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Systematic Review

A Systematic Review on Water Fluoride Levels Causing Dental Fluorosis

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Abstract: Dental fluorosis is a long-existing public health issue resulting from inequitable access to potable water. Socially disadvantaged rural communities in fluoride-endemic areas, where a conventional irrigation system is absent and groundwater containing natural fluoride is the predominant source of drinking water, face a significant oral public health threat. This study aimed to determine the association between water fluoride levels and dental fluorosis. A systematic review aligned with PRISMA principles was conducted using the SPIDER search methodology and relevant keywords on many search engines, such as Google Scholar, PubMed, Elsevier, Sage, Web of Science, Cochrane, and Scopus. This review sought to ascertain the PICO model's application as a search strategy tool. The reviewers gathered and assessed 1164 papers from January 2010 to January 2023. In total, 24 research papers from diverse databases were included. Using the Newcastle–Ottawa Scale, grades resulting from several data screens were evaluated. According to a previous systematic review, there may be publication bias in studies examining the association between fluoride in drinking water and dental fluorosis. The findings of this systematic review indicate that subpar fluoride is detrimental to human health. The author outlines legislative tools and technological advancements that might reduce fluoride levels.

Keywords: dental fluorosis; tooth diseases; tooth demineralization; dental caries; fluoride; sustainable drinking water

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1. Introduction

Dental fluorosis is caused by increased ingestion of significant amounts of fluoride during tooth development [1]. This results in enamel that has a reduced mineral content and increased porosity. Fluorosis is a dental condition that may be caused by consuming excessive fluoride in one's diet. A study that was conducted by the World Health Organization (WHO) found that dental fluorosis may affect as many as 70 million people all over the world, with an estimated 60 million of those people residing in the countries of India and China [2]. The process behind dental fluorosis is the replacement of the biological enamel matrix with inorganic material, which leads to hypomineralization in the enamel [3]. Dental fluorosis can cause noticeable color changes in the tooth enamel, but severe cases can lead to discoloration and pitted enamel [1].

Although eating fluoride-contaminated food, drinking fluoride-contaminated water, breathing fluoride-contaminated air, and the excessive use of toothbrushes are all possible routes of exposure, drinking contaminated water is the most common. Food sources with high quantities of fluoride include tea, shellfish, bone meal, spinach, and gelatin [4]. Meanwhile, according to a study, the biggest source of fluoride-contaminated air is coal burning, and the main cause of fluoride-polluted air is the combustion of coal and coal bricks, and these fluorides are easily absorbed by exposed food products and human respiratory tracts [5]. Ingested food contaminated with fluoride is the main cause of significant human fluoride exposure [5]. Fluoride pollution in water occurs due to the decomposition and excretion of minerals from rocks and sediments, whereas water's alkalinity aids in the mobilization of fluoride from fluorite (CaF2) [6]. Other causes of fluoride exposure include the use of toothpaste, smoking of cigarettes, drinking of milk, eating of meals, and consumption of an excessive amount of meat [7].

The most common types of fluorosis are dental, skeletal, and non-skeletal. Dental fluorosis is a common, slowly developing condition that has no known cure and for which there is limited access to healthcare in remote areas [8]. Fluoride in drinking water can negatively affect teeth and the rest of the body, but exposure to it over an extended period can lead to major skeletal difficulties. Fluorosis is characterized by its early start and gastrointestinal symptoms. Early indicators of dental fluorosis include tooth discoloration and small irregularities. Skeletal fluorosis is caused by persistent high-level accumulation and is important to address due to its effects on children and adolescents. Inadequate diet and deficiency in vitamins A and D can also lead to enamel opacities. Rigidity and stiffness in the primary joints affect almost everyone as they age [8].

Only 0.08% of the planet's solid surface comprises fluorine, which ranks thirteenth in terms of its overall abundance [9]. Fluorine is one of the most reactive chemical elements, dissolving easily in water, soil, and air. The fluoride symbol represents compounds with the F-ion [10]. Groundwater may have higher quantities of fluoride than surface water, although this will depend on the underlying geology. In most cases, fluoride concentrations in surface water are typically lower than 1.5 mg/L [9]. Since the late 1940s, when the first experiments on fluoridating public water supplies were carried out in the United States, fluoride has significantly impacted the oral health of millions of people all over the globe. This includes both adults and children [11]. On average, the severity of caries in teeth has decreased by 20–40% [12]. According to the World Health Organization, dental fluorosis is more likely to occur at fluoride concentrations in drinking water greater than 1.5 mg/L, whereas skeletal fluorosis is more likely to occur at values greater than 3 mg/L. Both forms of fluorosis are caused by excess fluoride in the body [13]. Skeletal fluorosis may produce a wide range of health issues, some of which, such as bone fractures, might be confused with the symptoms of other diseases [14]. The presence of tooth abnormalities is one of the most common criteria used in the early stages of diagnosing human dental fluorosis [15]. People exposed to fluoride for an extended period often experience symptoms such as weight loss, anorexia, anemia, and cachexia [16]. Excessive fluoride intake has been connected to many health issues, including paralysis, respiratory issues, and low blood pressure [17]. Fluorosis of the tooth enamel is a common condition that may arise during tooth development, affecting mineralization and the structure that ultimately forms [11]. Depending on the severity of an injury, it can cause a range of cosmetic and practical problems [9]. There is a possibility that dental and skeletal fluorosis would affect more than 200 million individuals across more than 25 countries [13]. Beverages, foods, and ways of life that contribute to fluorosis have been identified [18–23]. Examples include smoking tobacco, drinking brick tea, using "Magadi" in the Rift Valley, and burning coal for fuel. Fluoride in drinking water is listed as a major contributing factor in the development of the disorder by the World Health Organization, and another study by Mohanta and Mohanty also supports this idea [13,24].

