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Fluoride in dentifrices: Safe or unsafe?

Mabiaku Y.O [1,*], Mabiaku T.O [2] and Omokhua HA [3]

[1] *Department of Restorative Dentistry, Faculty of Dentistry, College of Health Sciences, Delta State University, Abraka, Delta State, Nigeria.*
[2] *Department of Family Medicine, Faculty of Clinical Sciences, College of Health Sciences, Delta State University, Abraka, Delta State, Nigeria.*
[3] *Department of Restorative Dentistry, School of Dentistry, College of Health Sciences, University of Benin, Nigeria.*

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Abstract

Fluoride-based dentrifices/Toothpaste emerged at the forefront of preventive dentistry in the eighteenth century and have remained relevant over the years. However, as knowledge continuously evolves and expands, the safety of the continued consumption and prophylactic use of fluorides in different formulations has come under deep scrutiny in recent years. Following reports of dental malformations of fluorosis and the potential of skeletal deformations from its toxicity, the net benefit of fluoride in dentrifices used over time deserves an assessment. The review of published scientific literature in this article revealed that the use of toothpaste containing fluoride is beneficial on topical application, provided it is used in strict compliance with evidence-based regulations and recommendations of global health agencies and associations. The review acknowledges the possibility of a negative impact from the excessive consumption of fluoride; however, it highlights the fact that the benefit of using fluoride-containing dentrifices in the prevention of dental caries, particularly in the right volume and the right environment, is more beneficial in preventing dental caries and it substantially outweighs the potential risks.

Keywords: Fluoride; Dentifrices; Toothpaste; Dental caries; Fluorosis

1. Introduction

Fluoride-based dentifrices are regarded as the pillar of preventive dentistry, because it remains the most globally accepted consumer-friendly method of delivering caries prophylaxis agents [1,2]. Brushing twice daily with fluoride-based dentifrice (Toothpaste) is an established global standard for maintaining optimum oral hygiene and for keeping dental caries at bay. However, in recent times, there have been a lot of concerns over the overall safety of the long-term use of dentifrices containing fluoride, particularly among children and their dental development [3]. The focus of this paper, therefore, is to weigh the balance between the historically well-established benefit of " effective remineralization of enamel, against the long-standing reported potential risk of systemic toxicity and developmental enamel defects [4,5].

2. Historical Context and Development

The origin of oral hygiene products began with the production of abrasive non-fluoride formulations designed primarily for the mechanical removal of plaque. Then came the discovery of the clinical anticariogenic properties of fluoride, which transformed the industry completely [3]. The transition from simple abrasive powders to fluoride-enriched pastes signified a paradigm shift in public health, and resulted in the long-term decline in global caries prevalence [6] In the mid-20th century, different regulatory frameworks evolved through organizations such as the American Dental Association (ADA), which established, by rigorous testing criteria, a standard for the safety and efficacy profiles for

* Corresponding author: Mabiaku Y.O

fluoride inclusion in commercial products [7]. Subsequently, fluoride concentrations in consumer dentifrices were restricted internationally to a range of 1000–1450 ppm as the optimum balance for the caries prevention benefit and the lowest point for systemic ingestion risks [7]. Several studies in the 1940s and 1950s reported that fluoridated products resulted in a significant reduction in caries occurrence; hence, dentifrices were no longer regarded as just cosmetic cleaners but as therapeutic medical formulations [8].

2.1. Evolution of Fluoride Toothpaste

Historically, fluoride-containing toothpaste transitioned from the traditional stannous fluoride formulations to the more stable sodium fluoride and monofluorophosphate variations, enhancing bioavailability and clinical efficacy [9,10]. Then further progress was in the stratification of products that were age-specific, with low-concentration formulations specifically designed for the younger population in order to prevent the risk of fluorosis [11]. However, manufacturers still had challenges with the stability and bioavailability of the ionic fluoride in the products, due to chemical degradation that could occur during storage before reaching the consumer [12].

