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# Graphene – A New Innovative Material in Dentistry – A Review

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## Abstract

Graphene and its derivatives are used for various purposes in different fields of medicine because of their fascinating mechanical, physical and chemical properties. Although it has wide variety of applications the invitro and in vivo studies of graphene in dentistry are very limited. This article provides the application of graphene and its nanomaterials in clinical dentistry

**Keywords:** Graphene, nanomaterial, implants, tissue engineering

## Introduction

Graphene is an isolated pristine flat monolayers carbon from graphite. It was first isolated by Konstantin Novoselov and Geim in 2004(1). GRAPHENE is the name given to a first monolayer of carbon atoms tightly pack into a two-dimensional (2D) honeycomb lattice and is a building block for various graphitic materials. It can be converted into fullerenes, rolled into 1D Nanotubes or stacked into 3D graphite (1). It is the building block of various graphitic materials like graphite, nanoribbons, carbon nanotubes and fullerenes. Graphene is made into bi-layers and multi-layers. The properties of graphene get altered according to the number of layers. Graphene layers with less than the 10 layers they are called Few Layer Graphene (FLG). when their layers more than 10, their properties are similar to bulk properties. (1-3)

## Synthesis

Graphene can be produced by various methods like separation, peeling, solvent-based exfoliation of graphene, chemical vapour deposition, mechanical exfoliation called 'scotch-tape' method or ´peel-offs' method, unzipping of carbon nanotubes, reduction of graphene oxide from graphite by using various reducing agents, chemically modified graphene, epitaxial growth of graphene (4)

**Derivatives of Graphene**

The derivatives of graphene include Pristine graphene (PG), Graphene oxide (GO), reduced graphene oxide (rGO), Few Layer Graphene (FLG), Carbon Nanotubes (CNTs), Graphene Nanoribbons. Various forms of graphene differ from each other by surface properties, size and number of layers. Among the various derivatives of graphene, graphene oxide (GO) has shown excellent potential in many research fields and various applications in engineering, biomaterials, biomedical, drug delivery and tissue engineering (6).

**Graphene Oxide** has variety of chemically reactive functional groups on its surface, this functional groups on its surface, this functional groups helps in connecting with various materials such as DNA, proteins, biomolecules this is because graphene oxide has interesting properties such as high surface area, mechanical strength modulus ≈100 Gpa, excellent biocompatibility, affordable cost, very good optical property(5). This fascinating property leads the graphene to be used in the various possible dental applications. This review provides the overview of graphene and its applications in Prosthodontics.

**Biocompatibility**

Biocompatibility is the most important factor to be considered while introducing the new material for biomedical applications. The cytotoxicity of Graphene depends on the various factors like size, shape, surface charges, number of layers, purity, method of manufacturing. This is because the morphological characters could play a vital role in cellular uptake by the distinctive functional groups and they alter the interaction with cellular proteins and biomolecules.(7)

**Graphene and Their Applications**

**Antibacterial Effect:** Graphene´s antibacterial effect has gained attention in Biomedical sciences and Nanomedicine. The antimicrobial effect is mainly depending on the lateral size, shape and number of functional groups and surface modifications. So, the main reason for the antimicrobial property of Graphene Family Nanomaterials remains controversial (8). Various Microscopic studies shows that antimicrobial effect of graphene family nanomaterials is due to their

- Interaction of graphene materials with bacterial components like their phospholipid bilayer cell wall, DNA/RNA, or their proteins.
- Graphene family nanomaterials have spikes on their surface which pierces the bacterial cell wall which leads to the cell shrinkage and cell death
- Wrapping and photothermal ablation of the graphene family nanomaterials can prevent the bacterial proliferation by isolating bacterial colonies away from the growth medium by inhibiting their metabolic activity which leads to the bactericidal effect (9)

Experimental studies shows that GFNs has antimicrobial activity against E. coli, Streptococcus Aureus, Klebsiella species, Pseudomonas Aueroginosa and also has the antimicrobial effect on some oral pathogens such as Streptococcus Mutans, Porphrymonas Gingivalis. He et al, evaluated the antimicrobial effect of Graphene Nanosheets against the oral pathogens, at 40µg/ml – graphene oxide inhibits the growth of the P. Gingivalis and F. Nucleatum (10). Graphene Nanplatelets(GNPs) which is extracted via Thermal Exfoliation was studied for their antimicrobial properties properties against S. Mutans. The planktonic forms of S. Mutans gets killed when they get pierced by the spikes of graphene nanoplatelets (11). The antimicrobial effect of graphene is improved by their synergistic effect when they are combined with other materials like zinc oxide. The synergistic effect of graphene and Zinc Oxide (GZNC) shows the reduced biofilm formation and cariogenic property of S. Mutans (12) .

**Graphene As A Suture Material:** Mechanical Exfoliated Graphene (MEG) When mixed with conventional polyvinyl alcohol matrix showed the antibacterial effect against gram positive bacteria thereby improving the wound healing property(13).

