GRAPHENE A MAGICAL NANOMATERIAL IN CONSERVATIVE AND ENDODONTIC DENTISTRY

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ABSTRACT

Graphene, a two-dimensional carbon allotrope, is the strongest, stiffest, and thinnest known material, exhibiting exceptional mechanical strength, electrical conductivity, biocompatibility, and biodegradability. Produced via the Hummers method, graphene, and its derivatives, particularly graphene oxide (GO) and reduced GO, are emerging as engineered nano materials in dentistry. They interact with dental pulp stem cells, enhancing Odontogenic and osteogenic gene expression, making them valuable in regenerative dentistry. Graphene's anti biofilm and anti-adhesive properties contribute to root canal debridement, caries prevention, and erosion control. Incorporated into biomaterials like glass ionomers, bio dentine, and bleaching agents, graphene enhances their properties and serves as an effective antibacterial agent. There is graphene's promising role in conservative dentistry and endodontics, though further research is essential to fully realize its clinical potential.

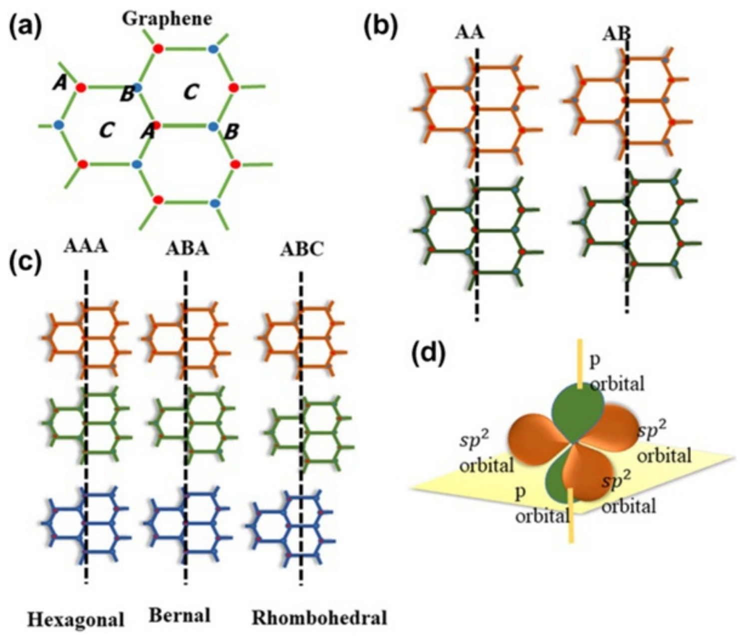
Keywords: graphene, hummers method, graphene oxide, reduced graphene oxide

INTRODUCTION

Graphene, a two-dimensional carbon allotrope arranged in a honeycomb pattern, exhibits exceptional mechanical, physical, and chemical properties. Its derivatives, such as graphene oxide (GO) and reduced graphene oxide, offer a wide range of biological and clinical applications. Graphene oxide is biocompatible and antibacterial, making it an innovative material in various dental fields, including restorative dentistry and endodontics.1

The concept of graphene dates to 1962, but its isolation was achieved only in 2004 by Andre Geim and Konstantin Novoselov, a breakthrough that earned them the Nobel Prize in Physics. Over time, advancements in the preparation of graphene derivatives, such as GO, have enabled their application in biomedical fields.[1]

Graphene is a single atomic layer of carbon atoms arranged in a hexagonal pattern. It has a thickness of only 0.334 nm, making it the world's thinnest material. It has numerous distinguishing qualities due to its unique properties, such as a large specific surface area (~2600 m2/g), high electron mobility (200,000 cm2/Vs), enhanced thermal conductivity (3000–5000 Wm/K),extreme optical transparency (97.4%), and exceptional mechanical strength, with a Young's modulus of 1 TPa.[2]



Urade AR, Lahiri I, Suresh KS. Graphene Properties, Synthesis and Applications: A Review. JOM (1989). 2023;75(3):614-630. doi: 10.1007/s11837-022-05505-8. Epub 2022 Oct 14. PMID: 36267692; PMCID: PMC9568937.

