FULLERENE CARBONNANO TUBES IN DENTAL MATERIALS- A REVIEW

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Abstract-

Over the past two decades, much research has focused oncarbon nanotubes in various fields, including medical and dental applications.Carbon nanotubes are light and biocompatible,exhibiting good electrical and thermal conductivity and having exceptional tensile strength due to the size and strength of the bonds in between the carbon atoms. Due to these characteristic features, they are used in material science in dentistry.Various dental materials incorporated with carbon nanotubes have shown to enhance the mechanical properties and antimicrobial effects.

Key words- Carbon nanotubes, buckytubes, polymethyl methacrylate, dental materials,dentistry

Introduction

An allotrope of carbon, "fullerene", consists of carbon atoms that stay connected either by single or double bonds, resulting in a closed or half-closed mesh like structure. Fullerene molecules consist of carbon in hollow spherical, cylindrical, or ellipsoidal form. Cylindrical forms are referred to as carbon nanotubes or Buckytubes, whereas spherical ones are referred toas Buckyballs.[1,2,3]In the year 1991, Sumio Ijima, through his experiments, created carbon nanotubes which had hexagonal lattices.[3]Over the past two decades, various researches are focused into carbon nanotubes in various fields, including medical and dental applications.Carbon Nanotubes have the potential to be the building blocks of future new technologies, which promise to be an accelerator for a revolution in medical and dental fields.

Fundamentally, there are two types of carbon nanotubes, namely single-walled carbon nanotubes (SWCNTs) and multiple-walled carbon nanotubes (MWCNTs).Single walled carbon nanotubes have a single layer of graphene, that is made of hexagonal rings of carbon atoms.Whereas multiple-walled carbon nanotubes have multiple layers of graphene, where a stack of graphene sheets form into concentric cylinders, giving it a very complex structure.[4,5,6]

Carbon nanotubes are light and biocompatible.[1,4] They exhibit good electrical and thermal conductivity, and have exceptional tensile strength due to the size and strength of the bonds in between the carbon atoms.Due to these characteristic features, they are used in material science in dentistry.[7]

CARBON NANOTUBES IN DENTAL MATERIALS

In Polymethyl methacrylate resin-

Polymethyl methacrylate resins are widely used in dentistry, but the major drawback remains their poor antimicrobial properties, accelerating the chance of infection in the oral cavity. Research has proved the efficiency of carbon nanotubes in polymethyl methacrylate resins, thus favouring their use in removable or temporary biomaterials as well as implant biomaterials. A study by Andrew has concluded that PMMA with carbon nanotubes shows enhanced strength and ductility.[8,9]Kim et al. in their study have developed CNT-PMMA composites with antimicrobial adhesive properties in order to reduce microbial induced infections and further complications. Microbial adhesion was reduced by nearly 30–95% when carbon nanotubes were used in PMMA. Among 0.25-2%, 1% of CNT was considered

the optimal concentration to be added in PMMA due to its enhanced mechanical properties and good antimicrobial activity.[10]

To check on the toxic response of CNT-PMMA, a cytotoxicity test was carried out using oral keratinocytes and no adverse effects were noted, thus proving the safety of its use on the outermost mucosal layers.[11]

However,the use of CNTs and any of their composites has not yet been approved by the FDAin any country for its clinical applications, thus demanding future in vitro or in vivo research to confirm their biocompatibility, which is of utmost importance for clinical applications.

In composite resin

Considering the safety and aesthetics, composite resins are widely used as a restorative material and as a substitute to dental amalgams. But high polymerization shrinkage and low fracture toughness make its performance life shorter. To extend its service life, fillers were incorporated, showing better performance. Incorporation of nanofillers in the form of nanofibers and nanotubes have been employed inorder to strengthen the mechanical properties of dental composites. Nanofillers are considered to be different from traditional fillers because of their large surface area and specific microstructure.[12] They act by dispersing evenly in the matrix. Apart from these, nanotubes have specific interfacial property which makes them enhance the performance of dental composites.