Fluoride is one of the most important minerals found in groundwater, and can harm human health in high concentrations but is also beneficial at trace levels. The fluoridation of water via artificial means and the widespread use of fluoride toothpaste have significantly reduced the incidence and prevalence of caries. The health of individuals can suffer significantly due to high amounts of fluoride in groundwater. Specifically, individuals who reside in high-fluoride areas can be quickly affected. This can lead to a wide range of health problems due to their exposure to fluoride and its accumulation. Prevention efforts have been abandoned in countries where these substances are present [25]. Fluorosis is a major health hazard, with the great majority of people originating from economically disadvantaged nations in tropical regions affected by it. It can damage teeth and bones [26].

It has been shown that using fluoride that is safe for consumption may decrease the prevalence of dental caries in populations, with the largest effect exhibited in those at the highest risk [27,28]. Therefore, fluoride has been added to public water supply schemes in many countries to raise the concentration of fluoride ions to a level that effectively prevents caries; this has been the most successful approach to dealing with wide inequalities in access to oral health care across the population [27]. Fluoride has a long-term impact when used in fluoride toothpaste, and other topical fluoride treatments come into close contact with the tooth surface [29]. It has been found to prevent demineralization and promote remineralization by speeding up the growth of fluorapatite ions on demineralized sub-surface crystals [30].

This report summarizes the previous fourteen years' research on the link between ingesting fluoridated water and the development of dental fluorosis. To broaden the scope of the evaluation, we analyzed studies from different epidemiological regions and compared studies published between 2010 and 2017 to studies published in the last five years, i.e., 2018–2023.

2. Materials and Methods

This systematic review was conducted using the PRISMA 2020 criteria and checklist [31]. The selection, assessment, and data extraction of studies were performed separately by two reviewers. By consensus, we settled disagreements in our reviews. Also, as shown in Table 1, we used the SPIDER framework [32] to choose which studies would be included in our systematic qualitative reviews. The overall research design is displayed in Figure 1.

Table 1. SPIDER framework.

Sample	**Adults, Children, Global**
Phenomenon of Interest	Effect of fluoride intake
Design	Review of already-published articles using search engines
Evaluation	Dental fluorosis
Research Type	Case report; controlled study; cohort, retrospective, longitudinal, and qualitative analyses

Search Strategy

Different keywords were used in different databases, such as fluoride-containing liquid, dental fluorosis, teeth malformation, and fluoridated water; some were searched in Google scholar, while others were searched in Scopus, PubMed, Cochrane, and Web of Science. Abstracts and titles were matched to identify duplication. Duplicate articles were not eliminated until the final review and availability check. PICO was used as a search strategy tool in different databases, as can be seen in Tables 2 and 3.

Table 2. Search strategy.

No.	**Search Strategy (PICO—Population Intervention Comparison Outcomes)**
1	Water (tw) OR dihydrogen oxide (tw) water based (tw) liquid (tw) OR liquid (tw) OR liquid with fluoride* (tw) OR fluoride containing liquid* (tw) OR well water* (tw) tap water* (tw) OR drinking water* (tw) OR fluoridated water* (tw) OR fluoridation* (tw) OR teeth malformation* (tw) OR dental fluorosis (tw) OR fluoride level (tw) OR fluoridated meals* (tw) OR tooth decay.
2	Water (Abstract and Keywords) OR liquid (Abstract and Keywords) OR fluoride containing liquid*(Abstract and Keywords) OR well water*(Abstract and Keywords) tap water*(Abstract and Keywords) OR drinking water*(Abstract and Keywords) OR fluoridated water*(Abstract and Keywords) OR fluoridation*(Abstract and Keywords) OR teeth malformation*(Abstract and Keywords) OR dental fluorosis (Abstract and Keywords) OR fluoride level (Abstract and Keywords)
3	Water (tw) OR liquid (tw) OR liquid with fluoride* (tw) OR fluoride containing liquid*(tw) OR well water* (tw) tap water* (tw) OR drinking water* (tw) OR fluoridated water* (tw) OR fluoridation* (tw) OR teeth malformation* (tw) OR dental fluorosis (tw) OR Fluoride level (tw)

Table 3. PICO model.

