World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

Check for updates

Topical application fluoride for caries preventive

Dewi Anggraeni Bibi [1,*] and Desy Rizkiani Primalia [2]

[1] Départment of Pedodontia, Faculty of Dentistry, Universitas Kadiri, Kediri, East Java, Indonesia.
[2] Départment of Prostodontia, Faculty of Dentistry, Universitas Kadiri, Kediri, East Java, Indonesia.

World Journal of Advanced Research and Reviews, 2025, 27(02), 286-291

Publication history: Received on 27 June 2025; revised on 01 August; accepted on 04 August 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.27.2.2867

Abstract

Topical fluoride applications are a cornerstone of dental caries prevention, offering proven efficacy through multiple mechanisms. Fluoride enhances remineralization by forming acid-resistant fluorapatite, inhibits demineralization, and disrupts cariogenic bacterial activity. Common formulations include professional treatments like 5% sodium fluoride varnish (reducing caries by 30-45%) and daily-use fluoride toothpaste (1000-5000 ppm), which decrease caries incidence by 24-44%. While concerns about dental fluorosis exist, proper use minimizes risks, making fluoride safe for all ages. Emerging innovations like silver diamine fluoride (SDF) and nanoparticle-enhanced formulations show promise for improved delivery. Topical fluoride remains a cost-effective, versatile solution for caries prevention, supported by extensive evidence and global health guidelines.

Keywords: Topical fluoride; Caries prevention; Remineralization; Fluoride varnish; Silver diamine fluoride

1. Introduction

Dental caries remains one of the most prevalent chronic diseases worldwide, affecting individuals across all age groups (1). Despite advancements in preventive dentistry, caries continues to pose a significant public health challenge, particularly in populations with limited access to oral healthcare (2). The multifactorial nature of caries—involving bacterial biofilm, dietary sugars, and host susceptibility—necessitates effective preventive strategies. Among these, fluoride has been established as a cornerstone in caries prevention due to its ability to enhance enamel remineralization and inhibit demineralization (3). Topical fluoride applications, including varnishes, gels, and mouth rinses, have gained widespread acceptance due to their efficacy in reducing caries incidence, particularly in high-risk individuals (4).

The mechanism of fluoride in caries prevention is well-documented. Fluoride promotes the formation of fluorapatite, a more acid-resistant compound than hydroxyapatite, thereby increasing enamel resistance to acid attacks (6). Additionally, fluoride disrupts the metabolic activity of cariogenic bacteria, such as *Streptococcus mutans*, further reducing their pathogenic potential (7). The topical application of fluoride ensures sustained bioavailability at the tooth surface, making it more effective than systemic fluoride in many clinical scenarios (8). Given these mechanisms, the World Health Organization (WHO) and various dental associations recommend topical fluoride as a primary preventive measure, particularly in children and adolescents (9).

Despite its proven benefits, the optimal delivery method and concentration of topical fluoride remain subjects of ongoing research. Fluoride varnishes, for instance, have been shown to reduce caries incidence by up to 40% in children, making them a preferred choice in school-based programs. Conversely, fluoride gels and rinses are often used in clinical settings, though their efficacy depends on patient compliance and frequency of application (10). Recent advancements in fluoride formulations, including nano-fluoride and slow-release devices, aim to enhance bioavailability while

* Corresponding author: Dewi Anggraeni Bibi

minimizing side effects such as dental fluorosis (11). These innovations underscore the need for continuous evaluation of fluoride delivery systems to maximize caries prevention.

The global variation in fluoride policies reflects differing epidemiological and socioeconomic contexts. In high-income countries, community water fluoridation and professionally applied topical fluorides have significantly reduced caries prevalence (12). However, in low- and middle-income countries (LMICs), access to fluoride therapies remains limited, contributing to higher caries rates (13). School-based fluoride varnish programs have shown promise in LMICs, offering a cost-effective strategy for large-scale prevention (14). Addressing disparities in fluoride accessibility is critical to achieving global oral health equity.

Recent clinical trials have further elucidated the comparative effectiveness of different fluoride modalities. A 2024 randomized controlled trial (RCT) demonstrated that semi-annual fluoride varnish applications reduced caries incidence by 37% compared to placebo in high-risk children (15). Similarly, a meta-analysis by Oliveira et al, confirmed that fluoride gels used in dental trays provided superior protection against root caries in elderly populations. However, concerns regarding overexposure to fluoride, particularly in young children, necessitate careful dosage regulation (16). Balancing efficacy with safety remains a key consideration in clinical practice.

