The Role of Fluoride in Modern Dentistry: Benefits and Controversies

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Abstract

Dental caries is the localized destruction of dental hard tissues resulting from the acidic by-products, which are produced by the bacteria present in the oral cavity. Dental caries is considered the most common health condition affecting humanity, affecting 2.3 billion people worldwide. As a result, minimally invasive dentistry was developed to treat dental caries at an early stage and to decrease the high prevalence of dental caries among children and adults. Fluoride is one of the main components used in preventive measures in dentistry and in minimally invasive dentistry. It can inhibit enamel and dentin demineralization and induce enamel remineralization due to the replacement of fluoride ions with hydroxyl groups in the enamel hydroxyapatites, forming fluorohydroxyapatite, which has greater stability and reduced solubility in an acidic medium. Moreover, fluorapatite exhibits the lowest solubility and the greatest stability in the acidic medium. When these components are integrated into the composition of the enamel, it becomes more resistant to demineralization. Despite the presence of several studies confirming the benefits of fluoride in dentistry, it can result in multiple complications, such as dental fluorosis, skeletal fluorosis, and acute fluoride toxicity. Therefore, many countries have developed community water fluoridation to reduce the prevalence of dental caries. However, many individuals debated the ethics of community water fluoridation; therefore, several countries have developed alternatives to water fluoridation, such as fluoride in salt and milk. Additionally, caregivers and parents should be educated about the importance of topical fluoride, either in toothpastes or the topical fluoride that is applied professionally by dentists, to prevent the prevalence of dental caries in children.

Introduction

Dental caries is defined as the localized destruction of dental hard tissues resulting from the acidic by-products produced by bacteria present in the oral cavity after fermenting the ingested carbohydrates [1].Dental caries is considered the most common health condition affecting humanity, affecting [2,3] billion people worldwide.2,3 Dental caries is prevalent in children as well, affecting 46.9% of children aged 1 to 4 years old and 39.3% of children aged 5 to 9 years old[4]. Therefore, minimal intervention dentistry was developed to treat dental caries at an early stage, aiming to decrease the high prevalence of dental caries among children and adults.5 The goal of minimal intervention dentistry is to conservatively treat dental caries to maintain the tooth for life[5]. This can only be achieved through the early diagnosis, risk assessment, remineralization of the demineralized enamel and dentin, minimally invasive restorative intervention, repair rather than replace, and optimal caries preventive measures[6].

Minimal intervention dentistry protocols include the atraumatic restorative technique, which is used for sealants and restorations, the Hall technique, which is used for sealing carious lesions in primary molars using preformed stainless steel crowns, and using diamine fluoride for caries arrest and prevention[7-9].

Fluoride is one of the main components used in preventive measures in dentistry. It has the ability to inhibit dental hard tissue demineralization and induce enamel remineralization[10]. This property is attributed to the ability of fluoride ions to partially replace the hydroxyl groups in the enamel hydroxyapatites and form fluorohydroxyapatite, which has greater stability and reduced solubility in an acidic medium compared to the pure hydroxyapatite crystals[10,11]. Moreover, if the fluoride ions completely replace the hydroxyl groups, they form fluorapatite, which exhibits the lowest solubility and the greatest stability in the acidic medium. These components render enamel more resistant to demineralization.

Additionally, the presence of fluoride ions in the saliva or the dental plaque stabilizes the calcium and phosphate ions near the tooth, hence facilitating the remineralization of the tooth into demineralized enamel lesions[10]. Fluoride has an antibacterial effect, specifically against Streptococcus mutans, which is the primary causative pathogen in dental caries. Fluoride inhibits the enolase enzyme produced by bacteria, which decreases their acid production, hence diminishing their cariogenic ability[12,13]. Despite the remineralizing effect of fluoride, its benefits can be attenuated by the conditions of the oral cavity. For instance, if the plaque biofilm is thick, it reduces the ability of the fluoride ions to diffuse to the enamel crystals. Further attenuation can be caused by the limited buffering capacity of the saliva, reduced salivary flow, and variations in the biofilm matrix, which inhibit the cariostatic effect of fluoride[13].

2.Fluoride consumption sources

Fluoride has mostly been obtained via food before the 1960s. Fluoridation and fluoride-containing oral care products were introduced in the 1950s and 1970s, which improved the situation. In Developed Market Economies, fluoride can be found in aquatic, salt, and meals containing fluoride, drinks, infant cereals, and cereals formulae, fluoride supplementation, mouthwashes, toothpaste, and local fluorides. Furthermore, fluoride in water causes a ripple effect, in which beverages and food produced in fluoridated zones are accessible to the entire populace, even those living in non-fluoridated areas. When these different fluoride methodologies were joined, it created an incoherent fluoride distribution strategy. More coordinated and effective fluoride delivery systems could result in significant savings, optimum caries reduction, and reduced dental fluorosis, it is now clear [14]. Other fluoride media, such as salt, milk, tablets, toothpaste, gels, and varnishes, were developed, evaluated, and promoted as a result of massive breakthroughs in understanding how fluoride affects the caries process [15].