PICO	Search Strategy
Population	Adults, teenagers, malnourished, infants
Intervention	Acceptable levels of fluoride ions (0.6 mg/L) in drinking water, breastfeeding for newborns and young children, and use of fluoridated water
Comparison	Fluoride water, water supply, tap water, drinking water fluoridation, well water, ground water
Outcome	Teeth malformation, dental fluorosis, dental caries, fluoride level

Literature Selection

Databases like Google Scholar, PubMed, Web of Science, Cochrane, and Scopus were utilized to compile the data for this systematic study. Other than these databases, peer-reviewed articles from journals like the *International Dental Journal*, *Ecotoxicology and Environmental safety*, *Gaceta Sanitaria*, etc., on Elsevier were also selected. In order to organize the information, we employed the filtering features of the available search channels. The search strategy for each database was to use mesh terms and free-text keywords that would yield results related to the study question after. Articles published in the decade beginning in January 2018 and ending in January 2023 were analyzed to see the difference in the prevalence and occurrence of dental fluorosis in articles published from 2010 to 2018. Our review focuses on related topics, including fluoride, dental fluorosis, and dental caries. Several more terms were combined: longitudinal, prospective, retrospective, case study, cohort, reviews, and follow-up. The keywords used are shown in Table 3.

Inclusion and Exclusion Criteria

Articles had to meet the following criteria to be included in this review:

- ➢ Recent scientific articles on dental fluorosis were generally accepted.
- ➢ Research published with a high impact factor was considered.
- ➢ Research papers published between 2010 and 2023 in peer-reviewed journals were categorized based on quality within the last 5 years.
- ➢ Further screening of the papers between 2018 and 2023 was performed for better relevance.
- ➢ Articles should focus on fluoride use, dental carries caused by dental fluorosis, and dental fluorosis causes, etiology, mechanisms, prevention, diagnosis, or treatment, addressing etiology, mechanisms, prevention, diagnosis, or treatment.
- ➢ Articles should provide a comprehensive and evidence-based analysis, citing relevant literature, scientific references to support findings, and conclusions.
- ➢ Articles must include original research studies, including experimental, observational, and clinical trials, systematic reviews, meta-analyses, or case–control studies, to provide robust and reliable evidence on dental fluorosis.

The exclusion criteria were followed by considering the points given below:

- ➢ Studies completed prior to the year 2010 were excluded from the evaluation.
- ➢ Data from conference papers or dissertations that reused the same samples as other articles published in peer-reviewed journals were not included.
- ➢ Articles that did not specifically focus on fluoride use, dental fluorosis, related etiology, mechanisms, the prevention of dental fluorosis, diagnosis, or treatment were excluded.
- ➢ Articles that were not published in peer-reviewed journals were excluded.

Research Design

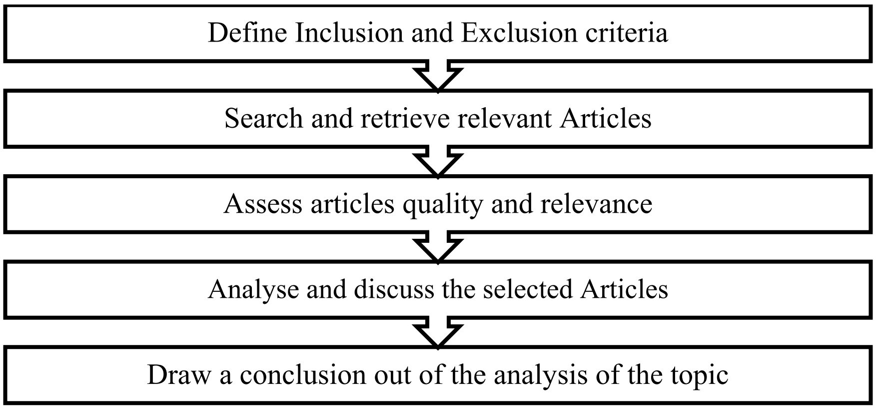

Figure 1. Flow diagram of research design.

Study Selection

There were a total of 1164 papers obtained from included databases (Google Scholar, PubMed, Web of Science, Cochrane, and Scopus), and articles from Elsevier's Journals were also included; out of these, 819 articles were directly searched using keywords from the databases mentioned above, while 345 articles were manually searched by reviewing the reference lists or bibliographies of the initially retrieved articles from the same databases. Following the import of all the articles into Mendeley (Version 1.17.13), any duplicate studies (n = 391) were subsequently deleted from the database. The papers' abstracts and titles were used to categorize them, and as they did not give enough information, 401 of them were removed. A further 300 were removed due to a lack of access to full-text downloads. The entire texts of the publications were retrieved and evaluated to determine whether or not they were eligible. Because of the many barriers to entry and requirements for qualification, articles on animal fluorosis and articles on fluorosis due to soil, air, industrial, and other sources were not included and were never located. This review incorporates a total of 24 publications, as seen in Figure 2. The collection of reviews in this study included 10 reviews from January 2010 to December 2017 and 14 reviews from January 2018 to January 2023.

