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Review Article

Demystifying dental caries - A comprehensive review of causes, mechanism and treatment strategies

Ali Haider[1], Saqafat Ahmad[3], Saira Sattar[2*], Iqra Shaukat[4], Fatima Khizar[5], Areeha Aslam[4], Saima[5]

[1]Department of Medical Lab Technology, Faculty of Life Sciences, University of Okara, Okara 56300, Pakistan
[2]Department of Food Science and Technology, Faculty of Life Sciences, University of Okara, Okara 56300, Pakistan
[3]Department of Medical Lab Technology, Riphah International University, Sahiwal, Pakistan
[4]Department of Microbiology and Molecular Genetics, Faculty of Life Sciences, University of Okara, Okara 57000, Pakistan
[5]Department of Zoology, Faculty of Life Sciences, University of Okara, Okara 56300, Pakistan

***Corresponding author's email:** drsairasattar@uo.edu.pk

Abstract

Dental caries, a chronic disease of significant global reach, represents a leading public health problem affecting individuals across all age groups. The condition is characterized by the aggravating the loss of minerals in dental hard tissues, primarily due to the byproducts of bacterial metabolism that are acidic in nature. Bacterial species involved in caries development include *Streptococcus mutans, Streptococcus sobrinus,* and several species of *Lactobacillus* . These microorganisms contain unique pathogenic mechanisms that enable them to stick to tooth surfaces, convert sugars into harmful acids and then grow in acidic environments. This review analyzes the historical context and microbiology of dental caries and details the specific roles and mechanisms of *Streptococcus mutans* and various strains of *Lactobacillus* in advancement of caries. It also discusses the formation and composition of dental plaques as a significant factor in caries development, as well as the stages and symptoms of dental cavity formation. The review further explores the current treatment strategies, including antibiotics, fluoride applications, and advanced dental restoration techniques, highlighting their effectiveness and limitations in managing the prevalence of oral health problems. The comprehension of dental caries has evolved significantly; it remains a widespread problem, especially in areas with limited access to dental care. Continued investigation and innovation are crucial to developing more potent prevention and treatment methods, ultimately reducing the worldwide burden of this disease.

Keywords: Dental Caries, Streptococcus Mutants, Lactobacillus, Dental Plaque, Cavity Formation.

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Introduction

Caries is an ancient illness that is not specific to human beings. In addition to domestic animals, Caries have been found in bears and various other wild creatures. The initial theory was the "tooth worm theory" proposed by an ancient Chinese scholar around 2500 BC, positing a tooth worm as the cause of this decay [1]. A Sumerian text from 5000 BC illustrates a "tooth worm," a caries based. The term caries originated from the Latin word that means decay or decayed. It is the most common unremitting disease around the world. It's an irresistible disease characterized by a complex etiology and moderate advancement that causes the annihilation of hard dental tissues [2]. It concerns an irresistible bacterial post-eruptive infection that is characterized by advanced demineralization preparation. It appears to be the most prevalent oral condition worldwide and the leading cause of tooth removal among people. Due to dental caries harsh tissues of teeth become smooth. When bacteria contact with the sugars, it arises a hole in the teeth due to acid extraction. This tooth damage is terrible and makes it difficult to speak and eat. When the cavity becomes extreme it affects overall health such as it can affect the social relationship, eating, speaking, sleeping, and mod [3]. So, this disease is a serious issue globally. *Streptococcus mutans*, *Streptococcus sobrinus*, and *Lactobacilli* are microorganisms that can cause dental caries. Streptococcus mutans is the main contributor to the development of dental caries and significantly influences the deterioration of enamel [4] Bacteria from the Lactobacillus genus play an important role in the progression of caries, particularly in the secondary layer of teeth known as dentin. Mutans streptococci and lactobacilli are characterized by their capacity to thrive in acidic environments and their rapid metabolism of dietary sugars. A variety of facultatively. Bacteria produce acids as a result of carbohydrate metabolism. Therefore, the main cause of dental caries is bacterial acid, which is produced by metabolism. As shown in Figure 2. Dental caries affects 36% of the population in their permanent teeth[5]. In baby teeth, 9% of the population is affected. Nikiforuk in 1985 proposed the etiology of dental caries by primary factors such as susceptible host, a suitable substrate, and carcinogenic microflora, while secondary factors such as oral hygiene, saliva, fluoride, diet, nutrition, oral sugar clearance, the composition of enamel, morphology of the enamel, age of the teeth, and crystalline structure of the enamel. If dental caries is not addressed, then it can cause pain, infection, and limitation of normal daily activities. Dental caries can also cause death from sepsis. In this literature, we will explain the main cause of dental cavities, mechanisms of action, dental plaque, dental cavities, dental biofilm, stages, symptoms, and treatment [6]. The basic tooth anatomy and the key conditions required for caries formation are presented in Figures 1 and 2.