**Graphene In Dental Implants:** Titanium implants have primarily and increasingly been used for oral rehabilitation due to their success in replacing missing teeth (Daubert and Wainstein 2019). Primarily osseointegeration is the most vital process that takes place between the host biological system and dental implant, secondarily tight soft tissue epithelial sealing around the dental implants determines the success of implant treatment. The bacterial colonization at the implant-osteogenic interface on the implant epithelial interface will impair osteogenesis and induce bone loss. This can be prevented by either inhibiting the bacterial proliferation or promoting tissue healing and osseointegeration. Graphene promotes osteogenesis by the expression of genes like RUNX 2 COL-I AND ALP, boosting osteocalcin gene and protein expression(14) . These genes help in the formation of mineralized matrix. TITANIUM is the first material of choice because of their excellent biocompatibility, corrosion resistance, toughness and low rigidity. Despite of their high clinical success rate of dental implants, periimplantitis is one of their major drawbacks. Recent advancements in nanotechnology improves the surface modifications of the implants such as surface composition, geometry, topography, roughness of implant surface to promote the osseointegeration and to avoid periimplantitis. Coating of graphene over Titanium substrate, because of the hydrophobicity of graphene film, this helps in decreasing the adhesion of S. Mutans (15)

**Periodontal stem cell differentiation:** Graphene oxide/chitosan/Hydroxyapatite- Titanium (GO/CS/HA-Ti) is produced by incorporating (GO) And chitosan (CS) into the Hydroxyapatite -Titanium substrate by using electrophoretic method (17) . in vivo study showed the improved adhesion, proliferation and differention of BMSC cells and improved Osseointegeration (16). Qin et al 2020 used graphene oxide to enable the reosteogenesis of previously contaminated titanium. Graphene oxide significantly removed polymicrobial biofilms that remained on previously contaminated titanium surfaces. Kalisz et al 2014, studied the comparison of mechanical and corrosive properties of graphene monolayer and niobium pentoxide. studies showed the use of combined layers of niobium pentoxide and graphene in the hybrid multilayer surface can improve mechanical and corrosion properties of alloy surface. so, this can be used as protection coating for Ti alloy in various biomedical applications and also for other engineering applications in future. So, with excellent antimicrobial effect of graphene and their improved mechanical and anticorrosive properties and also their potential osteogenic differentiation around implants shows that graphene graphene gained the attention in dental implantology(16) .

**Graphene in the drug delivery system:** Graphene can be used in the drug delivery system in dentistry by incorporating graphene oxide over the dental implant surface because of their antibacterial activity. Studies showed that graphene oxide modified materials successfully released Levofloxacin, Gentamicin sulfate from graphene, Dexamethasone and BMP-2. This drug delivery system studies could help to overcome the periimplantitis which is one of the major reasons for implant failure.

**Graphene in tissue engineering:** The main aim of tissue engineering research is to develop stem cells together with their biomaterials. Graphene oxide nanosheets along with chitosan 3D scaffolds composition showed the enhanced bioactivity and improved osteogenesis (17) . graphene oxide scaffolds in tissue engineering and this improves the cell proliferation, differentiation. Xie et al, evaluated the use of graphene to induce osteogenic and odontogenic differentiation in DENTAL PULP STEM CELLS (DPSCs). Radunovic et al studied about GO – coated collagen membranes on DPSCs. Graphene oxide coated membrane promotes better proliferation of DPSCs differentiation into odontoblasts and osteoblasts along with that they can control the inflammatory events.

**Graphene in dental materials:** Graphene and their various forms can be mixed with dental implant materials to improve their properties because of their better tensile strength and young's modulus (18) . Algamir et al., studied about GO when incorporated with PMMA showed the improved the dimensional stability (PMMA/GO) than pure PMMA. (19) Sava et al., investigated the properties of nanocomposites when using the hydroxyapatite and graphene, bio glass, colloidal silica, as the reinforcing filler along with BIS -GMA & TEGDMA as a matrix. This addition of graphene Nanoparticles showed the improved surface hardness and flexural strength (20).

**Other biomedical applications:** Graphene and their derivatives also used in biosensors (21) , bioimaging, cancer therapy- targeted drug delivery system. Tissue engineering, guided bone regeneration (22), gene therapy, as antibacterial agents, photothermal therapy. Because of their high flexibility, very thin and transparency of 97.4%, graphene could be used in prosthetics and also used for manufacturing diagnostic tools (21).

**Conclusion**

Graphene with their incomparable physical and chemical properties like chemically inert, extremely light, transparency and flexibility, electrical conductivity, mechanical strength and improved bioactivity when added with different substrate. In dentistry graphene is the promising upcoming new candidate with robust applications. Graphene, the unique material with one carbon atom thickness needs further investigations to explore their usage and its derivatives in all aspects of dentistry.

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