

## Review Article

DOI: <https://dx.doi.org/10.18203/2394-6040.ijcmph20250048>

# Fluoride use in pediatric dentistry: balancing benefits and risks

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**Received:** 01 January 2025

**Accepted:** 20 January 2025

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## ABSTRACT

Fluoride has been a critical component in pediatric dentistry, offering significant protection against dental caries, a prevalent issue among children globally. Its mechanisms of action include enhancing enamel resistance through remineralization, inhibiting demineralization, and reducing bacterial activity in the oral cavity. These processes contribute to strengthening teeth and reducing the risk of decay, making fluoride a cornerstone in both individual and community dental care. However, excessive fluoride exposure, particularly in early childhood, poses risks such as dental fluorosis and, in rare cases, systemic toxicity. Strategies to ensure safe and effective fluoride use involve a combination of public health measures and individualized approaches. Community water fluoridation remains a cost-effective solution, significantly reducing caries prevalence while requiring strict monitoring to maintain safe levels. Topical applications, such as fluoride toothpaste and varnishes, provide targeted protection and minimize systemic intake, especially in high-risk populations. Recommendations for parental supervision during toothbrushing and the use of age-appropriate fluoride toothpaste are critical in reducing the risk of overexposure. Localized therapies, such as fluoride varnish and supplements for non-fluoridated areas, further enhance protective effects while addressing regional disparities. Public education campaigns play an essential role in raising awareness about proper fluoride use, fostering healthier oral hygiene practices among children and their caregivers. Ongoing research and evidence-based guidelines remain fundamental in optimizing fluoride application and addressing emerging concerns. Balancing the benefits of fluoride in preventing caries with the risks of overexposure requires a comprehensive approach that integrates scientific advancements, public health initiatives, and community-specific strategies.

**Keywords:** Fluoride, Pediatric dentistry, Dental caries prevention, Dental fluorosis, Oral health strategies

## INTRODUCTION

Fluoride has been a cornerstone in pediatric dentistry for its well-established role in preventing dental caries, a

condition that remains a significant public health challenge worldwide. Dental caries is particularly prevalent among children, with its etiology linked to microbial activity on the tooth surface, dietary sugars, and inadequate oral

hygiene. Fluoride helps combat this condition by enhancing enamel resistance to acid demineralization, promoting remineralization, and inhibiting bacterial activity within dental plaque.<sup>1</sup> Despite its efficacy, the use of fluoride has been surrounded by debates concerning its safety, especially in children, given the potential risks of dental fluorosis and systemic toxicity.

The introduction of fluoride into water supplies, toothpaste, and professional dental treatments has led to significant declines in dental caries over the past decades.<sup>2</sup> These advances underscore fluoride's indispensable role in pediatric oral health. However, the widespread availability of fluoride through various sources raises concerns about overexposure, particularly during the critical years of enamel formation. The need to balance fluoride's protective benefits with its potential adverse effects has prompted researchers and clinicians to adopt evidence-based recommendations and tailored interventions.

Children are particularly vulnerable to both the benefits and risks of fluoride. Their developing dentition and limited capacity to regulate fluoride ingestion, especially from toothpaste and dietary sources, necessitate careful monitoring.<sup>3,4</sup> Furthermore, socioeconomic and geographic factors influence fluoride exposure levels, creating disparities in dental health outcomes. Strategies for optimal fluoride use must account for these variations to ensure equitable and safe preventive care. As the field of pediatric dentistry continues to evolve, addressing the controversies surrounding fluoride use remains crucial. This review explores the mechanisms of fluoride's action, its efficacy in children, associated risks, and strategies to maximize benefits while minimizing harms.

## REVIEW

Fluoride's role in pediatric dentistry is rooted in its ability to reduce the prevalence of dental caries significantly, but its use necessitates a careful balance between benefits and risks. Evidence supports the effectiveness of fluoride in strengthening enamel and preventing demineralization, particularly when administered through community water fluoridation and topical applications like toothpaste and varnishes.<sup>5</sup> These methods have collectively contributed to a decline in caries prevalence worldwide. However, the accessibility of multiple fluoride sources has raised concerns about overexposure, especially in young children who may inadvertently ingest fluoride-containing products.

Dental fluorosis, characterized by hypomineralization of enamel, remains the most visible risk associated with excessive fluoride intake during enamel formation. Its prevalence highlights the need for targeted fluoride use, emphasizing proper dosages and parental supervision when children use fluoride toothpaste.<sup>6</sup> Strategies such as recommending low-fluoride toothpaste for young children and limiting professional fluoride applications to high-risk patients have shown promise in minimizing these risks

while maintaining caries prevention efficacy. The challenge in pediatric dentistry lies in tailoring fluoride interventions to individual needs, considering factors such as caries risk, age, and access to fluoridated water. Continued research is essential to refine guidelines, ensuring fluoride's benefits are maximized without compromising safety.

