International Journal of Research in Medical Sciences
Madhav VNV et al. Int J Res Med Sci. 2022 Jul;10(7):1565-1567
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20221807

Review Article

Graphene: a game changer in prosthodontics and implant dentistry

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Received: 05 May 2022
Revised: 25 May 2022
Accepted: 30 May 2022

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ABSTRACT

Graphene family nonmaterial, with supercilious mechanical, chemical, and biological properties, have grabbed attention on the path of researches seeking newer materials for future biomedical applications. Although potential applications of graphene had been highly reviewed in other fields of medicine, especially for their antibacterial properties and tissue regenerative capacities, in vivo and in vitro studies related to prosthodontics are very limited. Therefore, based on current knowledge and latest progress, this article aimed to present the recent achievements and provide a literature review on potential uses and applications of graphene that could be converted into clinical reality in prosthodontics.

Keywords: Graphene, Graphene based biosensor, Graphene oxide, Nitrogen doped graphene, Graphene nanoplates, Graphene nanoflakes

INTRODUCTION

Prosthodontic materials when placed within oral cavity are coming in contact with saliva, gingival crevicular fluid, and water. Also, it is exposed to high temperature changes, occlusal and masticatory forces and abrasion causing mechanical failures and overtime requiring restoration replacement with extra cost.

Additionally, almost all material comes in tight contact with oral tissues; for that reason, they must be noncytotoxic and biocompatible for a harmonious interaction with host tissue while doing their functions.[1]

Graphene was discovered by Andre Geim and Konstantin Novoselov at the University of Manchester in 2004. Their discovery gave them Nobel prize in 2010. Novoselov stick a flake of graphite to a scotch tape and then exfoliated it to separate the graphite layers and repeated this process several times to reduce the thickness of graphite until few layers of graphene sheet was isolated. The International Union for Pure and applied Chemistry (IUPAC) recommended use of the name "graphite" for the three-dimensional material and "graphene" only when the reaction, structural relation or other properties of layer are discussed. Graphene is a single sheet of one-atom thickness arranged in a honeycomb-like lattice.[1] The aim of this article is to furnish general outline of graphene in prosthodontics.

GRAPHENE STRUCTURE

Graphene is a single sheet of one-atom thickness arranged in a honeycomb-like lattice. Each carbon atom is covalently bonded to three other carbon atoms with Sp_2 hybridization. While the interlayer is re-arranged through weak van der Waal forces. These forces are responsible for the softness of this material.[2,3]

PROPERTIES OF GRAPHENE

Strength

Monolayer graphene is the strongest material ever tested with a strength of 42 N/m.

Toughness and stretchability

Comparatively brittle, it can be stretched by up to 25%–highly relevant for flexible electronics.

Impermeability

Even the minimum atom (helium atom) cannot pass through a sheet of graphene.

Electrical resistivity

1×10-8 Ω•m among the lowest of any known material at room temperature (~35% less than copper).

Other properties include: completely impermeable, highest density at room temperature, large surface area (-2600 m2g-1), exceptional thermal conductivity and chemical stability (S000W/m.k), high intrinsic mobility (100 times more than in Si), biocompatible, and antibacterial.[4,5]

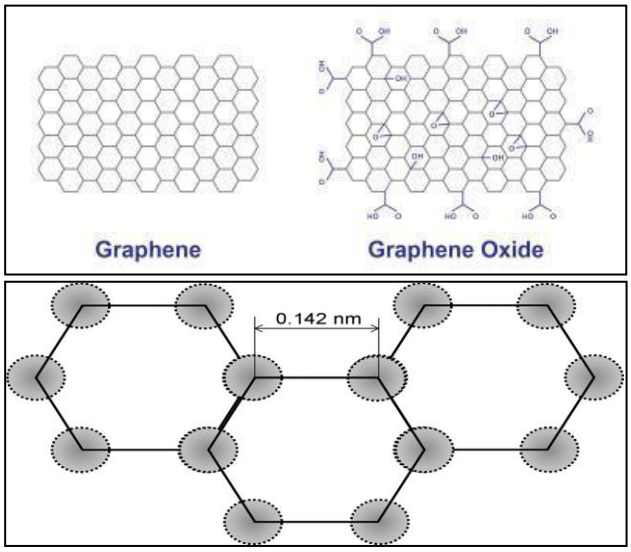

Figure 1: Structure of graphene and graphene oxide.[3]

GRAPHENE AND ITS DERIVATIVES

Graphene related materials can be classified based on either number of layers (e.g. mono- or multi layered) or their chemical modification into: graphene oxide (GO), reduced GO (rGO), and nitrogen doped graphene (N-G).