Quality Assessment

The Newcastle–Ottawa Scale was designed to evaluate the quality of research by Wells and colleagues in 2000 [33]. Specifics about the research groups employed, their comparisons, and the study's findings were given. The reviewers classified the studies as high-, medium-, or poor-quality based on score ranges of 7–9, 3–6, or 1–2, respectively. A perfect score of nine demonstrates that the individual is proficient in all aspects of the process. The assessment procedures employed for each experiment are fully outlined in Tables 4–6.

PRISMA 2020 Flow Diagram.

Table 4. Studies included and their descriptions (2010–2017).

Sr. #	Title	Author	Year	Reference	Country	Sample Age	Description	Score
1	Fluoride in drinking water and dental fluorosis	Mandinic, Z.; Curcic, M.; Antonijevic, B.; Carevic, M.; Mandic, J.; Djukic-Cosic, D.; Lekic, C.P	2010	[34]	Serbia	12 years	Fluoride levels in drinking water were strongly connected to prevalence of dental fluorosis and hair fluoride levels.	9

Table 4. *Cont.*

Sr. #	Title	Author	Year	Reference	Country	Sample Age	Description	Score
2	Fluoride exposure from groundwater as reflected by urinary fluoride and children's dental fluorosis in the Main Ethiopian Rift Valley	Rango, T.; Vengosh, A.; Jeuland, M.; Tekle-Haimanot, R.; Weinthal, E.; Kravchenko, J.; Paul, C.; McCornick, P	2014	[35]	Ethiopia	10–15 years	This study's findings suggest that many children drink water from sources with high fluoride levels, have high fluoride levels in their urine, and suffer significant adverse. consequences to their dental health due to dental fluorosis.	9
3	Relationship between water, urine and serum fluoride and fluorosis in school children of Jhajjar District, Haryana, India	Kumar, S.; Lata, S.; Yadav, J.; Yadav, J	2017	[36]	India	Children	Fluorosis was shown to be correlated with fluoride levels in water, urine, and serum.	9
4	Nutritional status and dental fluorosis among schoolchildren in communities with different drinking water fluoride concentrations in a central region in Mexico	Irigoyen-Camacho, M.; Pérez, A.G.; González, A.M.; Alvarez, R.H	2016	[37]	Mexico	8–12 years	Dental fluorosis in the TFI categories that impact the whole tooth surface was more prevalent in children with low height-for-age.	8
5	Impact of Dental Fluorosis, Socioeconomic Status and Self-Perception in Adolescents Exposed to a High Level of Fluoride in Water	Molina-Frechero, N.; Nevarez-Rascón, M.; Nevarez-Rascón, A.; González-González, R.; Irigoyen-Camacho, M.E.; Sánchez-Pérez, L.; López-Verdin, S.; Bologna-Molina, R	2017	[38]	Mexico	15 years	Self-perceptions of dental fluorosis affected adolescents.	7
6	Groundwater Fluoride and dental fluorosis in Southwestern Nigeria	Gbadebo, A.	2012	[39]	Nigeria	Not specified	Indicated a prevalence of dental fluorosis due to the average person's exposure to fluoride in their drinking water.	9
7	A national cross-sectional Study on the Effects of fluoride-safe Water Supply on the Prevalence of Fluorosis in China	Wang, C.; Gao, Y.; Wang, W.; Zhao, L.; Zhang, W.; Han, H.; Shi, Y.; Yu, G.; Sun, D	2012	[40]	China	Children and adults	This study showed that the incidence of dental and skeletal fluorosis has decreased dramatically due to fluoride-free water supply programs.	9
8	Fluorine in Water and Dental Fluorosis in a Community of Queretaro State Mexico	Juárez-López, M.L.A.; Huízar-Álvarez, R.; Molina-Frechero, N	2011	[41]	Mexico	Children	high incidence of dental fluorosis	9
9	Fluoride Exposure Effects and Dental Fluorosis in Children in Mexico City	Molina-Frechero, N.; Gaona, E.; Angulo, M.; Pérez, L.S.; González, R.G.; Rascón, M.N.; Bologna-Molina, R	2015	[42]	Mexico	10–12 years	Because of the correlation between how often children brushed their teeth and the absence of parental monitoring, dental fluorosis was more common and severe.	9

Table 4. *Cont.*

Sr. #	Title	Author	Year	Reference	Country	Sample Age	Description	Score
10	Soluble fluoride levels in drinking water-a major risk factor for dental fluorosis among children in the Bongo community of Ghana	Firempong, C.; Nsiah, K.; Awunyo-Vitor, D.; Dongsogo, J.	2013	[43]	Ghana	Children	High fluoride levels in the water supply were closely linked to dental fluorosis.	9

Table 5. Studies included and their descriptions (2018–2022).