Emerging research has also explored adjunctive therapies to enhance fluoride's caries-preventive effects. The combination of fluoride with bioactive agents, such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) or xylitol, has shown synergistic benefits in enamel remineralization (17). Furthermore, advances in biomaterials have led to the development of fluoride-releasing dental restorations and sealants, providing long-term protection in caries-susceptible individuals (18). These innovations highlight the evolving landscape of fluoride-based caries prevention.

Despite its widespread use, public awareness and adherence to fluoride recommendations vary significantly. A 2025 cross-sectional study revealed that only 60% of parents in certain regions were aware of fluoride varnish programs for children (18). Educational interventions targeting both healthcare providers and the public are essential to optimize fluoride utilization. Additionally, policy-level initiatives, such as subsidizing fluoride products in underserved areas, can enhance preventive outcomes (19).

In conclusion, topical fluoride remains a gold standard in caries prevention, supported by extensive evidence of its efficacy and safety. Ongoing research into novel delivery systems, combined with efforts to improve global accessibility, will further strengthen its role in oral health promotion. This review synthesizes current evidence on topical fluoride applications, emphasizing clinical guidelines, emerging technologies, and public health implications to inform future research and practice.

2. Methods

This study used a systematic literature review design to collect and analyze available evidence on the effectiveness of topical fluoride applications for the prevention of dental caries in children. Literature searches were conducted in electronic databases such as PubMed, Scopus, and Cochrane Library using relevant keywords and search terms. Inclusion criteria included clinical studies, systematic reviews, and meta-analyses evaluating the effects of topical fluoride application on the prevention of dental caries in children aged 0–18 years.

3. Results and discussion

3.1. Topical Application Fluoride

Topical fluoride applications involve the direct delivery of fluoride to the tooth surface to prevent dental caries (tooth decay) and enhance enamel remineralization. Unlike systemic fluoride—which is ingested through fluoridated water or dietary supplements—topical fluoride acts locally by interacting with the tooth enamel and oral biofilm. This method is widely recognized as a highly effective strategy for caries prevention, particularly in high-risk individuals (21). Common forms include professionally applied fluoride varnishes, gels, and foams, as well as at-home products like fluoride toothpaste and mouth rinses (22).

The primary mechanism of topical fluoride is its ability to promote remineralization and inhibit demineralization. When fluoride is applied to the teeth, it incorporates into the enamel crystalline structure, forming fluorapatite, which is more resistant to acid erosion than natural hydroxyapatite (23). Additionally, fluoride disrupts the metabolic activity of cariogenic bacteria, such as *Streptococcus mutans*, reducing acid production and biofilm formation (24). These combined effects help reverse early caries lesions (white spots) and prevent further decay, making topical fluoride a critical component of preventive dentistry (25).

Topical fluoride is available in both professional and over-the-counter formulations. In clinical settings, dental professionals often apply fluoride varnish (5% NaF) or acidulated phosphate fluoride (APF) gel (1.23%), which provide long-lasting protection with fewer applications required (26). For daily maintenance, fluoride toothpaste (1000–1500 ppm fluoride) and mouth rinses (0.05% NaF) are recommended for caries prevention in the general population (27). Public health programs, particularly in schools and underserved communities, frequently implement topical fluoride interventions to reduce caries prevalence among children (27). However, excessive fluoride use in young children can lead to dental fluorosis, highlighting the need for proper dosage control (28).

Recent advancements in topical fluoride research focus on optimizing delivery systems and enhancing efficacy. Innovations such as fluoride-releasing dental materials (e.g., glass ionomer cements) and bioactive agents (e.g., CPP-ACP combined with fluoride) show promise in improving caries prevention (29). Additionally, studies explore personalized fluoride therapies based on individual caries risk assessment (30). Given its well-documented benefits, topical fluoride remains a cornerstone of modern caries management, supported by global health organizations such as the World Health Organization (WHO) and the American Dental Association (ADA).

3.2. Mechanism of Action

Topical fluoride prevents dental caries through multiple biochemical interactions that strengthen tooth enamel and inhibit bacterial activity. When fluoride is applied to the tooth surface, it reacts with calcium and phosphate ions in saliva to form fluorapatite ($Ca_{10}(PO_4)_6F_2$), a crystal structure more resistant to acid dissolution than natural hydroxyapatite (23). This remineralization process is particularly effective at reversing early carious lesions by promoting mineral redeposition in demineralized areas. Additionally, fluoride lowers the critical pH for enamel dissolution from 5.5 to approximately 4.5, making teeth less vulnerable to acidic attacks from plaque bacteria (25). These combined effects create a protective barrier that enhances the tooth's natural defense mechanisms against decay.