2.2. Mechanisms of Fluoride Action

The biochemical efficacy of fluoride is based on its ability to promote the remineralization of dental enamel while simultaneously inhibiting the metabolic activity of cariogenic bacteria, thus reducing the rate of demineralization [13]. Specifically, fluoride ions substitute into the hydroxyapatite lattice to form fluorapatite, which is a more stable and acid-resistant crystalline structure that resists dissolution in low-pH oral environments compared with the natural hydroxyapatite structure of enamel [13]. Furthermore, fluoride ions inhibit the metabolic activity of cariogenic bacteria by slowing down the production of organic acids that weaken tooth integrity [14]. Also, at the tooth-biofilm interface, fluoride ions accelerate the reintegration of calcium and phosphate into demineralized lesions, thereby restoring the mineral density of the enamel surface [15].

2.3. Topical vs Systemic Action

Topically, fluoride promotes anticariogenic activity through the formation of fluorapatite crystals and by catalyzing the precipitation of calcium and phosphate in the oral fluid. While simultaneously exerting antimicrobial effects on cariogenic bacteria [16]. Furthermore, the therapeutic success of topical applications is strengthened by the formation of calcium fluoride reservoirs, which provide a sustained release of ions at the enamel-plaque interface during acidic challenges [17] On the contrary, systemic exposure to fluoride as it occurs in water fluoridation or dietary intake, particularly during the pre-eruptive development of enamel, directly influences the mineral maturation of teeth in children [18] While this systemic incorporation occurs during amelogenesis, it is distinct from the topical contact provided by dentifrices, which primarily targets existing enamel surfaces to arrest decay [19] Dental fluorosis occurs only during tooth development (from birth to approximately 8 years of age). The underlying mechanisms include: cellular stress from fluoride, which triggers apoptosis (programmed cell death, Protein retention from high levels of fluoride, which delays the hydrolysis and removal of amelogenin, and hypomineralization, which occurs due to the retained proteins disrupting proper crystal formation, hence creating a subsurface porous structure. Staining and Pitting: Abnormally porous enamel is susceptible to absorbing exogenous ions (iron and copper), which causes the characteristic yellow-to-brown staining.

Skeletal fluorosis develops following chronic, long-term exposure to high levels of fluoride (typically ≥ 4 mg/L in drinking water) over 10 to 20 years. This occurs when there is a crystal lattice alteration: Fluoride ions readily substitute for hydroxyl ions in the bone's hydroxyapatite structure, creating a more stable but less flexible crystal lattice (fluorapatite). This incorporation alters normal bone turnover rates, and it inhibits mineralization, leading to brittle, hardened, and less resilient bones. In extreme cases, it causes joint stiffness, ligament calcification, and bone deformation [20].

3. Evidence for Safety and Efficacy

There are clinical and epidemiological data that validates that the regular use of fluoridated toothpaste is associated with a 24% reduction in caries formation in permanent teeth [21]. Supported by over 800 controlled trials, the topical application of fluoride appears to be the most effective prophylactic measure against dental decay [22]. Furthermore, there are longitudinal studies that confirm that fluoride-induced reservoirs, such as calcium fluoride, ensure a sustained release of ions that stabilize the tooth surface against acidic challenges.

3.1. Clinical Trial Evidence

In a randomized controlled trial, fluoride dentifrice significantly reduced caries incidence compared to a placebo, with a dose-response relationship and the best therapeutic efficacy at concentrations of 1000 ppm and above [23]. Some Meta-analyses indicate that daily use of these formulations consistently achieves a 24–44% reduction in caries incidence across diverse populations [24]. These protective benefits are particularly pronounced in children and adolescents, where consistent application supports enamel remineralization and inhibits the activity of cariogenic bacteria [25].