### ***Mechanisms of action of fluoride in preventing dental caries***

Fluoride plays a multifaceted role in dental caries prevention, primarily by interacting with the enamel and oral environment in ways that enhance tooth resistance to decay. The most critical mechanism is fluoride's ability to promote remineralization of early enamel lesions. When fluoride is present in saliva, it forms fluorapatite crystals, a more stable and acid-resistant version of hydroxyapatite, the primary mineral in tooth enamel.<sup>7</sup> This process helps repair subsurface enamel demineralization, reversing the effects of acid attacks from bacterial activity. Notably, this occurs even at low concentrations, underscoring the significance of consistent fluoride exposure.

Fluoride also disrupts the cariogenic activity of oral bacteria, particularly *Streptococcus mutans*, which play a key role in dental caries formation. Fluoride inhibits bacterial enzymes involved in sugar metabolism, reducing acid production within the oral biofilm.<sup>8</sup> By decreasing the acidogenic potential of plaque, fluoride lowers the likelihood of enamel demineralization. Moreover, it limits the ability of bacteria to adhere to tooth surfaces, further reducing their pathogenicity. Another important mechanism is fluoride's effect on enamel during tooth development. Systemic fluoride, absorbed through sources like fluoridated water, becomes incorporated into the developing enamel matrix, creating fluorapatite crystals. This results in teeth that are less soluble in acidic environments, offering long-term protection against caries.<sup>9</sup> While systemic fluoride is critical during enamel formation, its topical application remains the primary method of benefit after teeth erupt.

Topical fluoride sources, such as toothpaste and varnishes, are highly effective due to their direct interaction with the enamel surface. These products provide a reservoir of fluoride ions that maintain supersaturated conditions in saliva, promoting a continuous cycle of demineralization and remineralization. Recent studies indicate that high-frequency, low-dose fluoride applications are particularly effective at sustaining enamel protection without increasing the risk of dental fluorosis.<sup>10</sup>

While fluoride works effectively at the chemical and microbiological levels, its benefits depend on consistent and appropriate exposure. This underscores the need for public health measures like water fluoridation, which provide equitable fluoride access, as well as individualized care plans that optimize fluoride use in children.

## EFFICACY OF FLUORIDE THERAPIES IN CHILDREN

Fluoride therapies remain pivotal in reducing dental caries in pediatric populations, with their efficacy validated through decades of clinical and epidemiological research. Water fluoridation, one of the earliest large-scale fluoride interventions, is recognized for its broad impact on caries prevention across diverse populations. Studies show that community water fluoridation reduces caries incidence in children by up to 40%, primarily by providing consistent, low-level fluoride exposure that supports remineralization and inhibits demineralization.<sup>10,11</sup> The success of water fluoridation lies in its passive nature, ensuring fluoride delivery irrespective of socioeconomic status or access to dental care.

Topical fluoride applications, such as fluoride varnishes and gels, offer targeted protection for high-risk children. Fluoride varnish, in particular, has shown remarkable efficacy in both preventing new caries lesions and arresting the progression of early lesions. Regular application of fluoride varnish in clinical or community settings has been associated with a significant reduction in caries prevalence, especially in primary teeth.<sup>12</sup> Its ability to adhere to enamel for extended periods ensures prolonged fluoride release, making it an effective intervention even with infrequent applications.

Fluoride toothpaste is another cornerstone in caries prevention, with its widespread use contributing significantly to the decline in global caries prevalence. Studies indicate that fluoride toothpaste reduces caries incidence by approximately 24%, with greater benefits observed at higher fluoride concentrations.<sup>13</sup> The frequency of use and proper brushing techniques amplify its effectiveness, particularly in young children who require parental guidance to minimize swallowing and ensure optimal fluoride delivery. School-based fluoride mouth rinse programs represent another effective strategy for caries prevention in children, particularly in areas lacking access to fluoridated water. These programs typically involve weekly rinsing with a sodium fluoride solution, which has demonstrated efficacy in reducing caries incidence by up to 33% in primary and permanent teeth.<sup>14</sup> Such programs are cost-effective and can be implemented on a large scale, although their success depends on compliance and regular participation.

