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**THE PERFORMANCE OF NANOMATERIALS IN ADHESIVE DENTISTRY: A CLINICAL REVIEW**

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***Abstract***

*The increased necessity for esthetics and noninvasive tooth restorations accelerated the advancements in adhesive dentistry. However, the safe use and cytotoxic outcomes of several dental materials are still in controversy. The oral cavity is a significant source of microorganisms and could be a possible reason for infections in patients. The utilization of nanomaterials in the treatment of dental caries has increased now-a-days. Nanoparticles in delivery schemes, can implicate drugs/ material and employ the benefits of small size and enhanced penetration. These nanomaterials also benefited from a biomimetic approach to contribute more effective treatments. Meticulously, nanomaterials may offer a new development for the treatment of dental infections in the adhesive dentistry. This review extends a brief overview of the recent developments about the use of nanomaterials and types of dental adhesives for the treatment of dental caries*

***Keywords:*** *Adhesive dentistry; Dental caries; Nanomaterials; Cytotoxicity;*

## Introduction

Tooth decay or dental caries are one of the most serious and prevailing issue worldwide in oral health. As per WHO (world health organization) report, around 60-90% of adolescents and almost 100% of adults worldwide have the problem of dental caries [1]. This multifactorial illness triggers from saliva mainly due to an imbalance between demineralization(loss of minerals) and remineralization (mineral gain). The significant factors that leading to remarkable continuous destruction of tooth structure (dental caries) are substrates, microorganism, acidic invasion from cariogenic bacteria at low pH, host/teeth and time [2-3]. Hydroxyapatite ($Ca_5(PO_4)_3(OH)$) is predominantly targeted by the bacterial acids, which is the fundamental mineral constituent of the hard-dental tissues i.e. enamel and dentine.

The formation of acid trigger this dilemma arises from bacteria fermenting carbohydrates that results in the formation of the cavity due to mineral loss (demineralization) of the dental enamel [4-5].

The pH of the oral environment is the governing factor that regulates the gain or loss of calcium (Ca) and phosphate ($PO_4$) from the mineral structure of the teeth as shown in Fig 1(a) and (b). Usually, the oral fluids such as saliva, biofilm liquids consist of Ca and $PO_4$ in supersaturated concentrations regarding the mineral configuration of enamel that leads to continuous deposition of these ions ($Ca^+$ and $PO^-_4$) on the surface of enamel. Due to the existence of bacterial acids in oral environments, the pH of surroundings decreases, and biofilm oral fluids becomes undersaturated regarding the enamel mineral configuration [6-9]. When the pH of oral atmosphere persist below around 5.5 for enamel and around 6.5 for dentine, the chemical dissolution of Ca and $PO_4$ starts and results in demineralization of tooth enamel [10].

For the restoration of an advanced form of demineralization i.e. cavities formation problem, tooth-colored restoratives are used due to enhanced esthetic properties and easy preparation method [11]. These materials are a combination of the set of materials consisting direct resins, inorganic fillers, adhesion promoters etc., and utilized as direct restoration to recover missing biological tissues from past 40-50 years without leaving any detrimental impact on caries-related pathogens. However, previous studies have reported that these resin-based restoratives promote cariogenic biofilm growth. The optimization for the design formulation of dental materials produces a chance to impart bioactivity in dental restorative materials [12-13].

The use of nanotechnology in oral science has captured significant attention over recent years. Nanomaterials are the type of materials with physicochemical properties and have a broad area of applications comprising pharmaceutical applications. Nanotechnology has been revolutionized the efficacy of dental materials such as dental implants, antimicrobial dental adhesives, aesthetic restorative dental materials etc. [14, 15]. Different varieties of nanoparticles based dental formulations have been reported by many researchers so far that can be used as an aqueous suspension or added into paste/gel [16]. In dentistry, nanomaterials can be used as restorative dental materials or preventive dental care. Many research studies have reported new approaches to use nanomaterial and nanotechnology for the prevention or treatment of tooth decay by controlling the remineralization of the tooth surface and plaque-related biofilms [17-18]. This literature review briefly explains the recent developments in utilizing nanomaterials for dental applications/treatment of dental caries.

***Nanomaterial in restorative dentistry to inhibits dental caries development***

The extensive use of engineering and nanotechnology in dentistry has accelerated the evolution of modified or composite materials for dental applications. It is challenging to attain the optimum synergy between dentine and restorative material due to the complexity of tooth substrate, dentine protein, and collagen. Polymerization shrinkage, restorative fracture, and secondary caries are some disadvantages of dental composite restoratives [19, 20]. The contamination in saliva disrupt the composite restoration bonding with tooth structure and dental composite may deteriorate in the tooth cavity. Biofilm formation facilitates to the adverse oral condition i.e. increased surface roughness and prone to composite deterioration that decreases the restoration lifespan [21, 22].

The increased bacterial accretion and increased roughness may contribute to the development of secondary caries around composite restoration which is the most prevalent reason for the failure of dental composite restorations [23]. The bond strength of dopamine-methacrylate, 2-methoxyethyl acrylate dental restorative material studied by Lee et al. [24]. They have reported that random copolymer i.e. catechol-functionalized methacrylate comprises $Fe_{3+}$, enhances the bond strength of dental material in contaminated artificial saliva medium because, during polymerization, catechol groups debilitate proteins on dentine surfaces. It can act as a dental restorative material for moist dentine surface and have the potential to reduce the problems correlated with the saliva contaminated environment. The researchers have recommended that polymeric film of this material may decrease the chances of dental restoration failure in contaminated saliva environment. However, this polymeric adhesive can be utilized as a coating in dental implants, where good cell adhesion and good biocompatibility are desirable.