3.2. Population-Level Outcomes

The use of fluoride dentifrice over the last 70 years is widely recognized as the primary factor driving the dramatic decline in dental caries prevalence [26]. Epidemiological studies consistently demonstrate that using fluoride dentrifices is protective to enamel [27]. Similarly, a cohort study has highlighted the additional benefit, particularly for pit and fissure surfaces on permanent first molars [28].

3.3. Potential Risks and Adverse Effects

In spite of the highly appraised therapeutic benefits of fluoride to enamel, there are valid concerns regarding fluoride ingestion, particularly the risk of dental fluorosis caused by chronic overexposure during the critical stages of tooth development [29]. This condition is characterized by insufficient mineralization of the enamel, hypomineralization. The condition manifests as visible opacities or pitting on the tooth surfaces of either deciduous or permanent teeth, especially in early childhood [30] This creates an unpleasant dental aesthetic that could be psychologically disturbing, depending on the severity [31]. Other concerns include the potential to cause systemic challenges such as skeletal fluorosis and neurological defects, particularly from chronic high-level fluoride ingestion in developing populations [32]. This is more likely in young children because they often struggle with controlling the swallowing reflex; hence, they inadvertently ingest dentifrice during the first six years of life when brushing. They therefore would require careful parental supervision to maintain an appropriate risk-benefit balance [33].

3.4. Dental Fluorosis

This is a condition that results from excessive fluoride ingestion during the pre-eruptive mineralization phase of the enamel. It occurs as a result of the disruption in enamel matrix formation and manifests clinically as visible opacities or structural pitting [34]. The severity of hypomineralization is often dose-dependent; hence, utilizing higher fluoride concentrations for children under six must be carefully weighed against the balance of the potential risk to aesthetic and structural integrity [35].

3.5. Systemic Toxicity Concerns

Acute toxicity typically occurs from accidental ingestion of high-dose fluoride and usually presents with nausea or abdominal pain. However, the major clinical concern, particularly in our contemporary times, is the possibility of a resulting systemic harm from chronic ingestion of fluoride from multiple sources, such as toothpaste, water, etc. [36]. However, during the literature search of this article, no scientific literature was found reporting systemic challenges from chronic use of fluoride-containing dentifrice. It is therefore critical to distinguish between clinical challenges of acute accidental high-dose fluoride ingestion and the subsurface hypomineralization in dental fluorosis, which occurs from chronic fluoride ingestion at early stages of life. Dental fluorosis remains the only scientifically established risk linked to chronic fluoride ingestion [37].

4. Risk-Benefit Analysis

The crux of the issue, then, is attaining the healthy balance between accessing the therapeutic benefit of fluoride in enamel while mitigating against the potential hazard of fluoride toxicity. challenge in clinical dentistry remains achieving a therapeutic balance where the potent anticariogenic efficacy of fluoride is maximized while minimizing the risk of developmental dental fluorosis [38].

4.1. Dose-Response Considerations

Optimal clinical management requires calibrating fluoride exposure to match developmental stages, such as acknowledging that children under five years of age may have a limited ability to expectorate, and may result in ingesting a significant quantity [39]. To mitigate these risks, it is recommended that the quantity of dentifrices used should be limited to a smear or pea-sized amount for young children, and that total fluoride intake remains below the threshold for systemic toxicity [40]. It is therefore important that careful considerations be given to procedures

requiring a combined fluoride regimen, particularly for children [41]. Consequently, in managing pediatric dental cases, a personalized approach is recommended, such that the fluoride concentration recommended is adjusted to the child's individual caries risk to minimize potential ingestion [42].

4.2. Vulnerable Populations

Besides children below age three, Pregnant mothers and those with swallowing difficulties require similar monitoring to prevent excessive systemic absorption, to prevent both fluorosis and potential toxicity Vigilant monitoring of total daily fluoride intake from all sources—including fluoridated water, food, and oral hygiene products—is essential for populations at elevated risk, as these cumulative exposures can influence the development of both dental and skeletal fluorosis [43]. Although clinicians must balance these prophylactic advantages against the potential for undesirable outcomes, it remains clear from documentation that serious adverse events are largely associated with acute, high-dose ingestion rather than standard topical regimens [44].

