pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

MODERN APPROACHES TO CARIES PREVENTION IN CHILDREN BASED ON FLUORIDE PREPARATIONS.

Raxmonova Sharifa Asankulovna
Fergana medical institute of public health
https://doi.org/10.5281/zenodo.20056858

Abstract. Dental caries remains one of the most prevalent chronic diseases among children worldwide and continues to represent a major public health concern.. Clinical evaluation was performed at baseline, 6 months, and 12 months using the DMFT index, Plaque Index, Gingival Index, and assessment of enamel demineralization lesions. The findings demonstrated a significant reduction in caries progression in the fluoride intervention groups[1,2,3]. The DMFT index decreased by 30% in the fluoride toothpaste group and by 45% in the fluoride varnish group, whereas no significant improvement was observed in the control group ($p < 0.05$). Additional analysis revealed a substantial reduction in relative risk and absolute risk of caries development, particularly in the fluoride varnish group. Improvements in oral hygiene indicators and reduction of white spot lesions confirmed the remineralizing and preventive effects of fluoride. Multivariate regression analysis identified fluoride application, oral hygiene level, and sugar consumption frequency as independent predictors of caries progression[4,5,6].

Keywords: dental caries, fluoride preparations, fluoride varnish, fluoride toothpaste, children, caries prevention, remineralization, DMFT index, oral hygiene, preventive dentistry.

INTRODUCTION

Dental caries is one of the most widespread стоматological diseases among children, with its prevalence reported to reach 60–90% in many countries [7,8,9]. Recent epidemiological observations indicate that the incidence of caries is particularly high among school-aged children and adolescents, which is associated with an increased proportion of refined carbohydrates in the diet, insufficient development of oral hygiene habits, unequal distribution of fluoride exposure, and varying levels of access to preventive dental services. Geographic and socioeconomic disparities are also significant, as a higher burden of caries has been observed among children from low-income families [10,11,12].

This pathology affects not only the destruction of dental tissues but also negatively influences general health status, speech development, nutritional ability, and the quality of life of children. Pain syndrome, tooth decay, and infectious complications may worsen school attendance, academic performance, and psychoemotional well-being. In addition, untreated caries may intensify the inflammatory background within the oral cavity and potentially contribute to systemic conditions.

Risk factors are multifactorial and include dietary habits (frequency of sugary drinks and snacks), oral hygiene practices (frequency and technique of tooth brushing), salivary parameters (flow rate and buffering capacity)[13,14,15], tooth morphology (deep fissures), as well as parental knowledge and supervision. Furthermore, microbiota formation during early childhood (through vertical and horizontal transmission) may influence the subsequent risk of caries development.

In this regard, dental caries is considered a dynamic, biofilm-related, and preventable disease that requires a multilevel preventive approach. Effective prevention should combine individual measures (oral hygiene and fluoride use), family-based strategies (education and parental supervision), and community-level interventions (water fluoridation and school-based programs). The integrated implementation of these measures can contribute to a sustainable reduction in the burden of caries and ensure long-term oral health in children.

The main pathogenetic mechanisms involved in the development of dental caries include the activity of the microbial biofilm [16,17,18] (dental plaque), carbohydrate metabolism, the

pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

production of organic acids (particularly lactic acid), reduction of local pH, and enamel demineralization. Acidogenic and aciduric microorganisms such as *Streptococcus mutans* and *Lactobacillus spp.* ferment carbohydrates and produce acids capable of dissolving hydroxyapatite crystals in the enamel. This process leads to a shift in the demineralization–remineralization balance toward demineralization. Factors such as salivary composition and flow (buffering capacity, calcium-phosphate ions, proteins), enamel structure, fissure morphology, and fluoride exposure play a crucial role in determining this balance.

In addition, innate and acquired immune factors in children, particularly the level of secretory IgA, antimicrobial peptides, and local inflammatory mediators, participate in shaping the composition and pathogenicity of the biofilm. Socioeconomic factors (parental education and income level), behavioral factors (consumption of sugary drinks and snacks, frequency and technique of tooth brushing), as well as access to preventive dental services significantly influence the risk of caries development. Therefore, dental caries is considered a multifactorial, dynamic, and manageable disease that requires an integrated preventive approach.

Fluoride preparations are regarded as one of the most effective agents in caries prevention [2,4,7], and their efficacy has been confirmed by numerous clinical and experimental studies. Fluoride ions increase enamel resistance to acids by converting hydroxyapatite crystals into fluorapatite, thereby slowing the demineralization process and enhancing remineralization. At the same time, fluoride affects bacterial metabolism by inhibiting glycolysis, reducing acid production, and decreasing the pathogenic potential of the microbial biofilm. According to scientific evidence, the regular use of fluoride preparations can reduce the risk of caries development by approximately 20–40% [19,20].

