Journal of Advanced Medical and Dental Sciences Research

@Society of Scientific Research and Studies *NLM ID: 101716117*

Journal home page: www.jamdsr.com doi: 10.21276/jamdsr Indian Citation Index (ICI) Index Copernicus value = 100

(e) ISSN Online: 2321-9599; (p) ISSN Print: 2348-6805

Review Article

Recent Advances in Dental Caries Prevention: A Review

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ABSTRACT:
Recent advances in dental caries prevention have significantly improved oral health outcomes through the development of innovative strategies and materials. One key area of progress is in the use of fluoride products, which remain a cornerstone in caries prevention due to their ability to strengthen enamel and inhibit bacterial activity. New delivery systems, such as varnishes and gels, provide prolonged exposure to fluoride, enhancing its protective effects. Additionally, the advent of bioactive materials, including remineralizing agents such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and hydroxyapatite, offers a novel approach to restoring demineralized enamel. These substances promote the natural repair processes of teeth, potentially reversing early lesions. Adhesion and sealant technologies have also seen advancements, with improved resins that provide better adherence and longer-lasting protection against caries. Moreover, the use of antimicrobial peptides and probiotics holds promise in modulating the oral microbiome, reducing the prevalence of cariogenic bacteria and promoting a healthier balance of oral flora. Technological innovations, such as real-time caries detection and monitoring devices, allow for earlier diagnosis and targeted preventive measures. Portable and user-friendly imaging devices enable better access to preventive care and personalized treatment plans. Finally, education and behavioral interventions leveraging digital platforms have been instrumental in changing oral hygiene behaviors, increasing adherence to preventive measures, and reaching wider populations. These combined advancements promise to significantly enhance preventive strategies, contributing to the reduction of dental caries globally.

Keywords: Dental caries, Prevention, Preventive Strategies

Received: 18 November, 2024 Accepted: 22 December, 2024

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This article may be cited as: Richa, Bhatt S, Shah R, Rodda R, Hasina, Sowki N. Recent Advances in Dental Caries Prevention: A Review. J Adv Med Dent Scie Res 2025; 13(1):7-10.

INTRODUCTION

Dental caries, commonly known as tooth decay, arises when the balance between demineralization and remineralization processes in the tooth is disrupted, favoring demineralization. This imbalance often results from various factors, including dietary habits, host susceptibilities, and particularly the presence of acid-producing bacteria within the plaque biofilm on the tooth surfaces. These bacteria are chiefly recognized as culprits, breaking down sugars in the diet to produce acids that erode the tooth enamel.[1]

Traditionally, the treatment of dental caries revolved around a surgical approach. This method involved the physical removal of decayed areas of the tooth. After scraping away the decayed material, a cavity was created and then filled with a biocompatible artificial material to restore the tooth's structure. Despite this restorative method, it often led to challenges over time. If the tooth continued to decay even after being

filled, it would typically result in the formation of larger cavities. These expanding cavities subsequently required more extensive treatment, continuing this cycle until the tooth could no longer be preserved and was eventually extracted.

Recent developments in caries management have shifted the focus significantly from surgical interventions to more disease-prevention-oriented strategies. This modern approach emphasizes the preservation of as much of the natural tooth structure as possible. Instead of simply treating the symptoms (i.e., the cavities), the focus is now on controlling and preventing the underlying disease process.[2]

Preventive measures may include better oral hygiene practices, the use of fluoride, dietary modifications, and regular dental checkups. These practices help maintain a healthy balance between demineralization and remineralization, thereby thwarting the progression of caries. There's also an increased emphasis on addressing and modifying lifestyle and dietary habits to decrease sugar intake and enhance oral health.[3]

In sum, the contemporary medical approach aims to stop or slow the progression of dental caries through prevention, thereby preserving the natural structure of the teeth. This evolution from a surgical to a medical strategy reflects an understanding that addressing the root causes of dental caries results in better long-term oral health outcomes.

Ideal Properties of Dental Caries Preventive Agent: An ideal caries-preventing agent should have several key characteristics to effectively minimize the risk and progression of dental caries. Here are the main requirements:[4,5]

Antibacterial Properties: It should have the capability to reduce or inhibit the growth of cariogenic bacteria, particularly Streptococcus mutans and Lactobacilli, which are primarily responsible for tooth decay.

Enhance Remineralization: The agent should promote the remineralization of enamel and dentin. It should work by supplying essential minerals like calcium, phosphate, and fluoride, facilitating the natural repair of mineral loss.

Low Toxicity: It should be non-toxic and safe for human use, causing no adverse effects on the oral tissues or the rest of the body.