3.Mechanism of fluoride

It was assumed that fluoride's mechanism was pre-eruptive (systemic) when it was initially introduced and for many years afterward. It was integrated into the affected tooth formation, resulting in a less fractured tooth soluble enamel apatite dissolving enamel. However, research on the mechanisms of a participant in tooth caries and the effect of fluoride has increased significantly. This notion has shifted our perception of it [14]. It is now widely accepted that fluoride is the main mechanism of action in preventing dental cavities. It is post-eruptive (topical), stimulating remineralization while inhibiting calcification.

4. Role of fluoride in the maintenance of oral hygiene

Fluoride levels in the mouth are linked to the frequency and incidence of dental caries. The fluoride ion can prevent caries through various methods, including impacts on bacterial metabolism, albeit these are unlikely to be the predominant factors. It also affects the production of extracellular polysaccharides, the sugar transport system, enolase, and Adenosine triphosphatase (ATPase); however, unlike Sodium Fluoride (NaF), it has less impact on these systems. The fluoride ion's main action is to promote remineralization of early caries and to prevent demineralization; even minute levels have a big impact on both processes. On the other hand, sodium monofluorophosphate (MFP) must be broken down in the mouth to release fluoride, whereas the fluoride ion in sodium fluoride is immediately and completely accessible. MFP will release fluoride extremely slowly in the absence of phosphatases in an in vitro setting and will not have the same impact as NaF. Increased numbers of cariogenic bacteria such as Streptococcus mutans and Lactobacilli are detected in patients who ingest too much sugar.Even a minor change in terminal pH and acid generation rate can stabilize plaque flora and remove some of the benefits of cariogenic (aciduric) species. Low fluoride ion concentration enhances remineralization of enamel defects in vitro. The amounts detected in saliva (0.01-0.03 ppm) are about in the range when solubility inhibition and remineralization enhancement begin to occur. Fluoride concentrations in plaque may hinder bacterial growth. Fluoride concentrations in plaque may impede acid generation by plaque organisms and elicit other metabolic effects. Plaque fluoride is a major reservoir in the mouth that stores fluoride for a long time. The increased total fluoride content in plaque compared to saliva is due to calcium fluoride's subsequent retention in the plaque. After using sodium fluoride dentifrices at varied doses, plaque and saliva fluoride levels are consistent with the established relationship between fluoride levels and clinical impact. Phosphatases, on the other hand, hydrolyze MFP relatively slowly on the tooth surface in vivo.

5. Role of fluoride in dental restorative materials

Microbes may erode tooth enamel, the strongest substance in the body. Gum disease is becoming most common in all populations worldwide [16]. Since the beginning of discovery in the 1930s, connected fluorosis has been a condition that occurs when there is a small amount of tooth deterioration. Fluoride has been recognized to play a function in preventing caries in the mouth. This problem has been extensively researched throughout the years, and it is now recognized that fluoride works topically rather than systemically. Long-term fluoride to which the teeth are exposed has also been proven to be the most efficient strategy to leverage this topical impact and reduce dental caries.

6. Over-the-counter fluoride-containing agents

6.1.Fluoride Toothpaste

There are high-quality indication resources to assist the use of fluoride toothpaste in preventing caries. Fluoride toothpastes such as Cheerio gel, Colgate sensitive, Close up deep action, Senquel-F, and Sensodent-KF have always been the subject of well-controlled clinical trials showing caries reductions of up to 30%.

Fluoride toothpaste is the most common fluoride application due to its accessibility for most of the population[12]. The most common fluoride compounds used are stannous fluoride (SnF2), sodium monofluorophosphate, or sodium fluoride. These compounds significantly inhibit demineralization and stimulate remineralization, resulting in a significant reduction in the prevalence of dental caries[27]. The combination of amine fluoride and SnF2 in toothpastes provides a synergistic effect, combining the anti-microbial and cariostatic properties of SnF2 and amine fluoride, respectively[28].

6.2. Fluoride Gels and Varnishes

To reduce caries in youngsters, a sufficient level of concentration gels that contains 12,300ppm fluoride are employed. The processes involve a four-minute application, with measures designed to minimize fluoride consumption. Fluoride gels are only for high-risk individuals and aren't meant for Programs aimed at society or the general citizenry's welfare.

6.3. Fluoride Mouthrinses

Fluoride mouth rinses had been tested to benefit both a group and an individual. There are two basic methods for administering rinses: low-potency sodium fluoride (0.05%) and high-potency sodium fluoride (0.2%) [17].
Another fluoride delivery vehicle is fluoride mouth rinse. They contain fluoride with a lower concentration, ranging between 230 ppm for daily use or 900 ppm for weekly use. They have a significant effect in reducing the incidence of dental caries; however, the suboptimal adherence to it often causes weak results. Mouth rinses are not recommended for children under the age of six years old, due to the high risk of ingestion, resulting in systemic toxicity[29].

6.4. Fluoride Supplements

Fluoride additives have been utilized for both the well-being of the general society and individual consumption. The recommended dose schedule differs by area [18].