PREPARATION

GO is commonly synthesized through the modified Hummers method, which involves the chemical oxidation of graphite. This method introduces oxygen-containing functional groups to the graphene structure, making it hydrophilic and increasing its binding capabilities. The development of these preparation techniques has paved the way for incorporating GO into a variety of biomaterials.[4]

BIOLOGICAL PROPERTIES

a. Biocompatibility

GO's hydrophilic nature enhances its biocompatibility, allowing for cell attachment and proliferation. Studies indicate that GO upregulates mineralizing cell activity, promoting tissue regeneration. Importantly, GO has shown no renal or hepatic toxicity in experimental models, underscoring its safety for medical applications.[3]

b. Antibacterial Properties:

GO demonstrates significant antibacterial activity by physically disrupting microbial membranes. It penetrates and breaks bacterial membranes, disrupting Van der Waals forces, making it effective against various oral pathogens. This property is particularly advantageous in restorative and endodontic applications, where infection control is critical.3

c. Biodegradability:

Neutrophils, a type of immune cell, have been shown to degrade GO, enhancing its biocompatibility, and minimizing long-term accumulation in tissues.3

POTENTIAL USES IN DENTISTRY

Graphene and its derivatives are now being incorporated into a wide range of dental materials, offering improved mechanical properties, antibacterial efficacy, and biocompatibility.

a. Restorative Dentistry

Incorporating graphene-derived nanomaterials into glass ionomer cements (GICs) has significantly enhanced their mechanical strength and antibacterial properties. For example, the addition of fluoride graphene reduces internal porosity and microcracks, while increasing resistance to microbial invasion and erosion. This makes graphene-modified GICs an excellent choice for long-lasting and durable restorations.[3]

b. Endodontics:

Irrigating Materials:

Graphene-based irrigants have been shown to effectively disinfect root canals while preserving dentin integrity. Recent innovations include combining graphene with silver nanoparticles, which provides antibacterial efficacy comparable to sodium hypochlorite while reducing cytotoxicity.

Photodynamic Therapy (PDT):

Photodynamic therapy, involving a photosensitizer such as indocyanine green (ICG), has been used for disinfection. However, when ICG is modified with GO, its stability, bioavailability, and antibacterial efficacy are enhanced, making it more effective against persistent infections such as **Enterococcus faecalis.**[3]

Obturating Materials:

Graphene nanosheets have been incorporated into bioactive materials like Bio dentine and Endocem Zr to reduce setting times and improve antimicrobial activity. Singh et al. developed a graphene oxide-based polymer nanocomposite obturating material that demonstrated superior mechanical properties and biocompatibility compared to conventional gutta-percha.[3]

c. G-CAM: A Graphene-Reinforced Biopolymer

G-CAM, a graphene-reinforced biopolymer disc, is a breakthrough material for dental restorations. It offers superior aesthetics, mechanical properties, and biocompatibility. Its benefits include:

Durability: Chemically inert and resistant to oral fluids, ensuring long-term stability.

Aesthetics: Available in a wide range of natural dental shades for optimal patient satisfaction.

Comfort: Lightweight and non-irritant, providing an improved patient experience.

Repairability: Easily repaired with light-cure composite in case of damage.

SCOPE IN CONSERVATIVE DENTISTRY AND ENDODONTICS

The integration of graphene into dental materials is revolutionizing the field. Graphene derivatives enhance the bioactivity, mechanical strength, and longevity of restorations. Their biocompatibility and antibacterial properties are particularly valuable in preventing recurrent caries and ensuring the success of endodontic treatments. The future scope includes the development of graphene-based scaffolds for tissue regeneration and further refinement of graphene composites for everyday dental applications.[4]

CONCLUSION

Graphene and its derivatives represent a paradigm shift in dental materials science. Their unparalleled mechanical strength, large surface area, and ability to integrate with other substances make them ideal for enhancing existing biomaterials. With ongoing research, graphene is set to play a pivotal role in the evolution of restorative and endodontic practices, providing more durable, biocompatible, and effective solutions for dental care.

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