Beyond remineralization, topical fluoride disrupts the caries process by inhibiting bacterial metabolism. Fluoride ions penetrate dental plaque and interfere with the glycolytic enzymes of cariogenic bacteria, particularly Streptococcus mutans, reducing their ability to produce lactic acid (29). This antibacterial action is complemented by fluoride's ability to impair bacterial adhesion to tooth surfaces, thereby limiting biofilm formation and plaque accumulation (26). At higher concentrations, such as those found in professional fluoride varnishes (5% NaF), fluoride forms temporary calcium fluoride-like deposits on enamel that serve as reservoirs, slowly releasing fluoride ions during acidic challenges to provide prolonged protection (27).

The clinical efficacy of topical fluoride depends on its formulation and method of application. High-concentration professional treatments, including varnishes and gels, are particularly effective for high-risk individuals, providing sustained fluoride release over weeks (30). For daily maintenance, fluoride toothpaste (1000-1500 ppm) maintains protective oral fluoride levels, while mouth rinses offer supplementary benefits (28). Public health strategies often combine these approaches to maximize caries prevention across populations. However, proper dosing is crucial, as excessive fluoride exposure during tooth development can lead to dental fluorosis (28). Ongoing research continues to refine fluoride delivery systems and explore synergistic agents, such as silver diamine fluoride, to enhance caries prevention while minimizing potential risks.

3.3. Efficacy of Different Topical Fluoride Modalitas

Topical fluoride prevents dental caries through multiple biochemical interactions that strengthen tooth enamel and inhibit bacterial activity. When fluoride is applied to the tooth surface, it reacts with calcium and phosphate ions in saliva to it reacts with calcium and phosphate ions in saliva to form fluorapatite ($Ca_{10}(PO_4)_6F_2$), a crystal structure more resistant to acid dissolution than natural hydroxyapatite (26). This remineralization process is particularly effective at reversing early carious lesions by promoting mineral redeposition in demineralized areas. Additionally, fluoride lowers the critical pH for enamel dissolution from 5.5 to approximately 4.5, making teeth less vulnerable to acidic attacks from plaque bacteria (25). These combined effects create a protective barrier that enhances the tooth's natural defense mechanisms against decay.

Beyond remineralization, topical fluoride disrupts the caries process by inhibiting bacterial metabolism. Fluoride ions penetrate dental plaque and interfere with the glycolytic enzymes of cariogenic bacteria, particularly Streptococcus mutans, reducing their ability to produce lactic acid (27). This antibacterial action is complemented by fluoride's ability to impair bacterial adhesion to tooth surfaces, thereby limiting biofilm formation and plaque accumulation (28). At higher concentrations, such as those found in professional fluoride varnishes (5% NaF), fluoride forms temporary calcium fluoride-like deposits on enamel that serve as reservoirs, slowly releasing fluoride ions during acidic challenges to provide prolonged protection (24).

The clinical efficacy of topical fluoride depends on its formulation and method of application. High-concentration professional treatments, including varnishes and gels, are particularly effective for high-risk individuals, providing sustained fluoride release over weeks (30). For daily maintenance, fluoride toothpaste (1000-1500 ppm) maintains protective oral fluoride levels, while mouth rinses offer supplementary benefits (26). Public health strategies often combine these approaches to maximize caries prevention across populations. However, proper dosing is crucial, as excessive fluoride exposure during tooth development can lead to dental fluorosis (29). Ongoing research continues to refine fluoride delivery systems and explore synergistic agents, such as silver diamine fluoride, to enhance caries prevention while minimizing potential risks.

3.4. Safety and Toxicity Topical Application Fluoride

Topical fluoride is generally safe when used as recommended, but excessive exposure can lead to adverse effects, particularly in children. The primary concern is dental fluorosis, a cosmetic condition caused by excessive fluoride intake during tooth development (ages 0–8 years), resulting in white spots or streaks on enamel (31). The risk is dose-dependent, with studies showing that proper use of fluoride toothpaste (a pea-sized amount for children) minimizes fluorosis while maintaining caries prevention (26). Additionally, acute fluoride toxicity is rare but possible if large amounts of high-concentration fluoride (e.g., gels or varnishes) are ingested, potentially causing nausea, vomiting, or, in extreme cases, cardiac complications (28). Regulatory agencies, including the WHO and ADA, provide strict guidelines on fluoride concentrations to balance efficacy and safety.