GO is a highly oxidized form of graphene prepared by oxidation of graphite. rGO can be further reduced to graphene like sheets by removing the oxygen containing groups with the recovery of a conjugated structure.[6]

GRAPHENE FORMS

The graphene forms include: graphene nanoplates, graphene nanoflakes, graphene powder, graphene thin sheets, and graphene foam.[7]

Advantages

Advantages include: it is the thinnest yet the strongest, it is a good conductor of heat and electricity, it is both pliable and transparent, used in production of high-speed electronic devices, enhance differentiation of stem cells, biocompatible, high elastic modulus and limit to ensure that the tensions generated during biting and chewing do not cause permanent deformations, and it is possible to manufacture prosthesis of smaller sections, high deformation resistance and stress limit, thus avoiding the formation of cracks and fractures, high impact resistance which is useful for removable prostheses, high-abrasion resistance that avoids excessive erosion from cleaning or eating, increased hardness of the material compared with acrylic resins used in dentistry, and chemically inert and insoluble in oral fluids.[8]

Disadvantages

Disadvantages include: graphene is prone to oxidative environments in the form of catalyst, through its jagged edge graphene penetrate cell membrane as well as disrupts normal function, and super expensive.[9]

APPLICATIONS IN BIOMEDICAL FIELD

Medical applications

Graphene based biosensors are used for detection of small biomolecules (dopamine, and glucose) proteins and DNA through pi-pi stack interactions.[3]

For drug delivery, GO and its derivatives exhibits properties used to carry DNA, proteins and antibodies.[10]

For cancer therapy, cancer stem cues (CSC) or tumour stimulating cells are resistant to predictable therapeutic approaches. Drug resistant CSC can cause unfavourable chemical outcomes.[11]

Dental application

Tensile properties of graphene are comparable to bone, enamel and dentin make it a suitable dental restorative material. With good incompatibility and aforementioned properties graphene can be used successfully in implant dentistry as well.

Detection of bacteria

The single atom thick graphene is of particular interest because of its optical properties as well. Specialization have been made to identify the specific type of organism.[12]

Antibacterial activity of graphene

A study conducted by He et al evaluated the antibacterial activity of GO nanosheets against these three common types of bacteria and found that GO nanosheets were

highly effective in inhibiting the growth of dental pathogens.[13]

Restorative dentistry

In recent years, attempts had also been made to incorporate graphene derived nanomaterial into commercially available glass ionomer for reinforcement. Graphene, when combined with glass ionomer prepared with poly (acrylic acid), has significantly enhanced physio-mechanical properties of GIs.[14]

Prosthodontics

As graphene is a single sheet of one-atom thickness arranged in a honeycomb-like lattice. Each carbon atom is covalently bonded to three other carbon atoms with Sp_2 hybridization. While the interlayers are re-arranged through weak van der Waal forces. These forces are responsible for the softness of this material. Graphene exists in different forms such as graphene sheets, GO and rGO. GO's properties, such as its biocompatibility and biodegradability, strength (Young's modulus of Y ~ 1.0 TPa), antimicrobial-adhesion characteristics, flexibility, and transparency make it a material with potential in prosthodontics.[10,11,13]

Coating for implants

Due to graphene's potential osteogenic and antibacterial ability, it appeared to be an excellent implant coating material to favour better osseointegration.[15]

CONCLUSION

Graphene has special properties that alter the world of prosthodontics in better way. Graphene has 2D like nature and its superior properties, making it useful for prosthodontics and implant dentistry. It is the strongest material till now; however, its brittle nature so it cannot be used structurally. However, it can be used to reinforce other materials. It has various applications in medical field. Further research is needed to look into depth of its usage in prosthodontics and implant dentistry.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

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Cite this article as: Madhav VNV, Joshi S, Kulkarni M. Graphene: a game changer in prosthodontics and implant dentistry. Int J Res Med Sci 2022;10:1565-7.