7. Benefits of systemic fluoride versus topical fluoride

Many studies reported that the ingestion of fluoride during the pre-eruptive stage resulted in a significant decrease in the prevalence of caries in permanent and primary teeth [19].Moreover, the residents in areas with fluoridated drinking water were found to have fewer carious lesions. Additionally, the systemic ingestion of fluoride during the prenatal stage reduced the caries prevalence in the deciduous teeth.[20,21].
Multiple studies provided evidence that confirms the caries-preventive effect of topical fluoride. For instance, toothpastes containing ≥1000 ppm fluoride can reduce caries incidence by 23% in children and adolescents in comparison to non-fluoridated toothpastes[12,22]. Whereas fluoride mouth rinses can reduce caries incidence by 27% in children and adolescents.21 However, topical fluorides applied directly to the teeth exhibited greater reduction in caries incidence than other topical fluorides. For example, fluoride varnish was found to reduce caries incidence in deciduous teeth by 37% and in permanent teeth by 43%, when applied two to four times annually. However, the effect of topical fluorides is attenuated by the lack of compliance[23].
The application of topical fluoride is essential in high-risk populations. For instance, in older patients, the use of fluoride varnishes, fluoride toothpastes, or fluoride mouth rinses can significantly reduce root caries resulting from gingival recession and xerostomia[24]. Patients with fixed orthodontic appliances can prevent the development of whit spot lesions and enamel demineralization by the regular use of fluoride toothpastes[25].Young children with early childhood caries, who cannot receive conventional treatment, can benefit from the cariostatic effect of topical fluoride through the use of silver diamine fluoride (SDF)[26].

8.Risks of using fluoride in dentistry

Despite the proven benefits of fluoride in dentistry, its excessive exposure can lead to several complications, such as dental fluorosis. Dental fluorosis is caused by the excessive ingestion of fluoride during tooth development. The severity of the condition is directly related to the dose of the ingested fluoride and the extent of time to which the individual was exposed to it. Excessive fluoride in the plasma interferes with the removal of amelogenins during the maturation of enamel, resulting in hypomineralized enamel[30]. The most susceptible population to dental fluorosis is children from birth to the age of eight. Water with a fluoride concentration of 1.5 ppm or more often causes enamel changes. The optimal level of fluoridated water is 1 ppm[31] Dental fluorosis affects primary and permanent dentition and affects both genders equally.
In mild cases, the patient may not be concerned, and it requires no treatment, unless the patient demands it for aesthetic purposes. In these cases, bleaching can be very beneficial, yielding positive results. In moderate cases, bleaching may yield optimal results; therefore, microabrasion of enamel and resin infiltration are recommended. If these treatment modalities did not result in a favorable outcome, a more invasive approach is followed using composite veneers or localized composite restoration to mask the discoloration. Whereas, in severe cases, indirect ceramic crowns or veneers are recommended[32].
Acute and chronic fluoride toxicity is a serious risk that can result from excessive exposure or ingestion of large amounts of fluoride. Most ingestion incidents are reported among children.
Acute fluoride toxicity occurs immediately after a single ingestion of a large amount of fluoride compounds, such as sodium fluoride. These compounds are completely absorbed through the gastrointestinal tract. The absorption of the fluoride compounds can be delayed if there is food or milk in the blood[33]. The levels of fluoride peaks in the plasma after one hour of ingestion, and most of the ingested fluoride is excreted in the urine. The symptoms of acute fluoride toxicity depend on the ingested dose of fluoride. In mild cases, acute fluoride toxicity is accompanied by nausea, vomiting, and stomachache. In severe cases, acute fluoride toxicity is accompanied by Convulsions, tetany, decreased myocardial contractility, hypocalcemia, hyperkalemia, ventricular arrhythmias, and cardiac arrest[33] Chronic fluoride toxicity can result in several local and systemic manifestations; one of the most common local manifestations is dental fluorosis[34] Systemic manifestations of chronic fluoride toxicity include increased bone density, joint pain, skeletal deformities, joint pain, and disability[35]. Additionally, chronic fluoride toxicity was linked to decreased intelligence quotient (IQ) scores and cognitive outcomes.

Conclusion

The role of fluoride in dentistry is pivotal in protecting teeth and preventing dental decay.
Fluoride plays an essential role in preventing dental caries, inhibiting demineralization, and stimulating mineralization. Although there are several studies confirming the benefits of fluoride in dentistry, it can result in multiple complications, such as dental fluorosis, skeletal fluorosis, and acute fluoride toxicity. Therefore, many countries have developed community water fluoridation to reduce the prevalence of dental caries. However, due

to ethical considerations and public opposition, many countries opted against community water fluoridation and replaced it with fluoride in salt and milk. Therefore, policymakers should provide a regulatory framework that balances the benefits of community water fluoridation and preserves the public's right. Additionally, caregivers and parents should be educated about the importance of topical fluoride, either in toothpastes or the topical fluoride that is applied professionally by dentists, to prevent the prevalence of dental caries in children.

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