Stable Compound: The agent should be chemically stable, maintaining its effectiveness over time and under various storage conditions.

Palatable: It should have an acceptable taste and texture, encouraging regular use without causing discomfort or taste aversion.

Long-Lasting Effect: The agent should have a sustained release or a long-lasting impact on the oral environment to offer prolonged protection.

Broad Spectrum: While targeting cariogenic bacteria, it should also cause minimal disruption to beneficial oral microorganisms, maintaining overall oral microbiome balance.

Compatibility with Oral Care Products: It should not react adversely with other common dental products such as toothpaste and mouthwash.

Ease of Application: The agent should be easy to use and integrate into daily oral hygiene routines, such as being present in toothpaste, mouth rinse, or as a varnish.

Proven Efficacy: There should be strong clinical evidence supporting its effectiveness in reducing caries incidence and progression.

Economically Accessible: It should be affordable and accessible to promote widespread use among various populations.

An agent meeting all these criteria would be highly effective in caries prevention, supporting both individual and public oral health.

Caries Prevention: Caries prevention is always preferable to treatment. Effective prevention requires a clear plan or series of steps. Here's how dental caries can be prevented:

Sugar Substitutes: Sweeteners are food ingredients that mimic the taste-enhancing properties of sugar, often referred to as sugar substitutes. Reducing sugar intake is crucial in preventing cavities, especially in children. Non-cariogenic sweeteners, when used sparingly, can provide an alternative to traditional sugars. Finding new, safe, pleasant, heat-stable, low-calorie sweeteners to replace more cariogenic sugars like sucrose, glucose, fructose, and maltose would be very beneficial in treating dental caries. Examples include Xylitol and Sorbitol.[3,4]

Sensi Stat Technology: SensiStat is a unique formulation that integrates calcium carbonate, commonly used as a mild abrasive in toothpaste, with arginine bicarbonate, an amino acid compound. This technology utilizes the ability of the arginine complex to bind the calcium carbonate particles firmly to the tooth's dentin or enamel surface. The binding facilitates a gradual dissolution of the calcium carbonate, leading to the release of calcium ions. This process supports the remineralization of the tooth surface, enhancing its structural integrity.[3-5]

ACP Technology: Amorphous Calcium Phosphate (ACP) technology is designed to keep calcium and

phosphorus components in a stable form until application, requiring a two-phase delivery system to achieve this. It employs calcium sulfate and dipotassium phosphate as the sources of calcium and phosphate ions. When these two salts come into contact, they rapidly react to form ACP, which can precipitate onto the tooth surface. Once ACP precipitates, it can readily dissolve into the saliva, making it available for tooth remineralization. This innovation in dental care was developed by Dr. Ming S. Tung. ACP first entered the market in 1999 as part of a toothpaste called Enamelon. After some time, this technology was reintroduced in 2004 under the name EnamelCare toothpaste.[3,7]

CPP-ACP: CPP-ACP, or Casein Phosphopeptide-Amorphous Calcium Phosphate, is a cutting-edge dental technology recognized for its significant anti-cariogenic, or cavity-preventing, properties. This innovative compound utilizes casein phosphopeptides, which are sequences rich in phosphoseryl residues. These residues play a crucial role in maintaining a stable quantity of amorphous calcium phosphate in the saliva, effectively acting as a calcium reservoir.

This stabilization process is vital as it enables the continuous release of calcium and phosphate ions into the mouth, promoting remineralization. This helps repair early carious lesions, or initial stages of tooth decay, reducing the risk of cavities, especially beneficial for individuals in high-cavity-risk groups.

CPP-ACP is versatile and available in various forms to accommodate different consumer preferences and needs. It can be found in chewing gum, lozenges, topical creams, toothpastes, sprays, mouthwashes, and even energy beverages, providing multiple avenues for incorporation into daily oral hygiene routines.

One of the standout benefits of CPP-ACP is its ability to neutralize harmful acids in the mouth, which is critical for oral health. In environments where acidic conditions are prevalent, such as after consuming food and beverages high in sugars and acids, CPP-ACP works to buffer these acids, protecting the teeth from demineralization and potential decay. Comparatively, using CPP-ACP products instead of traditional fluoride toothpaste is often seen as advantageous due to this acid-neutralizing capability, offering an additional protective mechanism against dental decay. The use of CPP-ACP is therefore a cost-effective and efficient therapy option, especially for populations at high risk for dental caries, making it a valuable addition to preventive oral care strategies. [3,7]

Bioactive Glass: Dr. Larry Hench developed bioactive glass, also known as Bioglass®, in the 1960s. This innovative material acts as a biomimetic mineralizer, meaning it imitates the body's natural ability to mineralize tissues. Bioactive glass influences cellular signaling processes, which is crucial for the restoration of tissue structure and functionality. A commercial form of bioactive glass, marketed under the trade name Novamin®, is produced by Novamin Technologies Inc. based in Alachua, Florida, USA.