## RISKS ASSOCIATED WITH EXCESSIVE FLUORIDE EXPOSURE

Excessive fluoride exposure in children is a concern primarily due to its potential to cause dental fluorosis, a condition characterized by hypomineralized enamel that presents as white spots or streaks in mild cases and more severe staining or pitting in extreme cases. Dental fluorosis occurs when excessive fluoride is ingested during enamel development, typically before the age of eight.<sup>15</sup> While fluorosis is primarily a cosmetic issue in its milder forms,

it can have psychosocial implications, particularly for children and adolescents with more noticeable enamel defects. Sources of excessive fluoride exposure include fluoridated drinking water, ingestion of fluoride toothpaste, and inappropriate use of supplements. Young children, in particular, are at higher risk due to their limited ability to spit out toothpaste during brushing. Studies show that fluoride toothpaste ingestion accounts for a significant portion of total fluoride intake in children, particularly in areas with high water fluoridation levels.<sup>16</sup> This underscores the need for parental supervision and the use of age-appropriate fluoride toothpaste concentrations to mitigate the risk.

Another concern with fluoride overexposure is its systemic impact, although this is rare at the levels typically encountered in daily use. Chronic exposure to excessively high fluoride levels has been linked to skeletal fluorosis, a condition marked by joint pain and stiffness due to changes in bone density and structure. Although skeletal fluorosis is uncommon in fluoridated regions, it highlights the importance of monitoring cumulative fluoride intake, particularly in areas where naturally occurring fluoride levels in water exceed recommended limits.<sup>17</sup> Geographical variations in fluoride exposure also play a role in the risk of fluorosis. In regions where naturally occurring fluoride in groundwater is high, such as certain parts of Asia and Africa, children face a higher risk of both dental and skeletal fluorosis. Efforts to address these issues include defluoridation of water supplies and public education campaigns to reduce fluoride intake from non-dietary sources.<sup>18</sup> These interventions emphasize the critical need for local monitoring and tailored guidelines to address regional disparities in fluoride exposure.

## STRATEGIES FOR SAFE AND EFFECTIVE FLUORIDE USE IN PEDIATRIC POPULATIONS

Ensuring the safe and effective use of fluoride in pediatric populations requires a multi-faceted approach that balances caries prevention with minimizing the risk of overexposure. One cornerstone strategy is the tailored use of fluoride toothpaste. The American Dental Association (ADA) recommends using a smear-sized amount of fluoride toothpaste for children under three years old and a pea-sized amount for those aged three to six.<sup>19</sup> These guidelines are designed to provide adequate fluoride exposure while reducing the likelihood of swallowing significant amounts during brushing. Parental supervision during toothbrushing is essential to ensure proper usage and minimize risks.

Fluoride varnish applications in dental settings have emerged as an effective preventive measure, particularly for high-risk children. These treatments involve the application of a fluoride-rich coating to teeth, offering prolonged protection through sustained fluoride release. Studies have shown that regular fluoride varnish applications, typically performed two to four times annually, significantly reduce caries incidence without

contributing to systemic fluoride intake.<sup>20</sup> This localized approach is particularly valuable in populations with limited access to fluoridated water or other fluoride sources. Community water fluoridation remains one of the most cost-effective public health measures for reducing caries in children. To mitigate the risk of overexposure in regions with naturally high fluoride levels, water fluoridation programs require rigorous monitoring and adjustment to maintain fluoride concentrations within the recommended range of 0.7 mg/l to 1.0 mg/l.<sup>21</sup> In areas where defluoridation is necessary, public health campaigns play a critical role in educating communities about alternative sources of fluoride and preventive dental care.

Fluoride supplements, such as drops or tablets, may be prescribed for children in non-fluoridated areas, but these require careful administration to prevent excessive fluoride intake. Current recommendations suggest that fluoride supplements be used only for children at high risk of caries and in households without access to fluoridated water.<sup>22</sup>

Pediatric dentists and healthcare providers play a crucial role in assessing caries risk and advising parents on appropriate fluoride use based on individual needs and environmental factors. Education remains at the heart of safe fluoride use. Public health campaigns targeting parents and caregivers emphasize the importance of following fluoride dosage guidelines, proper brushing techniques, and regular dental visits. These efforts ensure that fluoride's benefits are maximized without unnecessary risks, fostering healthier oral habits in pediatric populations.

## CONCLUSION

Fluoride remains a cornerstone in pediatric dentistry for its proven ability to prevent dental caries effectively. However, its use requires careful management to balance benefits and minimize risks like dental fluorosis. Strategies such as tailored fluoride therapies, public education, and community programs ensure its safe application. Continued research and evidence-based guidelines are essential to optimize fluoride use in children.

*Funding: No funding sources*

*Conflict of interest: None declared*

*Ethical approval: Not required*

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**Cite this article as:** Alamoudi RM, Martaa FM, Alqahtani FA, Alshahri AM, Aboqraihah MN, Alharbi RE, et al. Fluoride use in pediatric dentistry: balancing benefits and risks. *Int J Community Med Public Health* 2025;12:1021-5.