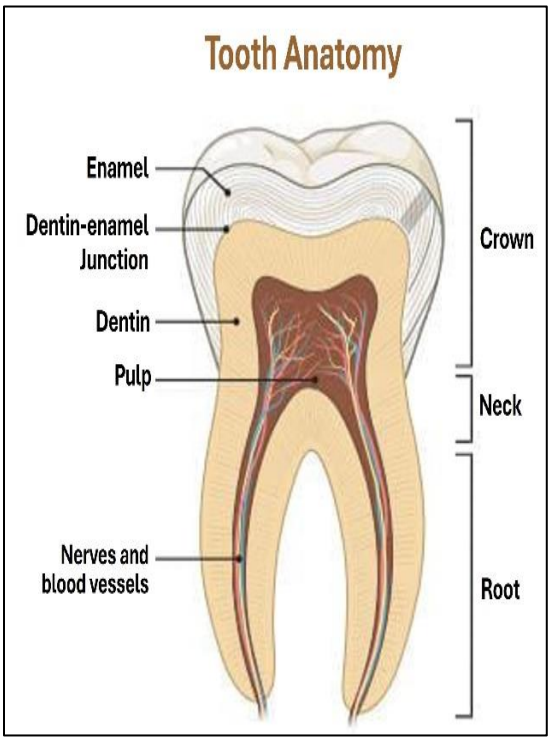

Figure 1: Basic structure of a human tooth showing enamel, dentin, pulp, crown, neck, and root.

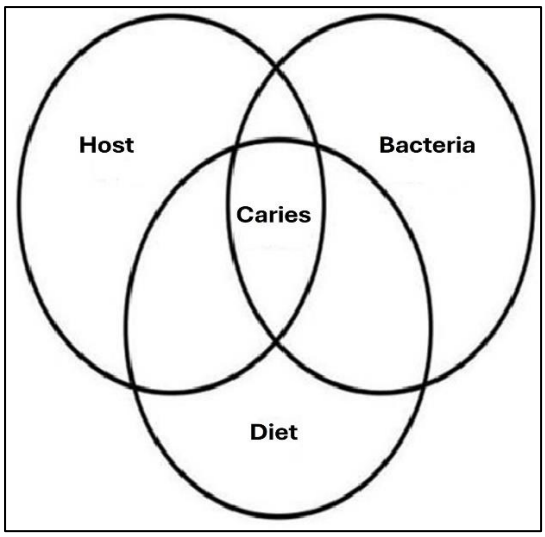

Figure 2: Essential factors required for dental caries development.

Bacteria that cause dental caries

Streptococcus mutans

Streptococcus mutants isolated in 1924 from a carious injury; this bacterium caught people's attention in the 1960s when analysts started considering dental caries [7]. Verbal organisms begin to colonize a baby's mouth shortly after they are born. The record of microbes in the oral cavity increases rarely due to contact with microbial sources from the surrounding environment Streptococcus salivarius, Streptococcus mitis, and Streptococcus oralism are oral microbes that can cause dental caries in newborns' mouth [8].