It is therefore paramount that the right knowledge regarding key issues of public health matters be disseminated among stakeholders, such as dental healthcare workers. This brings to the fore the role of continuous medical education(CME'S), as emphasized in a study among dental healthcare workers [45]. Fluoride in dentrifices is currently reported to be one of the most effective, cost-efficient interventions for preventing dental caries, despite the potential possibility of risk from acute toxicity. These risks are largely preventable through appropriate use, particularly among young children. Thus, fluoride toothpaste should be regarded as a highly beneficial preventive agent whose safety depends on proper usage and adherence to recommended guidelines [46].

5. Conclusions

Based on the reviewed scientific literature in this article, the use of fluoride-containing dentifrices\toothpaste is beneficial and safe, provided it's used within the limits of the recommended age-related concentration and the right population.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Martinez-Mier EA, Tenuta LM, Carey CM, Cury JA, van Loveren C, Ekstrand KR, Ganss C, Schulte A, Baig A, Benzian H, Bottenberg P. European Organization for Caries Research Workshop: methodology for determination of potentially available fluoride in toothpastes. Caries research. 2019 Jul 24;53(2):119-36.

[2] Valkenburg C, van der Weijden F, Slot DE. Dentifrices. Part 3: Dentifrice Recommendations. Dental Update. 2024 Apr 2;51(4):251-6.

[3] Zero DT. Dentifrices, mouthwashes, and remineralization/caries arrestment strategies. BMC Oral health. 2006 Jun 15;6(Suppl 1):S9.

[4] Walsh T, Worthington HV, Glenny AM, Appelbe P, Marinho VC, Shi X. Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents. Cochrane database of systematic reviews. 2010(1).

[5] Amaechi BT, AbdulAzees PA, Alshareif DO, Shehata MA, Lima PP, Abdollahi A, Kalkhorani PS, Evans V. Comparative efficacy of a hydroxyapatite and a fluoride toothpaste for prevention and remineralization of dental caries in children. BDJ open. 2019 Dec 9;5(1):18.

[6] Krishna V. (2025) The role of fluoride toothpaste in maintaining human oral health. International Journal of Zoology and Applied Biosciences, 10(6S),96-98

[7] Alamoudi RM, Martaa FM, Alqahtani FA, Alshahri A, Aboqraihah M, Alharbi R, Alaama I, Alourf A, Alnasser A, Kurdi D, Albalawi R. Fluoride use in pediatric dentistry: balancing benefits and risks. Int J Community Med Public Health. 2025 Feb;12(2):1021-5.

[8] Zhang J, Mylonas P, Banerjee A. Mineralizing agents to manage early carious lesions. Part II: clinical application. Dental Update. 2023 Jul 2;50(7):572-82.

[9] Kanduti D, Sterbenk P, Artnik B. Fluoride: a review of use and effects on health. Materia socio-medica. 2016 Mar 25;28(2):133.

[10] Khallaf A, Marir M, Felemban A, Gattan H, Alyamani M, Almalki A, Rais R, Naamani S, Felemban F, Alhajrassi S. The efficacy of fluoride in reducing tooth decay: A systematic review of evidence-based interventions. Journal of Ecohumanism. 2024;3(8):6859-66.

[11] Davies RM, Ellwood RP, Davies GM. The rational use of fluoride toothpaste. International journal of dental hygiene. 2003 Feb;1(1):3-8.

[12] Gupta A, Gallagher JE, Chestnutt IG, Godson J. Formulation and fluoride content of dentifrices: a review of current patterns. British dental journal. 2021 Sep 21:1-6.