Saliva plays a critical role in dental health, as it enhances the effectiveness of fluoride in preventing cavities. When saliva production is inadequate, often termed hyposalivation, this increased potential for dental cavities is due to the reduced availability of vital ions like calcium, phosphate, and fluoride. Bioactive glass can be a beneficial solution in such cases because it helps replenish these ions, promoting remineralization of the enamel.

Furthermore, women are particularly susceptible to dental caries during certain life stages such as ovulation, pregnancy, and post-menopause, due to fluctuations in salivary calcium levels. These fluctuations mimic the effect of reduced fluoride efficiency, making the protective role of bioactive glass even more significant during these periods.

The application of bioactive glass, particularly through Novamin Technology, shows great potential in enhancing enamel remineralization, especially for patients with systemic health issues. However, further research is needed to fully assess and confirm its effectiveness in these applications.[3,4,7-9]

Probiotics: Probiotics have garnered significant attention in the realm of dental health, especially in the prevention of dental caries. The central idea behind probiotics is to replace harmful bacteria with beneficial, nonpathogenic ones to improve oral health. Probiotics contribute to better dental health both directly and indirectly. They help lower the pH level in saliva and generate antioxidants, utilizing free electrons to aid in plaque mineralization. This process inhibits plaque formation by preventing the colonization of S. mutans on tooth surfaces, effectively stopping dental caries and plaque development.[2,8-11]

Caries Vaccines: Vaccines in dental health are designed as immuno-biological agents to trigger specific immunity against certain diseases. They work by stimulating immune responses and the production of protective antibodies. Dental vaccines can be composed of live, modified organisms, inactivated or killed organisms, isolated components of cells, toxoids, or combinations thereof. Notably, S. mutans, a key bacterium in dental caries, has various cell surface components such as adhesins, glucosyltransferases (GTFs), and glucan binding proteins (GBP). These elements are utilized in the development of vaccines aimed at preventing dental caries by targeting the biological mechanisms S. mutans uses to attach to and colonize teeth.[4,5]

Intraoral Fluoride Releasing Devices: Recent advancements in fluoride research have highlighted the potential of slow-release fluoride delivery systems for prolonged intraoral fluoride application. The two

primary types of these devices are copolymer membrane devices and glass devices infused with fluoride, along with several variations and enhancements available commercially. These devices are particularly effective because they can significantly increase fluoride levels in saliva without substantially affecting fluoride concentrations in urine. Research indicates that these intraoral fluoride-releasing devices hold substantial promise for various applications, such as preventing dental caries in children, high-risk groups, and individuals with inconsistent dental visits.[3-5]

CONCLUSION

Future prospects in dental caries prevention focus on integrating emerging technologies and personalized approaches to further ameliorate oral health outcomes. One promising area is the advancement of artificial intelligence (AI) and machine learning algorithms, which can predict caries risk based on individual health profiles and lifestyle factors, enabling personalized preventive strategies.

Nanotechnology also holds substantial potential, with ongoing research into nano-hydroxyapatite and other nanomaterials aimed at providing superior remineralization and antibacterial properties while being integrated into everyday dental products like toothpaste and mouthwash. These innovations could significantly enhance the protective layer on teeth, offering long-lasting defense against caries.

The development of more effective and longer-lasting dental sealants, potentially with self-healing properties and improved biocompatibility, could play a crucial role in widespread caries prevention, especially in high-risk populations.

Moreover, genomic studies may eventually lead to breakthroughs in understanding the genetic factors influencing susceptibility to dental caries, paving the way for gene-based therapies or preventive interventions.

Digital health technologies will likely continue to advance, offering tooth sensors that monitor oral health in real-time, providing feedback and reminders for optimal oral hygiene practices precisely when needed.

In conclusion, the future of dental caries prevention is promising, with numerous innovations on the horizon that will likely revolutionize oral healthcare. By combining technological advancements, personalized care approaches, and enhanced materials science, the dental community can look forward to reducing the prevalence of caries significantly. Continued interdisciplinary research and collaboration will be essential to successfully implementing these innovations, ensuring that they are accessible and effective across diverse populations and settings. The ultimate goal is to create a future where dental caries is a rarity rather than a common health issue.

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