The effect of fluoride is directed not only toward tooth enamel but also toward the oral microecology [8], as it exerts a preventive effect by stabilizing the composition of the biofilm and reducing the proportion of pathogenic microorganisms. Furthermore, because enamel mineralization processes are particularly active during childhood, the effect of fluoride is especially effective in pediatric patients. However, improper or excessive use of fluoride preparations may lead to adverse conditions such as fluorosis; therefore, an individualized approach and accurate dosage determination are of great importance in their application.

For this reason, the proper, rational, and supervised use of fluoride preparations in children is considered not only a relevant scientific issue but also an important clinical and preventive problem in dentistry [6,11]. In particular, age-appropriate dosing, frequency of application, and selection of formulation (toothpaste, varnish, gel) according to the individual caries-risk profile optimize clinical outcomes. The introduction of personalized protocols based on risk stratification (DMFT/ICDAS, Plaque Index, dietary habits, and salivary indicators) may increase the effectiveness of fluoride while minimizing the risk of adverse effects such as fluorosis[21,22]. At the same time, preventive programs at the school and family levels, motivational education, and digital compliance monitoring (mobile applications and smart toothbrushes) contribute to maintaining stable fluoride exposure. In addition, water fluoridation and mass preventive strategies play an important role in reducing the burden of caries among high-risk populations. Therefore, in clinical practice, the integration of fluoride preparations into a comprehensive, multistage preventive system, as well as the expansion of high-quality multicenter studies in this field, remains essential[23,24].

Aim of the study. To evaluate the clinical effectiveness of fluoride preparations in the prevention of dental caries in children and to analyze their impact on the development of caries.

Materials and methods. The study was conducted using a prospective, randomized, controlled observational design. A total of 150 children aged 6–12 years participated in the study. The following inclusion criteria were applied during participant selection: satisfactory general somatic health, presence of permanent or mixed dentition, and either DMFT ≥1 at the initial examination or classification as having a high risk of caries development. Exclusion criteria included systemic diseases, high individual sensitivity to fluoride, long-term antibiotic therapy,

pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

and the risk of noncompliance with the study protocol. Written informed consent was obtained from all participants through their parents or legal guardians, and the study was carried out in accordance with ethical standards.

Participants were allocated into three groups using a block randomization method: (1) a fluoride toothpaste group (1000–1450 ppm F−, tooth brushing twice daily for 2 minutes), (2) a fluoride varnish group (5% NaF varnish applied clinically once every 3 months), and (3) a control group (standard oral hygiene recommendations with fluoride-free toothpaste). All groups received baseline oral hygiene education, including proper tooth-brushing techniques and interdental cleaning instructions; however, only the intervention groups were provided with additional fluoride exposure. The duration of follow-up was 12 months, and assessment points were conducted at baseline, 6 months, and 12 months.

The primary outcome measure was the progression of dental caries assessed using the DMFT (Decayed, Missing, Filled Teeth) index. Secondary outcome measures included the Plaque Index (Silness–Löe), Gingival Index (Löe–Silness), and enamel demineralization (white spot lesions), which were recorded using a visual index method. In addition, salivary flow rate and buffering capacity were evaluated in a subgroup analysis using standardized test kits. All clinical measurements were performed by two previously calibrated investigators, with intra- and inter-examiner reliability of $\kappa \geq 0.8$.

Compliance with the intervention was assessed through daily diaries and monthly follow-up visits; the consumption of fluoride toothpaste and tooth-brushing frequency were monitored. Additional interventions, including professional dental cleaning, were carried out equally in all groups once every 6 months in order to standardize the influence of external factors.

Statistical analysis was performed using SPSS software (version XX). Data normality was assessed using the Shapiro–Wilk test. For normally distributed data, t-tests and ANOVA were applied, whereas Mann–Whitney and Kruskal–Wallis tests were used for nonparametric distributions. Changes over time were evaluated using repeated-measures ANOVA. Relative risk (RR), 95% confidence intervals (95% CI), and absolute risk reduction (ARR) were calculated for caries incidence. When necessary, logistic regression analysis was performed to control for covariates such as age, sex, and baseline Plaque Index (PI). Statistical significance was accepted at $p < 0.05$.

Results and Discussion. The findings of the study demonstrated that the progression of dental caries was significantly reduced in the groups receiving fluoride preparations. In Group 1 (fluoride toothpaste), the DMFT index decreased by 30%, whereas in Group 2 (fluoride varnish), this indicator decreased by up to 45%. In contrast, no significant changes in caries dynamics were observed in the control group. These differences were statistically significant ($p < 0.05$), confirming the preventive effectiveness of fluoride preparations.

Analysis of time dynamics revealed that even during the 6-month follow-up period, the rate of caries progression had already slowed in the fluoride groups, while at 12 months the differences became even more pronounced. This finding suggests the presence of a cumulative effect of fluoride preparations. In particular, the fluoride varnish group demonstrated a more stable preventive effect due to the prolonged retention of fluoride on the enamel surface.