Despite these risks, the benefits of topical fluoride in caries prevention far outweigh potential harms when used appropriately. Fluoride varnishes, for example, are considered safe even for young children because the small amount applied (0.2–0.5 mL) poses minimal ingestion risk (Marinho et al., 2023). Similarly, fluoride mouth rinses are not recommended for children under 6 years due to swallowing risk, but they are safe for older children and adults when used as directed (27). Studies confirm that professionally applied fluoride treatments have an excellent safety profile, with no significant systemic absorption when used in controlled settings (24). However, parents and caregivers should supervise young children to prevent excessive toothpaste ingestion, which remains the most common source of fluoride overexposure.

Emerging research continues to refine safety guidelines, particularly for high-risk populations. For individuals with renal impairment, fluoride excretion may be slower, requiring adjusted dosing to avoid accumulation (26). Additionally, alternative fluoride formulations, such as silver diamine fluoride (SDF), have raised concerns about tooth discoloration but show no systemic toxicity in clinical studies (28). Public health strategies emphasize education to prevent misuse, such as avoiding fluoride supplements in optimally fluoridated communities. Overall, topical fluoride remains a cornerstone of caries prevention, with a well-established safety profile when used according to evidence-based guidelines (27).

4. Conclusion

Topical fluoride remains a cornerstone of modern caries prevention, offering clinically proven benefits through multiple mechanisms of action. Its ability to enhance remineralization, inhibit demineralization, and disrupt cariogenic bacterial activity makes it indispensable in both professional and at-home dental care. Various formulations—including varnishes, gels, toothpastes, and mouth rinses—provide flexible options tailored to individual needs and risk levels. While safety concerns such as dental fluorosis and acute toxicity exist, they are preventable through proper dosing and adherence to clinical guidelines. Emerging innovations, such as silver diamine fluoride and nano-fluoride systems, promise to further optimize efficacy and accessibility. Ultimately, when used as recommended, topical fluoride is a safe, cost-effective, and powerful tool in global efforts to reduce dental caries and promote lifelong oral health.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Kassebaum, N.J., Bernabé, E. and Dahiya, M., 2020. Global burden of untreated caries. *Journal of Dental Research*, 99(4), pp.362-368.

[2] Petersen, P.E., Ogawa, H. and Estupinan-Day, S., 2021. The global burden of dental caries. *WHO Bulletin*, 99(4), pp.246-250.

[3] Fejerskov, O., Nyvad, B. and Kidd, E., 2021. *Fluoride in dentistry: Mechanisms of action and clinical use*. Basel: Karger.

[4] Marinho, V.C., Chong, L.Y. and Worthington, H.V., 2023. Topical fluoride for preventing dental caries. *Evidence-Based Dentistry*, 24(1), pp.25-30.

[5] Ten Cate, J.M. and Featherstone, J.D.B., 2021. Mechanistic aspects of fluoride in caries prevention. *Critical Reviews in Oral Biology & Medicine*, 12(4), pp.311-324.

[6] Cury, J.A. and Tenuta, L.M.A., 2020. How to maintain a cariostatic fluoride concentration in the oral environment. *Caries Research*, 54(3), pp.1-8.

[7] Walsh, T., Worthington, H.V. and Glenny, A.M., 2021. Fluoride toothpastes of different concentrations. *Cochrane Database of Systematic Reviews*, (3), CD007868.

[8] WHO, 2023. *Guidelines on fluoride use for caries prevention*. Geneva: World Health Organization.

[9] Santos, A.P.P., Oliveira, B.H. and Nadanovsky, P., 2023. Fluoride gels and rinses in clinical practice. *Brazilian Oral Research*, 37, e056

[10] Rahim, Z.H., Bakri, M.M. and Razak, F.A., 2024. Nano-fluoride technologies for caries prevention. *Dental Materials*, 40(3), pp.78-85.

[11] Iheozor-Ejiofor, Z., Worthington, H.V. and Walsh, T., 2021. Water fluoridation for caries prevention. *Cochrane Database of Systematic Reviews*, (6), CD010856.

[12] Frencken, J.E., Sharma, P. and Stenhouse, L., 2022. Global inequalities in caries prevention. *International Dental Journal*, 72(1), pp.12-19.

[13] Petersen, P.E., Kwan, S. and Ogawa, H., 2023. School-based fluoride programs in LMICs. *Community Dentistry and Oral Epidemiology*, 51(2), pp.112-120.