Ability to start and keep up microbial development and to proceed acid corrosive generation at low pH values, quickly accomplish the basic pH to accelerate the process of demineralization as compared to other common plaque microorganisms, the ability to produce intracellular polysaccharides like glycogen, which can serve as a nourishment source for utilize when dietary carbohydrates are low immunization of creatures against particular [9], S. mutans serotypes significantly lower the relative incidence of caries [10]. S. mutans won significance within the restorative community in the late 1950s. Three key characteristics of S. mutans contribute to its cariogenic potential [11]. The lasting colonization of difficult surfaces is brought on by the syncretization of a few numbers of extracellular polymers of glucans derived from sugar sucrose. The capability to exchange and process a critical amount of carbohydrates into acids in natural form (acidogenicity), and the capability to live in a natural pH environment, especially low pH (acidity) [12], as shown in Figure 3.

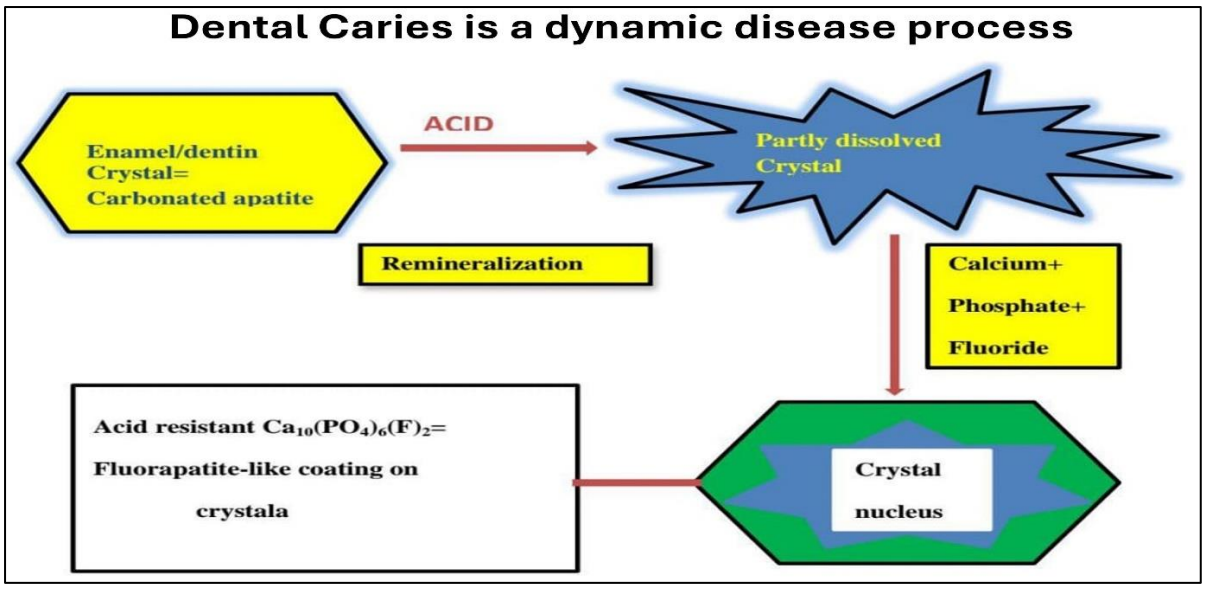

Figure 3: Overview of the caries process, showing demineralization by acids from cariogenic bacteria and subsequent remineralization forming a low-solubility surface on the crystals.

S. mutans synthesizes polysaccharides that are found in dental plaque. Dental caries is a condition where minerals dissolve, and acids are produced by bacteria that affect the enamel and dentine and spread within the tissue. *Mutans streptococci* are strong acid builders that thrive in an acidic environment and, therefore, constitute a risk of dent formation [13].

