using Stata/SE 11.1 (Stata Corp LP, College Station, TX 77845, USA). Random effect models were employed for reporting the results.[9]

Heterogeneity
The inconsistency was examined using the χ^2 test at a significance level of 10%. In addition, heterogeneity was quantified across studies using I^2 statistic.[10] The difference between the study variance was analyzed based on τ^2 statistic.[11]

Analysis
Measures of effect were plotted (95% CIs) if the data were in the right format. The heterogeneity was assessed based on visual examination of plots and χ^2 statistic. Meta-regression was carried out for significant heterogeneity.[12]

In addition, random effects models were used for combining the results. Furthermore, meta-regression was used for identifying the impact of study characteristics on the outcome for explaining any heterogeneity between studies. Data analyses were conducted with Stata/SE 11.1.

RESULTS

Thirteen articles met the inclusion criteria and were included in the study. Three articles that presented dental caries prevalence graphically were excluded from the study. Finally, 10 out of 13 articles, which contained all age groups, were selected. Hence, 10 articles including 56 study areas were reviewed. All the included articles were cross-sectional in design and were of evidence level B (low quality). A diagram showing the stages of a systematic review is presented in Figure 1.

Data categorization and analysis of subgroups were carried out to decrease the impact of confounding factors such as consumption of supplements or materials containing fluoride that can affect the relation between the fluoride levels in drinking water and dental caries.
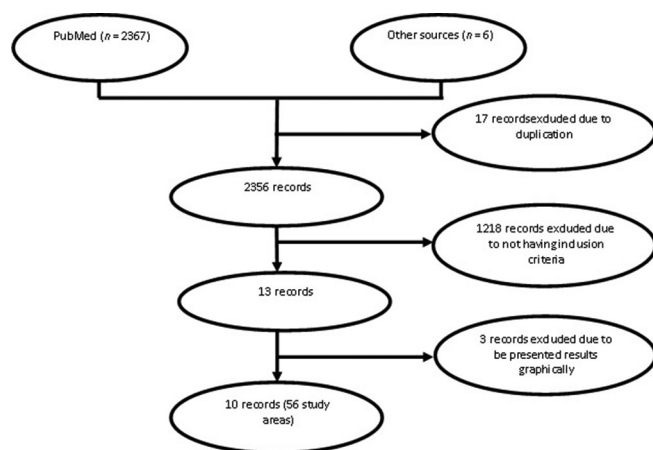

Figure 1: Process of inclusion of studies for review and analysis.

According to dentists and epidemiologists, age is considered as the most significant variable in dental caries. Hence, categorization was firstly based on age. The second and third significant variables were considered the fluoride level in drinking water and the social level. Other factors such as exposure time to fluoride in drinking water and any exposure to fluoride in supplements, diet, and air might also influence the prevalence of dental caries, but they were not considered because of the lack of studies, not mentioning in most of the studies, and their insignificant role in the social level.

The categorization of variables included tooth type (deciduous and permanent), fluoride in drinking water (<0.7 and >0.7), and social class (high, moderate and low).

Finally, two groups were identified. First, studies were categorized based on tooth type and fluoride level in drinking water. Second, the individuals were categorized based on social level. According to Table 1, in group 1 for the children with temporary teeth based on the amount of fluoride in drinking water and social class, significant heterogeneity ($P < 0.001$) was identified among these studies in subgroups. Therefore, the results of the studies in all the subgroups could not be pooled.

As it is illustrated in Table 2, group 2 consisted of subjects with permanent teeth based on the fluoride level in drinking water and social class; there was no significant heterogeneity among the studies in the subgroups. Therefore, the results of the studies in each subgroup could be pooled together. However, in the same level of fluoride, the prevalence of dental caries in subjects with low social class was higher than those with moderate social class, and the prevalence of dental caries in subjects with low or moderate social class was higher than those with high social class.

