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Mini Review

Advancements in Biomaterials Development Using Graphene Quantum Dots: A Mini Review

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Abstract

Today, Graphene Quantum Dots (GQDs) have attracted the attention of researchers in various industries. The development of these materials in bioscience and biomaterials is also significant. Graphene quantum dots are of interest due to their unique features in *in-vivo* imaging, develop drug delivery materials and improving the performance of dental implants. In the present research, some of the latest achievements in this field have been collected as a mini review. Graphene quantum dots can be used in drug delivery applications, development of *in vivo* imaging and similar cases. At the end of each section, suggestions are provided for researchers and more developing of Graphene quantum dots. Notably, this article only examines the latest achievements in the field of Graphene quantum dots and its results do not confirm or deny the use of this material in bioscience and biomaterials.

Keywords: Quantum Dots; Graphene; Biomaterials; Bioscience; GQDs

Introduction

Nowadays, the focus on quantum dots holds significant importance across multiple scientific fields, with numerous efforts being made to advance the understanding of quantum dots. Simultaneously, highlighting the significance of Graphene quantum dots is crucial [1-3]. Graphene quantum dots have garnered attention in multiple disciplines, particularly in the realm of biological sciences, owing to their exceptional biocompatibility [4]. Graphene Quantum Dots (GQDs) are also considered as a new group of fluorescent materials that have obvious advantages over their current competitors. Their unique features, including small size, novel stability and large surface area, have made them suitable for various applications. It is mentioned again that these materials have good biocompatibility [5]. As mentioned, Graphene quantum dots play an effective role in the development of biomaterials. For this reason, in the continuation of the current research, the latest achievements of this amazing material in the field of development of biological materials and also some biomaterials will be reviewed as a mini overview.

GQDs for Targeted Drug Delivery

One of the main areas in the development of Graphene quantum dots is the development of drug delivery materials. These materials facilitate precise control of drug release kinetics and enable targeted and sustained therapeutic effects. Also, by using this technology, there is the possibility of personalizing the medicine according to the needs of each person. Of course, there are challenges in this area. One of the main challenges is the difference in drug release conditions in the laboratory environment and the body environment (*in vivo*) [6-8]. According to this issue, the development of Graphene quantum dots for drug delivery materials has been the focus of researchers. In order to increase drug delivery capability, Graphene quantum dots coated with PMA DDA were investigated. This research was done with the aim of drug delivery in the treat and imaging of breast cancer. The results showed that the present material had the

desired biocompatibility and also the imaging results showed that the coated quantum particles have accumulated around the cancer cell [9].

GQDs in the form of composites

The development of Graphene quantum dots in the form of composites has also attracted the attention of researchers. Research results showed that Graphene oxide quantum dots with glucosamine and boric acid with and without doxorubicin can be used in cancer treatment. It is noteworthy that with the presence of doxorubicin, more cytotoxicity has been reported against MCF-7 cells. On the other hand, the above compound can have more potential to deliver anti-cancer drugs [10]. Of course, in the future, it is necessary for researchers to conduct more research on the development of quantum Graphene composites in order to reduce the level of cytotoxicity. Other research has been proposed in the development of GQDs in drug delivery materials [11-14]. Research results have shown that the use of two-dimensional Graphene quantum dots can be effective in the development of drug delivery materials [11]. Also, the synthesis method is considered as one of the prominent methods in the development of quantum drug delivery materials [12]. Finally, the development of Graphene Nanocomposite with hyaluronic acid has been of interest in cancer cell imaging and drug delivery [13]. At the end of this section, as a as a perspective for the future, it should be mentioned that researchers should conduct more studies to increase the biocompatibility of GQDs for drug delivery materials. Also, the studies conducted so far have focused on the treatment of cancer cells and it is suggested that researchers take useful measures in the development of GQDs for non-cancerous diseases.

GQDs for in vivo Imaging

One of the important applications of Graphene quantum dots is *in vivo* imaging. Graphene quantum dots have attracted attention in this field due to their high optical stability, strong quantum confinement and narrow emission spectra [15-17]. Also, previous research has shown that magnetic resonance signal amplifier can also be used in biomedical imaging [9]. Another research showed that the imaging of animal tissue with the presence of quantum dots can be successful and Graphene Quantum Dots (GQDs) can be tracked by ultrasound imaging. This issue will ultimately be effective in imaging contrast [18]. One of the important issues in the development of GQDs is the implantation of dots in nanoparticles. In this regard, in a research study GQDs were implanted in PEGylated nanoparticles for multimodal *in vivo* imaging of tumor. The results showed that the implantation of GQDs in PEG increases efficiency compared to the case where GQDs are used alone [19].

GQDs for fluorescence bio-imaging

Recent advances in GQDs for fluorescence bio-imaging have also attracted the attention of researchers [20]. It should be noted that extensive research has been done in this field to image cells in animals. Tissue and cell imaging is also of interest. It is necessary to mention that the researchers put extensive research in their agenda to investigate cancer cells with this method. Notably, this topic is one of the new research topics and it is necessary for researchers to focus more on this topic in the future.

GQDs in Dentistry

In addition to the previously mentioned cases, GQDs have also been of interest in dentistry [21-22]. The results of previous studies have shown that the presence of GQDs is effective in preventing bacterial infections of titanium-based implants. Quantum dots are embedded in titanium oxide Nano-rods using hydrothermal treatment and their presence reduces bacterial infection [21]. In the field of dentistry, Graphene nanoparticles show various applications [23]. Table 1 shows a summary of some applications of Graphene in specific situations. As it is known, this nanomaterial is used in different departments of dentistry such as periodontal or dental implant [24-28].

Table 1: Different states of Graphene and its applications in dentistry.

Applications	Graphene Type	Ref.
Periodontal tissue regeneration	Graphene Oxide	[23,24]
Dental implant and abutment	Single-layer Graphene sheets	[23,25]
	GO/Minocycline Hydrochloride (MH)	[26]
Bone tissue engineering	Monolayer Graphene	[27]
Dental pulp regeneration	Graphene dispersion	[28]

Conclusion

GQDs are of great interest in biomaterials. The lightness of these materials, high biocompatibility, lack of cytotoxicity and relative availability are among the reasons for paying attention to these materials. The results of this review article show that attention to this issue is increasing in biological sciences. It is necessary for researchers to consider the development of GQDs in the following cases:

A. Efforts should be made to find solutions to increase the biocompatibility of GQDs. Graphene as a biocompatible material can have the most biocompatibility even at the nanoscale.

B. More research should be done in the field of mechanical properties and wear resistance characteristics of GQDs. Graphene nanoparticles may improve the mechanical properties of dental implants.

C. In the field of *in vivo* imaging, Graphene-polymer composites are a suitable place for researchers to study.

D. Graphene quantum dots should be considered in drug delivery for diseases other than cancer to increase the speed of patient recovery.

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