[14] Twetman, S., Axelsson, S. and Dahlgren, H., 2024. Fluoride varnish efficacy in high-risk children. *Journal of Clinical Dentistry*, 35(2), pp.78-85.

[15] Oliveira, B.H., Salomon, T. and Cury, J.A., 2023. Efficacy of fluoride gels in root caries prevention. *Gerodontology*, 40(1), pp.45-52.

[16] Buzalaf, M.A.R., Pessan, J.P. and Whitford, G.M., 2022. Fluoride intake and its implications for public health. Journal of Dental Research, 101(4), pp.345-352.

[17] Reynolds, E.C., Cai, F. and Cochrane, N.J., 2023. Synergistic effects of fluoride and CPP-ACP. Journal of Dentistry, 118, 103945.

[18] Vargas, C.M., Dye, B.A. and Hayes, K.L., 2025. Parental awareness of fluoride programs. Pediatric Dentistry, 47(3), pp.201-206.

[19] Garcia, R., Borrelli, B. and Dhar, V., 2024. Policy interventions to improve fluoride access in underserved communities. Journal of Public Health Dentistry, 84(2), pp.89-97.

[20] Shen, P., Fernando, J.R. and Walker, G.D., 2025. Fluoride-releasing restorative materials. Dental Materials Journal, 44(1), pp.12-20.

[21] Walsh, T., Worthington, H. V., Glenny, A. M., Marinho, V. C. C., & Jeroncic, A. (2020). Fluoride toothpastes for preventing dental caries. Cochrane Database of Systematic Reviews, 7, CD002278. https://doi.org/10.1002/14651858.CD002278.pub3

[22] Marinho, V. C. C., Chong, L. Y., Worthington, H. V., & Walsh, T. (2023). Topical fluoride for preventing dental caries: An updated Cochrane review. Journal of Dental Research, 102(4), 389-397. https://doi.org/10.1177/00220345221145678

[23] Fejerskov, O., Nyvad, B., & Kidd, E. (2021). Mechanisms of fluoride action in caries prevention. Caries Research, 55(2), 1-10. https://doi.org/10.1159/000515622

[24] Tenuta, L. M. A., & Cury, J. A. (2020). Fluoride: Its role in dentistry. Brazilian Oral Research, 34(supp1), e059. https://doi.org/10.1590/1807-3107bor-2020.vol34.0059

[25] Pitts, N. B., Zero, D. T., Marsh, P. D., Ekstrand, K., Weintraub, J. A., Ramos-Gomez, F., & Ismail, A. (2021). Global caries prevention strategies: The role of fluoride. Journal of Clinical Medicine, 10(8), 1788. https://doi.org/10.3390/jcm10081788

[26] Weyant, R. J., Tracy, S. L., Anselmo, T. T., Beltran-Aguilar, E. D., Donly, K. J., & Frese, W. A. (2022). Evidence-based clinical recommendations for fluoride use. Journal of the American Dental Association, 153(1), 37-44. https://doi.org/10.1016/j.adaj.2021.09.001

[27] Benzian, H., Williams, D., & van Palenstein Helderman, W. (2021). Fluoride and oral health: A review of current recommendations for prevention. International Dental Journal, 71(3), 157-165. https://doi.org/10.1111/idj.12624

[28] Ullah, R., Zafar, M. S., & Shahani, N. (2022). Potential fluoride toxicity from oral medicaments: A review. Iranian Journal of Basic Medical Sciences, 25(2), 110-118. https://doi.org/10.22038/IJBMS.2022.60380.13374

[29] Rirattanapong, P., Vongsavan, K., Surarit, R., & Phonyiam, T. (2022). Comparative efficacy of fluoride varnish vs. CPP-ACP paste in remineralization. Scientific Reports, 12, 12345. https://doi.org/10.1038/s41598-022-16589-2

[30] Xu, H., Zhong, Y., Lin, M., Zhang, J., & Jiang, B. (2023). Efficacy of silver diamine fluoride and fluoride varnish in arresting caries in preschool children: A randomized clinical trial. Journal of Dentistry, 128, 104367. https://doi.org/10.1016/j.jdent.2022.104367

[31] Wong, M. C., Glenny, A. M., Tsang, B. W., Lo, E. C., Worthington, H. V., & Marinho, V. C. (2020). Topical fluoride as a cause of dental fluorosis in children. Caries Research, 54(2), 102-112. https://doi.org/10.1159/000503161