[13] Rathi BS, Kumar PS, Rangasamy G, Badawi M, Aminabhavi TM. Membrane-based removal of fluoride from groundwater. Chemical Engineering Journal. 2024 May 15;488:150880.

[14] Hung M, Hon ES, Mohajeri A, Moparthi H, Vu T, Jeon J, Lipsky MS. A national study exploring the association between fluoride levels and dental fluorosis. JAMA Network Open. 2023 Jun 23;6(6):e2318406.

[15] Adé DC, Filippi C, Filippi A. A survey on toothbrushing practices and dosing of fluoridated toothpaste among preschool children in the cantons of Basel-Stadt and berne, Switzerland. SWISS DENTAL JOURNAL SSO–Science and Clinical Topics. 2024;134(2):18-34.

[16] Arany PR, Charles-Ayinde M, Fontana M, Huang G, Levy SM, Messadi DV, Moffat R, Naavaal S, Tomar SL, Yu YH, Fox CH. The AADOCR Position Statement on Topical Fluoride. Journal of dental research. 2026 Mar;105(3):285-9.

[17] Meyer F, Amaechi BT, Fabritius HO, Enax J. Overview of calcium phosphates used in biomimetic oral care. The open dentistry journal. 2018 May 31;12:406.

[18] Adeghe EP. The multifaceted role of fluoride in preventing early childhood caries: A comprehensive review. International Journal of Life Science Research Updates. 2024;2(01):009-17.

[19] Featherstone JD. Delivery challenges for fluoride, chlorhexidine and xylitol. BMC Oral Health. 2006 Jun 15;6(Suppl 1):S8.

[20] Liane BJ, Chow A, Kline D. Skeletal fluorosis: an unusual manifestation of computer cleaner inhalant abuse. Cureus. 2020 Jun 5;12(6).

[21] Cadavid AM, Mejía SE, Palacio CS, Marín PA, Martínez-Pabón MC. Determination of bioavailable fluoride in toothpastes marketed in Medellín, Colombia, through capillary electrophoresis. Odontología sanmarquina. 2023;26(3):2.

[22] Moynihan P, Petersen PE. Diet, nutrition and the prevention of dental diseases. Public health nutrition. 2004 Feb;7(1a):201-26.

[23] Wong MC, Clarkson J, Glenny AM, Lo EC, Marinho VC, Tsang BW, Walsh T, Worthington HV. Cochrane reviews on the benefits/risks of fluoride toothpastes. Journal of dental research. 2011 May;90(5):573-9.

[24] Bibi DA, Primalia DR. Topical application fluoride for caries preventive. World Journal of Advanced Research and Reviews. 2025 Nov];27(2):286–91.

[25] Yeh CH, Wang YL, Vo TT, Lee YC, Lee IT. Fluoride in dental caries prevention and treatment: mechanisms, clinical evidence, and public health perspectives. InHealthcare 2025 Sep 8 (Vol. 13, No. 17, p. 2246). MDPI.

[26] Honóriob HM, ten Cated JM. Mechanisms of action of fluoride for caries control. Fluoride and the oral environment. 2011 Jun 23;22:97-114.

[27] Gao SS, Zhang S, Mei ML, Lo EC, Chu CH. Caries remineralisation and arresting effect in children by professionally applied fluoride treatment–a systematic review. BMC oral health. 2016 Feb 1;16(1):12.

[28] Rošin-Grget K, Peroš K, Šutej I, Bašić K. The cariostatic mechanisms of fluoride

[29] Goldberg M. Fluoride: double-edged sword implicated in caries prevention and in fluorosis. J Cell Dev Biol. 2018 Dec;1(1):10-22.

[30] Almishkhas SI, Almutairi MR, Baazeem RS, Sulaimani OM, Alwadi MA, Alkhadra SS, Alanazi MM. The Preventive Role of Fluoride in Dental Caries Management: Mechanisms, Efficacy, and Clinical Applications. Saudi Journal of Medicine and Public Health. 2025 Jul 2;2(1):1-1.