Streptococcus sobrinus

Streptococcus sobrinus has been related to tooth decay advancement and shown to be autonomous with *S. mutans*. Interestingly *S. sobrinus* is considered to have higher corrosive generation and corrosive resilience compared to *S. mutans* [14].

Lactobacillus

Lactobacillus was one of the to begin with known microorganisms connected with dental caries advancement. They can be obvious during the early stages of a child's life and are displayed inexhaustible in spit, on the upper surface of the tongue, in mucous layers; the difficult sense of taste, in dental plaque, and less common on the surfaces of the tooth [15].

Dental caries, specifically the development of advanced caries lesions in adults and children, has been linked primarily to *lactobacilli* [16]. The molecular mechanisms by which *lactobacilli* colonize and establish on the tooth surface, as well as how they interact with the surrounding environment and other major bacterial species in the plaque microbiota, are still unknown [17]. These interactions have an impact on the development of the plaque microbiota, including its temporal structure and composition. Groups of *lactobacillus Lactobacilli* are primarily two primary groups.

Homofermentative, which in the maturation handle of glucose, is byproduct lactic corrosive. For example, *lactobacillus casei* and *lactobacillus acidophilus.* Heterofermentative, such as lactic corrosive, generates acetate, ethanol, and carbon dioxide. For example: *lactobacillus* fermentum [18].

Lactobacilli are primarily thought to be nonpathogenic; some *Lactobacillus* species are shown in caries lesions. They are typically not found in caries-free children. The primary characteristic highlight of *Lactobacillus* is its capability to deliver lactic acid as a by-product of the glucose digestion system. The second most prevalent type of cariogenic bacteria in verbal vegetation is thought to be *Lactobacillus* [11]. The species of *Lactobacillus* that are fundamentally connected to the pathogenesis of dental caries are *Lactobacillus* gassier, *Lactobacillus fermentum*, and *Lacto-bacillus casei.*

Dental plaque

Dental plaque is a composite biofilm that forms on the challenging surfaces (teeth) within the oral cavity. The agreement in clinical dentistry has been that the collection of bacterial communities on the surfaces of teeth, known as dental plaque, referred as both rot and periodontal illness [19]. This conviction comes from the disappointment of 19th-century dental researchers to distinguish inside the plaques a microbial flora that was exclusively related to dental pathology. Black was the first to characterize the slimy microbial film found on the teeth' surface, which is the result of the accumulation of hundreds of species that are established in this biological specialty previously detailed by Miller and Williams [20]. The tooth surface is interesting among bodily surfaces because it is a non-shedding hard surface, which specifically absorbs different acidic glycoproteins (mucins) present in saliva, leading to the formation of what is termed the acquired enamel pellicle (AEP).

Plaque production generally requires microbial attachment to tooth surfaces, and microbial proliferation is most likely the main factor contributing to the buildup of dental plaque. The improvement of dental plaque can occur both supra-gingivally and sub gingivally [21]. The formation of plaque is a three-step process. Pioneer microorganisms will attach to a pellicle after it forms, multiply, and establish colonies. Spirochetes and filamentous organisms come together to form a coherent biofilm during the final step. Various items of the plaque bacterial byproduct enter the subepithelial tissue, causing provocative reactions such as upgraded and leukocyte diapedesis [22]. Both supragingival and subgingival plaque can create a difficult, mineralized mass known as calculus. The surface of calculus harbors microbes, which may compound the provocative reactions [23]. Both specific and general hypotheses. If the microorganism causing the disease was identified, then therapies for caries, periodontal disease, and other conditions might be more precisely targeted.

In order for an organism to be considered capable of a specific condition, Koch's hypothesis [24] has been utilized, which states that in every instance of the illness, the microorganism should have a distribution that matches the lesions found, the microbe needs to be cultured in artificial media for multiple subcultures, an animal that is vulnerable to the disease should contract it from a pure subculture, and during infection, it is important to detect a high antibody titer in the microorganism, as this may prevent reinfection.