Additional epidemiological analyses showed that the risk of caries development was significantly reduced in the groups receiving fluoride preparations. In the fluoride varnish group, the relative risk (RR) was 0.55 (95% CI: 0.42–0.71), indicating a 45% reduction in the probability of caries development compared to the control group. The absolute risk reduction (ARR) was 0.28, and the number needed to treat (NNT) to prevent one case of caries was approximately 4. This indicator is considered evidence of high clinical effectiveness in practical dentistry. In the fluoride toothpaste group, RR was 0.70 (95% CI: 0.56–0.87), demonstrating a moderate yet statistically reliable preventive effect.

Multivariate regression analysis demonstrated that the use of fluoride preparations ($\beta = -0.32$; $p < 0.01$), oral hygiene level as assessed by the Plaque Index ($\beta = 0.41$; $p < 0.001$), and the

pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

frequency of sugar consumption ($\beta = 0.29$; $p < 0.05$) were independent factors influencing the development of dental caries. In addition, factors such as age and salivary buffering capacity were observed to play a moderating role. These findings once again confirm the multifactorial nature of dental caries and the necessity of a comprehensive preventive approach.

Analysis of clinical indicators also revealed reductions in the Plaque Index and Gingival Index values in the groups using fluoride preparations ($p < 0.05$). This suggests that fluoride exerts effects not only on enamel but also on overall oral hygiene and the stability of the microbial biofilm. Furthermore, both the number and size of demineralization lesions (white spot lesions) decreased, indicating activation of the remineralization process.

Furthermore, during the course of the study, the number of newly developed carious lesions was significantly lower in the groups using fluoride preparations, which serves as a direct clinical indicator confirming their preventive effectiveness. In addition, better outcomes were observed in groups with higher patient compliance, indicating that the effectiveness of preventive measures also depends on the active participation of patients.

From an immunological perspective, although fluoride preparations do not directly affect the immune system, they reduce microbial load, thereby decreasing inflammatory reactions and maintaining the stability of local tissues. This may be considered an additional factor contributing to the slowing of caries progression.

Overall, the obtained results demonstrate that fluoride preparations are highly effective in the prevention of dental caries in children, particularly when a comprehensive approach (oral hygiene + fluoride) is applied, allowing the achievement of optimal clinical outcomes. These findings are consistent with international studies and once again confirm the leading role of fluoride preparations in preventive dentistry.

Conclusion. The results of the present study scientifically confirmed once again the high clinical effectiveness of fluoride preparations in the prevention of dental caries in children. The obtained data demonstrate that the regular and proper use of fluoride preparations not only reduces the incidence of caries but also slows demineralization processes, thereby preserving the structural and functional stability of enamel tissue.

In particular, the significant reduction in the risk of caries development observed with the use of high-concentration fluoride varnishes, as demonstrated through RR, ARR, and NNT indicators, highlights their superiority as a preventive strategy. At the same time, the regular use of fluoride toothpaste also produced significant positive outcomes, indicating its suitability for widespread application in mass preventive programs.

Considering the multifactorial nature of dental caries, the highest preventive effectiveness can be achieved when fluoride preparations are applied not as a single intervention but as part of a comprehensive preventive approach. Such an approach should include improvement of oral hygiene, restriction of sugar consumption, regular dental examinations, and preventive education. The multivariate regression results obtained in this study also demonstrated that the effect of fluoride becomes stronger when combined with favorable hygiene and dietary factors.

From a biological perspective, fluoride preparations exert their effects by enhancing enamel remineralization, converting hydroxyapatite into fluorapatite, and reducing the metabolic activity of the microbial biofilm. This allows fluoride to influence several important stages of caries pathogenesis simultaneously. In this regard, fluoride preparations may be considered universal and highly effective agents for preventive dentistry.

At the same time, special attention should be paid to safety issues related to the use of fluoride preparations. Since excessive dosage may lead to dental fluorosis, a differentiated approach is required that takes into account the child's age, caries-risk level, and individual characteristics. This highlights the necessity of personalized preventive strategies.

From social and economic perspectives, the widespread implementation of fluoride preparations may reduce expenditures associated with dental caries, decrease the burden on dental healthcare services, and improve the quality of life of children. In addition, the

pISSN:2349-5707 Volume:13,Issue 5, May -2026 eISSN:2349-5715

introduction of preventive programs at school and family levels may contribute to improving oral health awareness and dental culture within the population.

In conclusion, fluoride preparations represent one of the principal and most effective methods for the prevention of dental caries in children, and the application of individualized and comprehensive preventive approaches can ensure the achievement of optimal clinical outcomes. Future directions should include the expansion of multicenter studies, the development of novel fluoride-containing preparations, and the implementation of digital monitoring technologies in order to further enhance preventive effectiveness.

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