Carbon nanotubes have good biocompatibility and excellent mechanical properties,being ten times stronger than steel, with a tensile strength of 50-100GPa, which is five times more than steel.Single-walled carbon nanotubes form a favourable reinforcement for dental composites and are hence most likely to replace glass fillers.Single walled carbon nanotubes have proved to improve the flexural strength of dental resin-based composites.[13]

As nanotubes have a tendency to agglomerate, it is difficult to get an even dispersion. And as the surface of nanotubes is smooth, it will affect the interfacial adhesion force between the nanotubes and composites. But in contrast to this, Zhang et al. in their research by coating single-walled carbon nanotubes with modified nano-SiO_2, achieved a well distributed effect in dental composites, giving a hopeful addition which can enhance the mechanical properties of dental composites.[13]

In glass ionomer cements

Glass ionomer cements (GICs) were introduced by Wilson and Kent as a "new translucent dental filling material" in the year 1972 and are presently used as restorative and luting dental materials. It consists of three basic components, including a polymeric water-soluble acid, a basic (ion-leachable) glass, and water.

Significant disadvantages of GICs include low flexural strength, reduced fracture toughness, and limited durability. Other limitations, include prolonged setting time, poor hydrolytic stability, and roughness, which can hamper the final mechanical properties of the restoration after setting. To overcome these clinical constraints and provide enhanced performance for the patient, further improvements are required, particularly to enhance mechanical strength.[14]

Goyal et al. studied the effects of multi-walled carbon nanotubes (MWCNTs) on reinforced glass ionomer cements with respect to their mechanical, thermal and chemical properties as a posterior restorative material. In their study, 0%, 1%, and 2% *w*/*w* concentrationsof MWCNTs were used and a definitive improvement in mechanical properties was noted. It was noted that the hardness was raised to 5.70 MPa from 2.19 MPawith the 2% reinforced group, tolerating higher wear forces than the other two reinforced groups.In the case of anterior aesthetics, the colour stability of restorative materials plays a crucial role. Thus, it was observed that incorporation of carbon nanotubes into GICsshowed enhanced color stability compared to other reinforcement materials like silver nanoparticles.[14,15]

In dental implant materials

As carbon nanotubes have excellent mechanical, chemical,and electrical properties, their use as a coating to improve the durability and strength has been studied. Multiwalled carbon nanotubes (MWCNTs) were coated on to titanium surface, which is a common dental implant material. In the study, carboxylated MWCNTs were coated homogenously onto the collagen attached to the titanium plate, that showed strong attachment even as a thin layer and increased surface roughness, helping in good cell proliferation and strong cell adhesion. Thus, it was concluded that MWCNT coating could be useful for the enhancement of cell adhesion on titanium implants.[16]Teixeira-Santos et al. in their studyevaluated and proved that carbon nanotube coated dental implantshowed antibacterial effectiveness against Staphylococcus aureus.[17,18]

In bone regeneration

Carbon nanotubes have the potential for bone tissue engineering. Bone reconstruction is considered as a vital necessity inregenerative dentistry for the functional rehabilitation of the oro- maxillofacial system.

Eventhough autologous bone is the most considered material for bone reconstruction, the high cost of surgical procedure and the availability of bone in the donor region remain as hindrances in the selection of this procedure. In this context, the biocompatible carbon nanotubes orCNT composites with biopolymers have been assured to be used in cases of bone defects. Recent studies have proved carbon nanotubes as a promising material that can increase bone formation in the tooth sockets of rats.[19]

Conclusion

Carbon nanotubes give a promising future in dentistry by the development of many newer materials and applications, thus bringing improvement in dental field. They can be used not only as a reinforcement in dental materials, but as scaffoldsand for targeted drug delivery thus enhancing the clinical performance of dental materials.

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