[31] Mabiaku YO, Mabiaku TO, Ibhawor LO. Beyond Aesthetics: Understanding the Impact of Intrinsic Tooth Discoloration on Wellbeing of Patients in a Nigerian Population. Ibom Medical Journal. 2025 Oct 1;18(4):621-7.

[32] Samaranayake L, Porntaveetus T, Tsoi J, Tuygunov N. Facts and fallacies of the fluoride controversy: a contemporary perspective. international dental journal. 2025 Aug 1;75(4):100833.

[33] Štepec D, Ponikvar-Svet M. Fluoride in human health and nutrition. Acta Chimica Slovenica. 2019 Jun 1;66(2).

[34] Sicca C, Bobbio E, Quartuccio N, Nicolò G, Cistaro A. Prevention of dental caries: A review of effective treatments. Journal of clinical and experimental dentistry. 2016 Dec 1;8(5):e604.

[35] Walsh T, Worthington HV, Glenny AM, Appelbe P, Marinho VC, Shi X. Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents. Cochrane database of systematic reviews. 2010(1).

[36] Whelton HP, Spencer AJ, Do LG, Rugg-Gunn AJ. Fluoride revolution and dental caries: evolution of policies for global use. Journal of dental research. 2019 Jul;98(8):837-46.

[37] Jullien S. Prophylaxis of caries with fluoride for children under five years. BMC pediatrics. 2021 Sep 8;21(Suppl 1):351.

[38] Wong MC, Zhang R, Luo BW, Glenny AM, Worthington HV, Lo EC. Topical fluoride as a cause of dental fluorosis in children. Cochrane Database of Systematic Reviews. 2024(6).

[39] Chibinski AC, Maluf AB, Ito LY, Wambier LM, Gevert MV, Monteiro V. The Use of Fluoride for Enamel Caries Management in Infants. InDental Caries Perspectives-A Collection of Thoughtful Essays 2023 Oct 28. IntechOpen.

[40] Wierichs RJ, Rupp K, Meyer-Lueckel H, Apel C, Esteves-Oliveira M. Effects of dentifrices differing in fluoride content on remineralization characteristics of dentin in vitro. Caries research. 2020 Nov 27;54(1):75-86.

[41] Ferreira SC. Pediatric dentistry and the controversy over fluoride use: integrative review Portuguese National Funding Agency for Science, Research and Technology (RCAAP Project by FCT). 2025 [cited 2026 Mar]. Available from: http://hdl.handle.net/10284/15178.

[42] Nasiri P, Malekzadeh Shafaroudi A, Elyassi Gorgi N, Arab-Nozari M, Nahvi A. Efficacy and safety of fluoride in children: a narrative review. Journal of Pediatrics Review. 2021 Jan 10;9(1):37-46.

[43] Bagińska J, Rodakowska E, Kobus A, Jamiołkowski J, Kierklo A. Polish school nurses' attitudes and knowledge towards topical fluoride treatment. Acta Stomatologica Croatica. 2019;53(2).

[44] Wong MC, Zhang R, Luo BW, Glenny AM, Worthington HV, Lo EC. Topical fluoride as a cause of dental fluorosis in children. Cochrane Database of Systematic Reviews. 2024(6).

[45] Mabiaku YO, Mabiaku TO, Isarah AR. Assessment of the Knowledge of Infectious Diseases and Their Mode of Transmission Among Dental Health Care Personnel in a Tertiary Health Institution in Southern Nigeria: Knowledge of Infectious Diseases among Dental Health Care Personnel. Nigerian Journal of Dental Research. 2022 Aug 14;7(2):116-22.

[46] Liévana FS, Moreno AP, Vilela MM, Ferreira JT, Saraiva MD, De Rossi A. Use of Fluoride Dentifrices for Children: Evaluation of General and Pediatric Dentists' Recommendations.