Dental cavity

Dental cavities are like holes in the teeth or structural deterioration. Tooth decay is a very exceptionally common issue. It essentially influences children and youthful grown-ups, but it concerns anybody. Tooth decay is a commonplace cause of tooth misfortune in more youthful individuals. Plaque is a bacterium, acid, nourishment pieces, and saliva combined in the mouth to form a sticky substance [25]. Plaque, that is, if not evacuated from the teeth, turns into a substance that becomes tartar, also known as calculus. Plaque and tartar chafe the gums and can lead to gingivitis and periodontitis. Plaque starts to accumulate on teeth within twenty minutes after eating. If it is left in place, it will harden and become tartar (calculus) [26]. The acids in plaque haram the enamel covering your teeth. It also causes gaps in the teeth. These gaps are called cavities. Cavities regularly do not cause pain, unless they develop exceptionally expansive and haram nerves or cause a tooth fracture [27]. Common verbal well-being issues around the world are caries, tooth rot and dental cavities. This study proposes utilizing High-Intensity Color Detection and Neural Turing Machines to attempt a computerized approach to dental cavity reorganization [28]. NTM is a sort of counterfeit neural network (ANN) design that interfaces neural systems to outside memory structures. The essential reason for NTM is to fortify a Turing machine to explore curiously designs algorithms from different infection discoveries. The prescribed NTM-HICD framework integrates the qualities of numerous in-depth learning methods to boost the precision and vigor of dental depth detection [29].

Dental biofilm

A biofilm is defined as a collective bacterial association that sticks to a solid (such as a denture prosthesis) or with one another while covered by an extracellular polysaccharide matrix. Approximately 65% of human infections are connected to microbial biofilms. Dental plaque developed on tooth surfaces is a common appearance of a biofilm [30]. A developed dental biofilm consists of multiple microbial species, potentially including up to 100 different types. Biofilm microscopic organisms are the essential cause of dental

disorders [31]. The initial attachments of microbes to dental surfaces are headed by the advancement of a conditioning film on the clean tooth surfaces, primarily containing salivary glycoproteins, known as obtained pellicle [32]. The developing biofilm composition is administered by neighborhood biological components at the location of colonization and changes enormously at distinctive surfaces. Inevitably, if left unchecked, a highly diverse biofilm is formed. During biofilm development, bacteria are actively metabolically, consuming predominantly supplements from saliva [33].Steps of biofilm formation (a)Association: Dental film made on the tooth and providing a surface for bacterial attachment. (b)Adhesion: Within hours, bacteria attach loosely to the film.(c)Proliferation: Bacteria extend all over the mouth and start multiplying. (d) Microcolonies: Microcolonies are defined by *streptococci's* excrete layer of protection (slime layer). (e) Biofilm formation: Microcolonies made multiplex groups with metabolic additional benefits. (f) Maturation: The biofilm forms a primigenial circulatory system, as shown in Figure 4.

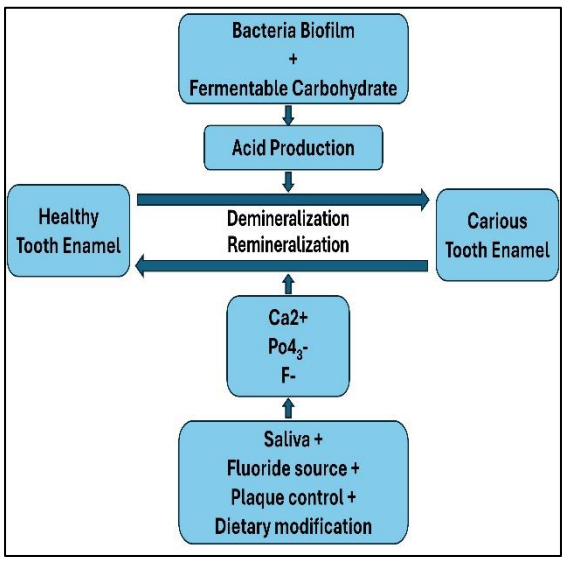

Figure 4: Diagram of the caries process showing the continuous flux of demineralization (destruction) and remineralization (repair).