Sr.#	Title	Author	Year	Reference	Country	Sample	Description	Score
1	Molar-incisor hypomineralization (MIH), dental fluorosis and caries in rural areas with different fluoride levels in the drinking water	Fernandes, I. C., Forte, F. D. S., & Sampaio, F. C	2021	[44]	Brazil	Children	School MIH prevalence and drinking water F-levels were unrelated. Dental fluorosis and MIH severity were linked in areas with moderate-to-high drinking water fluoride levels.	9
2	Associations of low level of fluoride exposure with dental fluorosis among U.S. Children and Adolescents, NHANES 2015–2016	Dong, H., Yang, X., Zhang, S., Wang, X., Guo, C., Zhang, X., Ma, J., Niu, P. and Chen, T	2021	[32]	China	Children and adolescents	Dental fluorosis was linked to exposure to fluoride, whether in the water or the blood.	9
3	Effect of Fluoride Concentration in Drinking Water on Dental Fluorosis in Southwest Saudi Arabia	Das, G., Tirth, V., Arora, S., Algahtani, A., Kafeel, M., Alqarni, A.H.G., Saluja, P., Vij, H., Bavabeedu, S.S. and Tirth, A.	2020	[45]	KSA	9–50 years	The fluoride levels in the bodies of those who drank well water were higher.	9
4	Hydrogeogenic fluoride in groundwater and dental fluorosis in Thai agrarian communities: a prevalence survey and case–control study	Rojanaworarit, C., Claudio, L., Howteerakul, N., Siramahamongkol, A., Ngernthong, P., Kongtip, P., & Woskie, S.	2021	[46]	Thailand	Children	High rates of dental fluorosis were seen in fluoride-endemic regions, where residents drink groundwater laced with naturally occurring fluoride.	9
5	Prevalence of Dental Fluorosis among Southern Jordanian Population	Al Warawreh, A. M., Al Tamimi, Z. H., Al Qatawna, M. I., Al Momani, A. A., Al Mhaidat, M. R., El Naji, W. S., & AlSaraireh, S.	2020	[47]	Jordan	12–52 years	Fluorosis was more prevalent in extremely mild and localized forms among tap-water-drinking individuals.	9
6	Incidence of fluorosis and urinary fluoride concentration is not always positively correlated with drinking water fluoride level	Bhowmik, A. D., Shaw, P., Mondal, P., Munshi, C., Chatterjee, S., Bhattacharya, S., & Chattopadhyay, A.	2019	[48]	India	N/M	As previously reported, high fluoride levels in crops and vegetables cultivated in fluoride-affected regions contributed to fluorosis, but fluoride from other sources also had a significant impact.	9

Table 5. *Cont.*

Sr.#	Title	Author	Year	Reference	Country	Sample	Description	Score
7	Spatial distribution of groundwater fluoride levels and the population at risk for dental caries and dental fluorosis in Sri Lanka	Ranasinghe, N., Kruger, E., & Tennant, M.	2019	[49]	Sri Lanka	N/M	12% of 12-year-olds had dental fluorosis, whereas 81.4% of those in low-fluoride areas had tooth decay. A total of 82.4% of the population lived in low-fluoride zones, whereas 11.2% were at risk of serious health issues from fluoride absorption.	9
8	Occurrence of fluorosis in a population living in a high-fluoride groundwater area: Nakuru area in the Central Kenyan Rift Valley	Gevera, P., Mouri, H., & Maronga, G.	2019	[50]	Kenya	N/M	According to the findings, dental fluorosis was substantially more common in the younger population.	9
9	The cholinergic system, intelligence, and dental fluorosis in school-aged children with low-to-moderate fluoride exposure	Wang, S., Zhao, Q., Li, G., Wang, M., Liu, H., Yu, X., . . . & Wang, A.	2021	[51]	China	Children	Children's cholinergic system impairment was linked to mild-to-moderate fluoride exposure.	9
10	The influence of fluoride in drinking water on the incidence of fluorosis and intelligence of elementary school students in Palu City	Yani, S.I., Seweng, A., Mallongi, A., Nur, R., Abdullah, M.T., Salmah, U., Sirajuddin, S., Basir-Cyio, M. and Anshary, A.,	2021	[52]	Indonesia	6–12 years	Fluorosis was more prevalent in high-F areas, where pupils also had lower IQs than those in low-F areas.	8
11	Factors associated with dental fluorosis among Malaysian children exposed to different fluoride concentrations in the public water supply	Mohd Nor, N.A., Chadwick, B.L., Farnell, D.J. and Chestnutt, I.G.,	2021	[53]	Malaysia	9–12 years	Children born after the fluoride content in the water was altered had a reduced prevalence of fluorosis. Even when the fluoride content in the water was lowered, fluorosis was still a significant concern.	9
12	Assessing Fluorosis Incidence in Areas with Low Fluoride Content in the Drinking Water, Fluorotic Enamel Architecture, and Composition Alterations	Strużycka, I., Olszewska, A., Bogusławska-Kapała, A., Hryhorowicz, S., Kaczmarek-Ryś, M., Grabarek, B. O., . . . & Czajka-Jakubowska, A	2022	[54]	Poland	15–25 years	Among the clinical sample, 89 patients were found to have dental fluorosis of varied degrees (12.8%). Compared to teeth without fluorosis, individuals with mild and severe fluorosis had considerably greater protein (p 0.001) and fluoride levels (p 0.001) in their enamel.	9
13	Brick tea consumption is a risk factor for dental caries and dental fluorosis among 12-year-old Tibetan children in Ganzi	Zhang, R., Cheng, L., Zhang, T., Xu, T., Li, M., Yin, W., Jiang, Q., Yang, Y. and Hu, T.,	2019	[55]	China	12 years	Dental fluorosis and dental caries were more common in children whose mothers drank brick tea regularly. The dental health of children born to mothers who drink less brick tea during pregnancy and breastfeeding may improve.	9