Considering the following forest plot, there was no heterogeneity in group 2 for the children with

Table 1: Fluoride level in drinking water and social class; Group 1 for children with temporary teeth

Subgroup number	Fluoride level (ppm)	Social class	Number of studies	I^2* (%)	P**	Pooled estimate of dental caries prevalence (95% CI)
1	<0.7	High	7	97.8	<0.001	55.7% (37.4-73.9)
2	<0.7	Medium	6	98.6	<0.001	65.2% (44.9-85.4)
3	<0.7	Low	6	98.7	<0.001	72.7% (53.9-91.5)
4	>0.7	High	6	97	<0.001	49.1% (36.8-61.4)
5	>0.7	Medium	6	95.2	<0.001	48.6% (38.6-58.7)
6	>0.7	Low	6	84.8	<0.001	50.9% (30.7-58.7)

*I^2 (variation in estimation attributable to heterogeneity), **P value (based on heterogeneity statistics). CI: Confidence interval

permanent teeth, the fluoride level of <0.7 ppm, and high social class (subgroup 1). Therefore, the pooled estimate of dental caries prevalence could be reported. The prevalence of dental caries in this subgroup was 70.6% (95% CI, 66.2%–75.0%) [Figure 2].

Regarding the forest plot below, there was no heterogeneity in group 2 for the children with permanent teeth, and the fluoride level of <0.7 ppm, and moderate social class (subgroup 2). Therefore, the pooled estimate of dental caries prevalence could be reported. The prevalence of dental caries in this subgroup was 76.6% (95% CI, 73.9%–79.3%) [Figure 3].

Considering the forest plot below, there was no heterogeneity in group 2 for children with permanent teeth and the fluoride level of <0.7 ppm, and low

social class (subgroup 3). Therefore, the pooled estimate of dental caries prevalence could be reported. The prevalence of dental caries in this subgroup was 78.9% (95% CI, 77.3%–80.6%) [Figure 4].

Regarding the forest plot below, there was no heterogeneity in group 2 for children with permanent teeth and the fluoride level of >0.7 ppm, and high social class (subgroup 4). Therefore, the pooled estimate of dental caries prevalence could be reported. The prevalence of dental caries in this subgroup was 65.1% (95% CI, 57.7%–72.4%) [Figure 5].

Regarding the forest plot below, there was no heterogeneity in group 2 for the children with permanent teeth, the fluoride level of >0.7 ppm, and moderate social class (subgroup 5). Therefore,
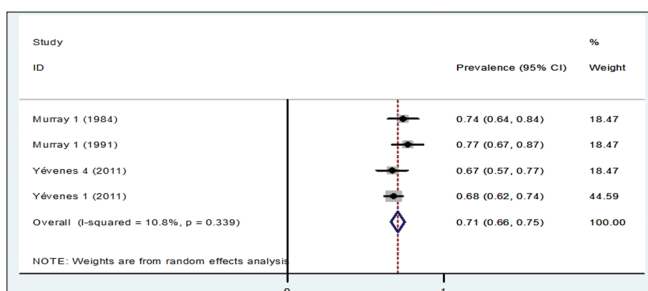

Figure 2: Forest plot of dental caries prevalence for subjects with permanent teeth, a fluoride level of <0.7 ppm in drinking water and high social class (subgroup 1).
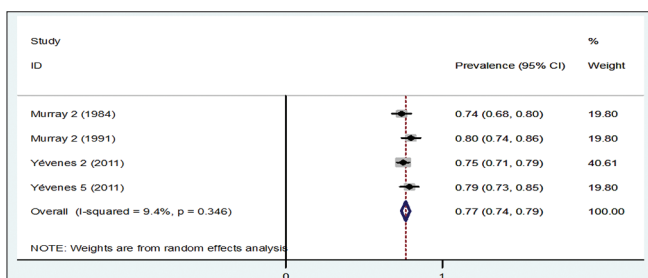

Figure 4: Forest plot of dental caries prevalence for subjects with permanent teeth, a fluoride level of <0.7 ppm in drinking water and low social class (subgroup 3).

Figure 3: Forest plot of dental caries prevalence for subjects with permanent teeth, a fluoride level of <0.7 ppm in drinking water and moderate social class (subgroup 2).
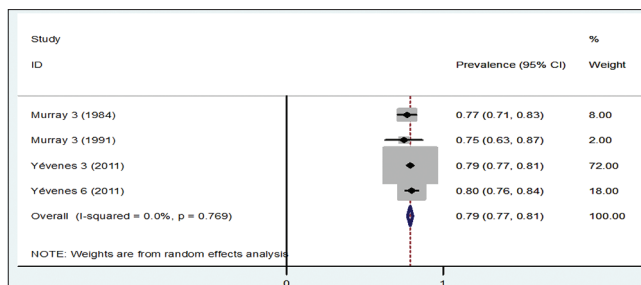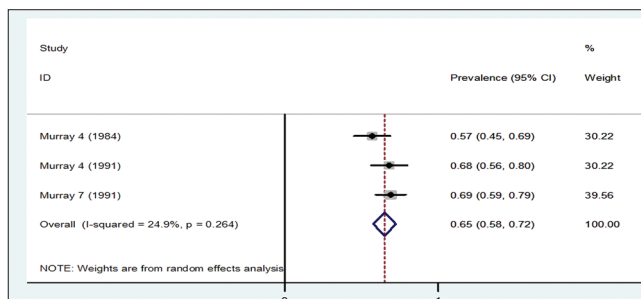

Figure 5: Forest plot of dental caries prevalence for subjects with permanent teeth, a fluoride level of >0.7 ppm in drinking water and high social class (subgroup 4).