Stages & symptoms of dental caries

The five particular stages of dental caries and their corresponding symptoms are described below:

Stage one

White spots: The arrangement of yellow markings or colorless white spots on the tooth's surface due to calcium loss, it is the starting stage of tooth rot, which remains treatable with appropriate treatment [34]. No prejudiced indications, including pain, exist.

Stage two

Enamel decay: The outer layer of the tooth begins to decay beneath the surface, while the outer shell remains intact, during this stage. The tooth's surface is crushed as decay progresses. Such sort of harm is irreversible with no sensation or pain [35].

Stage three

Dentin decay: In this phase, the rot painfully penetrates the second layer of a tooth and breaks through the enamel.

Stage four

Involvement of the pulp: At this stage, the pulp of the tooth becomes infected due to microbes acting on it. This infection affects the blood vessels and nerve fibers within the pulp, leading to pus development [36].

Stage five

Abscess formation: This is the final stage of the contamination, infection reaches the tip of the tooth's root, causing serious pain. There is a visible surrounding the cheeks, and the surrounding tooth is also affected as well [37], as shown in Figure 5.

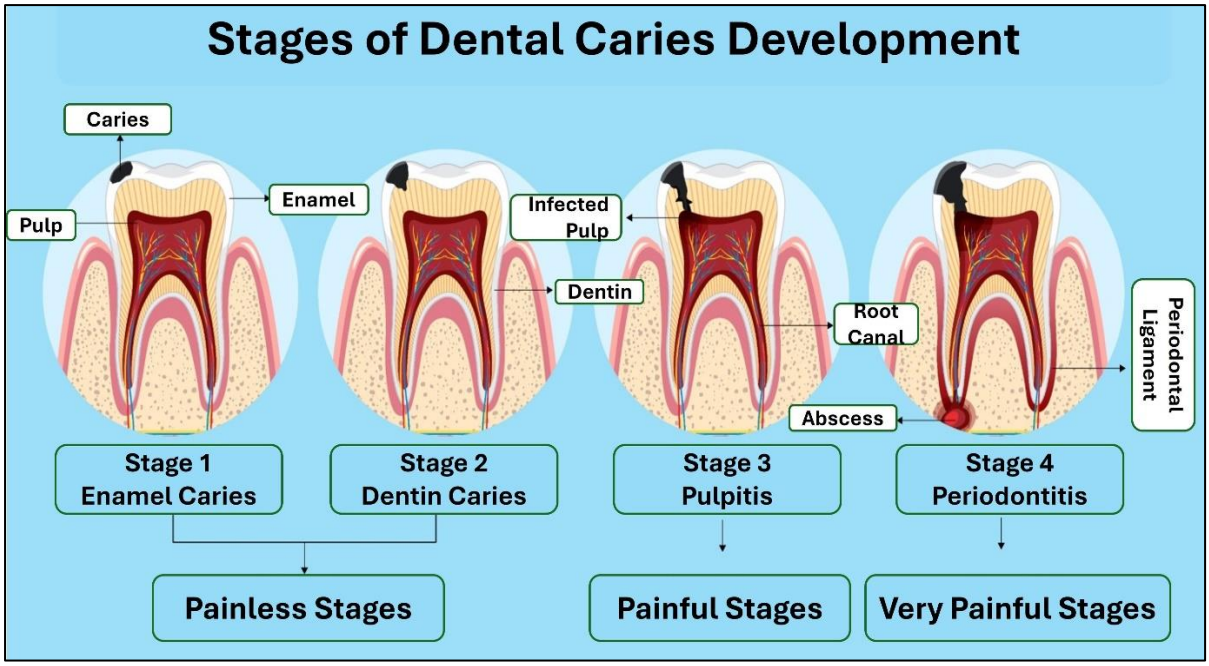

Figure 5: Stages of dental caries development, from enamel decay to abscess formation.