Table 5. *Cont.*

Sr.#	Title	Author	Year	Reference	Country	Sample	Description	Score
14	Effect of fluoridated water on dental caries and fluorosis in schoolchildren who use fluoridated dentifrice	Silva, M. C. C., Lima, C. C. B., Lima, M. D. D. M. D., Moura, L. D. F. A. D. D., Tabchoury, C. P. M., & Moura, M. S. D.	2021	[56]	Brazil	5–12 years	Both the frequency and severity of dental caries were reduced in children and adolescents who drank fluoridated water as opposed to those who used fluoridated toothpaste. Fluorosis, ranging in severity from extremely low to substantial, has been linked to water fluoridation in teenagers.	9

Table 6. The studies included in this systematic review were evaluated for quality.

First Author, Year	Representativeness of the Exposed Variable	Selection of the Un-exposed Variable	Ascertainment of Exposure	The Outcome of Interest Not Present at the Start of the Study	Control for Important Factors or Additional Factors	Outcome Assess-ment	Follow-Up Long Enough for Outcomes to Occur	Adequacy of Follow-Up of Variables	No Response Rate	Total Score
[34]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[35]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[36]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[37]	✓	✓	✓	✓	✓	✓	✓	✘	✘	8
[38]	✓	✓	✓	✓	✓	✘	✓	✘	✘	7
[39]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[40]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[41]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[42]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[43]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[44]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[32]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[45]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[46]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[47]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[48]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[49]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[50]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[51]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[52]	✓	✓	✓	✓	✓	✓	✓	✘	✘	8
[53]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[54]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[55]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9
[56]	✓	✓	✓	✓	✓	✓	✓	✓	✘	9