Table 2: Fluoride level in drinking water and social class; Group 2 - permanent teeth

Subgroup number	Fluoride level (ppm)	Social class	Number of studies	I^2*(%)	P**	Pooled estimate ofdental caries prevalence (95% CI)
1	<0.7	High	4	10.8	0.339	70.6% (66.2-75.0)
2	<0.7	Medium	4	9.4	0.346	76.6% (73.9-79.3)
3	<0.7	Low	4	0.0	0.769	78.9% (77.3-80.6)
4	>0.7	High	3	24.9	0.264	65.1% (57.7-72.4)
5	>0.7	Medium	3	24.9	0.264	69.1% (64.4-73.9)
6	>0.7	Low	3	26.1	0.258	69.2% (61.4-77.0)

*I^2 (variation in estimation attributable to heterogeneity), **P value (based on heterogeneity statistics). CI: Confidence interval

the pooled estimate of dental caries prevalence could be reported. The prevalence of dental caries in this subgroup was 69.1% (95% CI, 64.4%–73.9%) [Figure 6].

Considering the forest plot below, there is no heterogeneity in group 2 for the children with permanent teeth, the fluoride level of >0.7 ppm, and low social class (subgroup 6). Therefore, the pooled estimate of dental caries prevalence could be reported. The prevalence of dental caries in this subgroup was 69.2% (95% CI, 61.4%–77.0%) [Figure 7].

Meta-regression showed that tooth type and social class had a significant association with the difference in the prevalence of dental caries. These variables
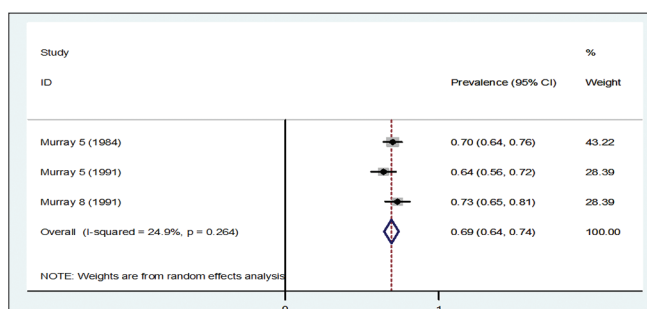

Figure 6: Forest plot of dental caries prevalence for subjects with permanent teeth, a fluoride level of >0.7 ppm in drinking water and moderate social class (subgroup 5).
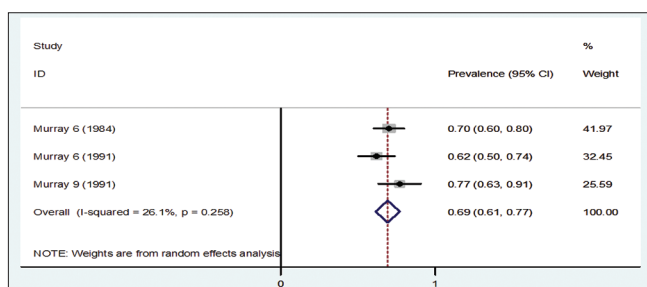

Figure 7: Forest plot of dental caries prevalence for subjects with permanent teeth, a fluoride level of >0.7 ppm in drinking water and low social class (subgroup 6).

were the sources of heterogeneity. As a result, studies must be grouped and subgrouped based on these variables and the analyses must be carried out in the groups [Table 3].

DISCUSSION

Fluoride can be ingested from water supplies, beverages and nutriments, and its intake among individuals depends on food and use of fluoride supplements. In the current study, the variables included tooth type, fluoride in drinking water and social class. In addition, the number of included studies in this review considerably decreased because of considering all the detected confounders.