Treatment

Usage of antibiotics

Antibiotics are most frequently used in dentistry as prophylactic agents for preventive measures and management of endocarditis. Antibiotics are used for medicinal conditions including infections of oral hard and soft tissues [38]. In the mid of the 20th century sulpha containing drugs, like penicillin, which was discovered in 1941, were used to treat infections [39]. Penicillin, tetracycline, metronidazole, macrolides, and clindamycin are some examples of systematic antibiotics that demonstrate their uses, procedures, and aftereffects. The first beta-lactam antibiotic is penicillium, which originated from the Penicillium shape [40]. Firstly, Penicillium was utilized by McClure and Hewitt for the prevention of caries in rats. Tetracycline belongs to the class of broad-spectrum antibiotics that can avoid protein production because it binds to the 30S ribosomal subunit [41]. It appears that tetracycline integrates into human teeth, causing discoloration. Metronidazole is a class of antibiotics. Metronidazole is a cream that works against a broad spectrum of bacteria. 1960, in France, the first metronidazole used in a business setting [42]. With a somewhat wider antibacterial spectrum than penicillin, macrolides, a polyketide category of innate items, are used to treat infections [8].

Usage of fluoride

Fluoride is a substance that reduce the solubility of dental enamel when consolidated into the hydroxyapatite crystal, resulting in decreasing in its solubility and the critical pH required for dissolution [43]. Fluoride also carries its anticarcinogenic impact by being in solution and altering the saturation properties concerning the tooth mineral in the biofilm fluid at the tooth surface [44]. It also works inside the tooth mineral by promoting remineralization and decreasing demineralization. Fluoride's cariostatic effect is thought to be caused by a diversity of processes, including the inhibition of bacterial acid production, inhibition of extracellular polysaccharide (EPS) growth, prevention of enamel demineralization, and stimulation of remineralization. These procedures can work separately or in collaboration. This is illustrated by an

experiment in which the application of Sodium fluoride (NaF) fully stopped the process of demineralization without having any effect on the production and growth of the biofilm [45].

Dental extraction/crowning/filling

The non-surgical treatment of caries involves the utilization of pharmaceuticals, entering gum, or remineralization methods without utilizing dental drills or other devices for cavity preparation [46](Duncan, 2022). Hydrogel has been used in tooth fluoridation, cavity fillings, and root canal therapy for caries so far. Many conventional substances carrying antibacterial properties, especially silver, have been used in dental practice for a long time. Silver and mercury amalgam has demonstrated a strong antibacterial action against germs, both Gram-positive and Gram-negative [47]. Furthermore, silver cross-linked nanocrystalline cellulose (CNC) has illustrated the controlled discharge of silver, amplifying its antimicrobial activity in the dental setting. Furthermore, biomaterials based on silver, such as chitosan (CS), exhibit good adhesion qualities to mucosal surfaces due to its linear cationic biopolymer with excellent biological affinity. Zinc oxide NPs (ZnO-NPs) doped Ze (ZnONC) in combination with CS gel has demonstrated good biocompatibility in vitro and a synergistic impact for increased antibacterial activity [37].

Conclusion

Dental caries remains an important and persistent health issue globally; individuals of all age groups are affected by it. This review highlights the multidimensional etiology of dental caries, including the roles of bacteria such as *Streptococcus mutans* and *Lactobacillus*, the development of dental plaque, and the complex process of cavity formation. The reciprocal relationship between microbial metabolism, host factors, and dietary habits contributes to the progression of the disease. Although advancements in preventive and treatment strategies, including the use of fluoride, antibiotics, and restorative techniques, dental caries continue to be challenging particularly in at-risk populations with limited access to dental care. Future research should concentrate on improving preventive approaches, creating more effective treatments, and increasing accessibility to dental health resources. A detailed comprehension of caries progression, prevention, and management will be significant in mitigating the global burden of this oral disease.

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