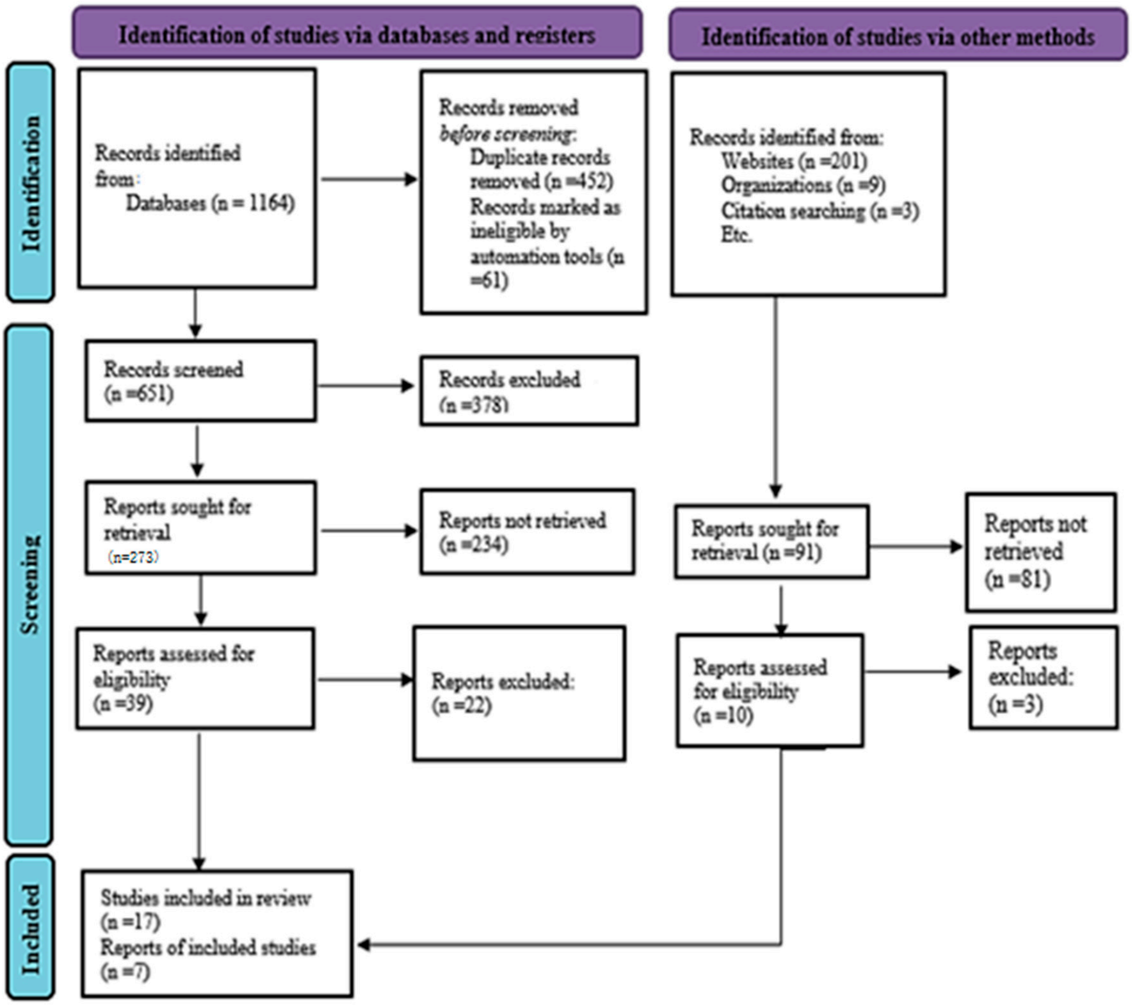

Figure 2. PRISMA 2020 Flow diagram for new systematic reviews, which included searches of databases, registers, and other sources (http://www.prisma-statement.org/ (accessed on 18 January 2023)).

3. Results

This study investigated the occurrence of dental fluorosis from fluoride consumption in liquids. After a brief review of the included studies, a high prevalence rate was reported. Many confounding factors were also seen to contribute to dental fluorosis, such as age, socio-economic status, fluoride-containing sustenance, and breastfeeding history.

The prevalence of dental fluorosis has increased in the past five years, consistent with previous studies. A systematic review of studies from 2010 to 2017 found a correlation between prolonged exposure to high fluoride levels in drinking water and an increased prevalence of dental fluorosis. When fluoride levels exceeded 6 mg/L, dental fluorosis was more common than skeletal and non-skeletal fluorosis. Previous studies also considered factors like climate, altitude, age, gender, and dental caries. The current study explored various parameters, including exposure to time, exposure to fluoride in food and air, and other factors, to investigate their impact on dental fluorosis occurrence. These were reported in almost every published article on the consumption of liquid-carrying fluoride. Most of the included papers reported a high fluoride concentration in the water found on their respective countries' land. Infiltrated water in rural areas caused dental decay in many adults, whereas a high significance of dental fluorosis was seen in children. Studies also reported an immediate response of children's IQ to fluoride consumption. No favorable effect of fluoride was reported on mental health and physical health (bone matrix). Supplementary Materials files can be accessed through the link provided under the sub-heading "Supplementary Materials".

4. Discussion

The prevalence of dental fluorosis reported in the past five years agrees with the prevalence reported before the past five years. As shown in Tables 4 and 5, the studies included in this systematic review from the past five years were [32,44–56]. In comparison, the studies included in this review before the past five years were [34–43]. Research from the past five years, i.e., 2010–2017, was also considered to see the difference in the prevalence of dental fluorosis after fluoride consumption and the factors affecting it. While no distinct difference was seen, regardless of the time difference, confounding evidence of decrements in dental and skeletal fluorosis was recorded as a result of consuming fluorine-free water [40].

Every paper examined in this comprehensive analysis concluded a link between extended exposure to high fluoride levels (greater than 1.5 mg/L) in drinking water and increased dental fluorosis. Wherever the fluoride level in the drinking water exceeded 6 mg/L, there was a statistically significant rise in the prevalence of dental fluorosis, skeletal fluorosis, and non-skeletal fluorosis. On the other hand, when fluoride levels are high (more than or equal to 6 mg/L), dental fluorosis is more common than skeletal fluorosis and non-skeletal fluorosis. In previous studies examining the prevalence of dental fluorosis, climate, altitude, age, gender, and dental caries were all considered factors [34,36,37].

The current study investigated how the occurrence of dental fluorosis was impacted by several parameters, including exposure time, exposure to fluoride in food and air, and more. It has been shown that different ages exhibit different levels of fluoride excretion. Individuals can keep around half of the fluoride in their teeth and bones taken in via their diet. Urination is responsible for eliminating the remaining fifty percent [57].

However, since their systems have a larger necessity for fluoride for development, up to 80% of it is retained in young children and babies [58]. Children may have a lower fluoride excretion rate than teens, which might be why children's plasma fluoride levels are higher than those of teenagers. However, an unexpected study revealed that children had a higher plasma fluoride concentration than teens, despite fluoride levels in children's water supplies being higher than those found in teenagers' water supplies. Even moderate fluoride exposure has been linked, in recent research, to various adverse health effects in children. These effects include neurotoxicity [59–61], sleep disruptions, and alterations in kidney and liver function [62], amongst others. These studies indicate that young children are the population most likely to be exposed to fluoride. Despite this, the technique of fluoridating water ensures that people of all ages drink water with the same amount of fluoride (0.7 mg/L). Because of this, it is essential to ensure that children have access to water that has not been treated with fluoride to lessen the likelihood that they will experience any adverse effects from this material [21,42,43].