Analysis of the subgroups and examining the heterogeneity showed that in children in group 1, the heterogeneity among the studies in subgroups was statistically significant ($P < 0.001$). Therefore, the results of studies in the subgroups could not be pooled. However, in group 2, this heterogeneity was not significant, and the results of the studies in each subgroup could be pooled. In the same level of fluoride, the prevalence of dental caries in subjects with low social class was more than that in subjects with moderate social class. The prevalence of dental caries in subjects with low or moderate social class was more than that in subjects with high social class.

CONCLUSION

As it was mentioned earlier, two systematic reviews have been conducted in relation to fluoride concentration of drinking water and prevalence of dental caries. In the systematic review conducted in 2000, McDonagh *et al.* reviewed the safety and efficacy of fluoridation of drinking water through a search in 25 electronic databases and relevant websites. Another review was carried out by the Australian National Health and Medical Research in

Table 3: The results of meta-regression for exploring the source of heterogeneity*

Independent variable	Coefficient	SE	*t*	*P* >|*t*|	95% CI
Permanent teeth	0.15852	0.04195	3.78	0	0.07438-0.24266
Temporary teeth	Reference				
Moderate social class	−0.1549	0.04846	−3.2	0.002	−0.2521-0.05767
Low social class	0.04648	0.04894	0.95	0.347	−0.0517-0.14465
High social class	Reference				
Water fluoride level	0.07504	0.04965	1.51	0.137	−0.0246-0.17463
Constant	0.62007	0.04652	13.33	0	−0.5268-0.71337

*Number of observations=58; τ^2=0.02154; I^2=96.12%; adjusted R^2=29.32%; model F (7,126)=6.41; P>F=0.0003 temporary. SE: Standard error; CI: Confidence interval

Australia in 2007.[7] A lack of complete analysis in terms of inclusion of all the confounding factors is considered one of the most important shortcomings of these systematic reviews. In the current review, researchers tried to address the shortcomings of prior systematic reviews.

The authors suggest an in-depth investigation into the geographical distribution of dental caries prevalence in different regions by considering all the confounding factors for further research in order to provide a wide epidemiological outlook on the problems explained in the current study. Since previous investigations have not focused on extracting a model for the geographical distribution of dental carries in relation to water fluoridation, this model is useful to adopt appropriate policies to decrease dental problems systematically.

As a result, regarding the heterogeneity, the results of studies in group 1 could not be pooled, but the results of studies in group 2 could be pooled together.

Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, and financial or nonfinancial, in this article.

REFERENCES

1. Rugg-Gunn AJ, Do L. Effectiveness of water fluoridation in caries prevention. Community Dent Oral Epidemiol 2012; 40 Suppl 2:55-64.
2. Slade GD, Sanders AE, Do L, Roberts-Thomson K, Spencer AJ. Effects of fluoridated drinking water on dental caries in Australian adults. J Dent Res 2013; 92: 376-82.
3. Broffitt B, Levy SM, Warren J, Cavanaugh JE. Factors associated with surface-level caries incidence in children aged 9 to 13: The Iowa Fluoride Study. J Public Health Dent 2013; 73: 304-10.
4. Kotecha PV, Patel SV, Bhalani KD, Shah D, Shah VS, Mehta KG. Prevalence of dental fluorosis & dental caries in association with high levels of drinking water fluoride content in a district of Gujarat, India. Indian J Med Res 2012; 135: 873-7.
5. Newbrun E. Effectiveness of water fluoridation. J Public Health Dent 1989; 49:279-89.
6. Griffin SO, Regnier E, Griffin PM, Huntley V. Effectiveness of fluoride in preventing caries in adults. J Dent Res 2007; 86: 410-5.
7. McDonagh MS, Whiting PF, Wilson PM, Sutton AJ, Chestnutt I, Cooper J, *et al.* Systematic review of water fluoridation. BMJ 2000; 321: 855-9.
8. National Health and Medical Research Counsel. A systematic review of the efficacy and safety of fluoridation part A: Review methodology and results. Australian Government; 2007. Available from: www.nhmrc.gov.au/publications/synopses/eh41syn.htm
9. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials 1986; 7: 177-88.
10. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003; 327: 557-60.
11. Higgins JP, Green S. Cochrane Handbook for Systematic Reviews of Interventions. New Jersey: Wiley; 2008.
12. Azami-Aghdash S, Ghojazadeh M, Pournaghi Azar F, Naghavi-Behzad M, Mahmoudi M, Jamali Z. Fluoride concentration of drinking waters and prevalence of fluorosis in Iran: A systematic review. J Dent Res Dent Clin Dent Prospects 2013; 7: 1-7.