Freire et al. [25] investigated the cytotoxicity and antimicrobial effect of 4 chitosan–silver–fluoride nanocomposites with distinct sizes and shapes of fillers. They have found that shape and sizes of particles in nanocomposites did not show significant disparity in antifungal and antibacterial effect. Also, fabricated samples did not affect the growth curve of both positive and negative bacteria. It was concluded that fabricated nanocomposite encourages the regulation of multiple drug resistant microorganisms and do not imply extensive harm to human health i.e. no cytotoxic effect. This nanocomposite exhibits minimum inhibition concentration than that of silver diamine fluoride particles and shows efficient prevention for dental caries without leaving any stain on the teeth. Table 1 represents the effect of adding nanomaterials as well as the effect of market product with nanomaterials for dental caries application.

Yamagishi et al. [26] fabricated an acidic paste containing fluoride- hydroxyapatite that can repair small tooth decay without prior excavation by nanocrystalline growth and also assist to prevent their reoccurrence by strengthening the enamel. Authors have reported that within 15 min a 20 μm thick layer (i.e. consisting lengthened nanocrystals across the enamel-paste interface) of this formulation can be re-grown on the surface ofenamel.

Rigorous use of nanomaterials in biomedical field has changed these interests and growing in upward direction in which the high absorption rate of nanomaterials is a major problem. Large surface area to volume ratio has facilitated increased absorption rate of nanomaterials through

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skin, lungs and gastrointestinal tract. Accumulation of nano-biodegradable materials in various body parts could lead to an undesirable effect on biological tissues [30, 31]. However, underlying the potential of nanomaterials performance could be one of the future perspectives in the dental biomedical field.

## Conclusions

- In recent years, many studies have reported the performance of nanomaterials in dentistry for the cure of oral cavity issues. Nanoparticles can be used in a wide range of applications including drug delivery systems, biomacromolecules in the affected area etc. These nanoparticles use the advantage of being small that results in easy penetration of materials.
- The mechanical characteristics of dental materials are greatly governed by their bulk properties, whereas, biomaterials-tissue interactions are dictated by their surface characteristics. The surface properties of these materials can be modified by polymeric coatings that can provide excellent surface properties and biocompatible for clinical use.
- Despite enormous reports, clinical use of the specified techniques for dental caries is not yet enough. Many more products may be conferred based on the advanced nano-drug delivery systems that may provide better alternatives for human beings in the future.

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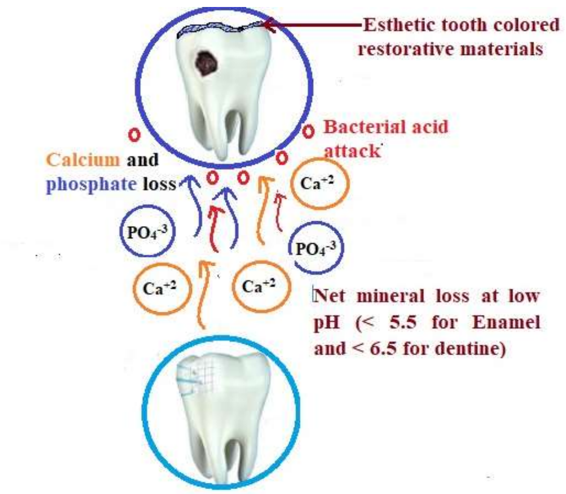


*Figure 1(a): The de-mineralization mechanism of human teeth*

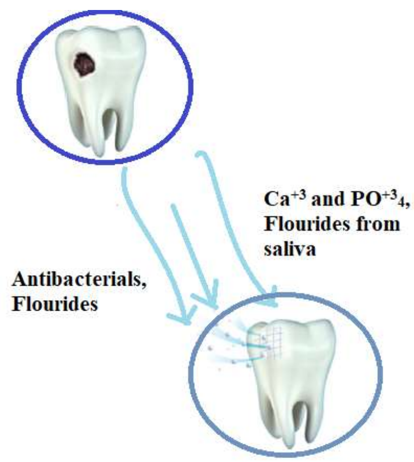


*Figure1(b): The re-mineralization mechanism of human teeth*

***Table 1:*** *Effect of adding nanomaterials on the dental caries*

| **S.No.** | **Strategies for adding nanomaterials** | **Effect of using nanomaterials** | **References** |
|---|---|---|---|
| 1. | An acidic adhesive containing fluoride-nano-hydroxyapatite | This material can repair small tooth decay without prior excavation by nanocrystalline growth and also assist to prevent their reoccurrence by strengthening the enamel. | 26 |

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| 2. | Fine rod-shaped apatite nanoparticles | It forms a mineral layer on the enamel surface with the help of amelogenin and fluoride by controlling the habit, size, orientation, and phase of apatite crystal. And shows comparable properties with tooth enamel surface. | 27 |
| 3. | Hydroxyapatites nanorods with modified surface | Modified Hydroxyapatites nanorods with specific characteristics enable it to self-assemble into organized prism-like structure on the surface of the water. The size and chemical compositions of these nanorods are comparable to natural enamel. | 28 |
| 4. | Amelogenin-chitosan hydrogel | The Amelogenin-chitosan hydrogel renovated enamel exhibits considerably better mechanical properties as elastic modulus and stiffness because the arrangement of apatite nanoparticles are similar to the structure of tooth enamel. | 29 |
| 5. | Nano Silica/Zirconia filled resin composites (market product of KetacTM Nano 3M ESPE brand ) | Improved mechanical and wear properties such as compression strength, flexural strength fracture toughness etc. | 30 |