Dental fluorosis is common in children aged 8 years and younger, when teeth and body tissues are still developing and mineralizing [63]. This condition makes the enamel more vulnerable to attacks, which may cause tooth discoloration or mottling [46]. According to research, Although fluorosis can damage both primary and permanent teeth, it tends to harm permanent teeth more than primary teeth when fluoride is equally distributed [64]. Studies that looked at the impacts of gender produced conclusions that contradicted each other. Although several studies have concluded that there is no connection between this factor and dental fluorosis, several other studies have discovered large differences between the sexes that do not follow any obvious pattern. Studies [47] have revealed that females are more prone than males to suffer from dental fluorosis, which may be connected to a lack of adequate nutrition in those affected. Hamdan, M (2003)study also revealed that patients who are between the ages of 12 and 20 make up the greatest age group afflicted by fluorosis (59.0 percent of the group; 89.3 percent of all patients with fluorosis) [65]. In addition to the influence on cementocytes and the creation of hypercementosis in the roots, both of which may create problems in scaling and root planning, fluorosis may disrupt the periodontium, either directly or indirectly, via its effects on bacterial adhesion and inflammation [66,67]. Fluorosis may also create problems in scaling and root planning. It is essential to ensure that the body's fluoride levels are as high as possible to keep the gums and teeth in good condition [68].

Table 6 indicates the quality of the selected studies evaluated in this systematic review. The selected studies were assessed using the Newcastle–Ottawa scale. The Newcastle–Ottawa scale, used in statistics, evaluates the quality of non-randomized research included in systematic reviews. Depending on the distribution of scores, the studies were categorized as high-, medium-, or low-quality (7–9, 3–6, or 1–2, respectively). A perfect score of nine indicates that the study is proficient in every area of the procedure.

Greater fluorosis prevalence was linked exclusively to the use of fluoridated toothpaste, the use of toothbrushes, and the use of toothpaste by children before the age of two [53]. The present study indicated that the fluoridation of water was more important than using fluoride toothpaste and other preventive measures. Previous research has established a relationship between the incidence of fluorosis and the use of fluoride toothpaste and other preventative measures. As a result, the possibility exists that the association might be explained by the fact that more children of wealthy parents were exposed to fluoridated water. The debate that has been ongoing for a very long time over whether or not it is better to use water from a well or water from a faucet has been settled by this clear evidence [46].

With acceptable fluoride ions (0.6 mg/L), dental caries may be avoided, and stronger bone mass and teeth may be produced. However, the impact of fluorosis on dental caries when fluoride levels are beyond this limit is unknown. Some authors [55,56] conclude that a lower incidence of dental caries may be predicted in regions where fluorosis is frequent, suggesting that higher fluoride dosages are useful. Some people with severe dental fluorosis also have increased caries, which may be attributed to the loss of protective enamel due to the pitting that occurs in severe fluorosis.

It has been shown that prolonged breastfeeding lowers the incidence of dental fluorosis [69–72], provided that breastfeeding is carried out for an adequate amount of time. According to these findings, there was no correlation between the amount of fluoride consumed by mothers and the quantity of fluoride that was discovered in breast milk [73]. Breastfeeding is suggested for newborns and young children during the first two years of life, corresponding with the period when the enamel is actively growing. This is to reduce the risk of dental fluorosis [71], which may affect the teeth.

5. Conclusions

This systematic review concluded that it is nearly impossible to uncover all the factors contributing to the development of dental fluorosis. However, according to the results of this systematic review, more in-depth research into dental fluorosis is needed to establish a stronger foundation of knowledge in various fields. These results, which suggest the need for more detailed dental fluorosis examinations, may guide future research directions. Research on additional possible factors, such as dietary habits and the regular use of beverages with high fluoride content, such as milk and its derivatives, juices, and the local tea known as Gauwa, is also advised. Finding out whether fluoride causes tooth decay or not might be made easier by this study.

6. Limitations

The number of publications from 2018 to 2023 was relatively lower than that from years before. Well, dams, and tap water cannot be the only factors contributing to the rapid increase in dental fluorosis. With the help of future research, more factors contributing to dental fluorosis can be detected.

7. Future Directions

Technical and socio-economic research support is required for the production of new technologies for the benefit of locals, regardless of whether national or international firms develop these technologies. Technological advancements can be used to lower the amount of fluoride found in drinking water; however, more effective filters cannot be transferred to and implemented in these countries without first gaining an understanding of local drinking water consumption customs and attitudes, as well as preferences regarding the implementation of the new technology.

Even though many governments are aware of the risks that dental fluorosis poses to the health of their citizens, they are not taking sufficient precautions to stop the condition from destroying the lives of millions of people in less developed countries. The difficulty faced by low-income people in fluoridated regions in obtaining clean drinking water contributes to the already high prevalence of dental fluorosis in such locations. Enhanced water management systems effectively solve the difficulties produced by naturally fluoridated water, but they are generally ignored in rural regions where people do not have access to clean water. This is the case despite these systems being an effective remedy. When people in outlying communities are forced to rely on springs and other unreliable water sources due to a lack of infrastructure, the government should fund contemporary social water policy projects to provide clean water to these communities. These projects could include the construction of water treatment facilities or the installation of water distribution networks.

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