Graphene based Antibacterial Coatings for Dental Applications

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I. Introduction

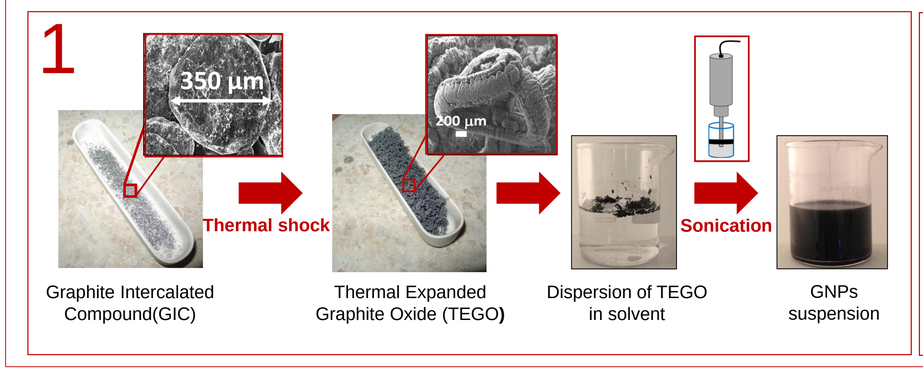
Over the past few years, orthodontic treatments are influenced by aesthetic considerations, methods for the treatment of malocclusions or dental misalignment defects, alternatives to the classic metal fixed devices. A recent survey has shown that while traditional metal brackets are aesthetically accepted only by 55% of adults, clear aligners are accepted by more than 90%, instead.[1] However, it seems rational that the mechanical properties should be coupled with antibacterial material to reduce the risk of developing caries and periodontal problems. For this reason, graphene-based materials are emerging as promising antimicrobial agents.[2] Among them, Graphene Nanoplatelets (GNPs) are cheap, easy to produce, have excellent mechanical and antibacterial properties.[3] And also, the only mechanism observed with GNPs was the punctuation of cellular membrane, without any production of reactive oxygen species (ROS).[4] Conroy et al. have shown that non-oxidized nanoplatelets typically do not produce ROS, demonstrating their high biosafety, thus enabling their use as antimicrobial agents.[5] Therefore, this work presents an investigation of graphene-based antibacterial coatings for dental applications.

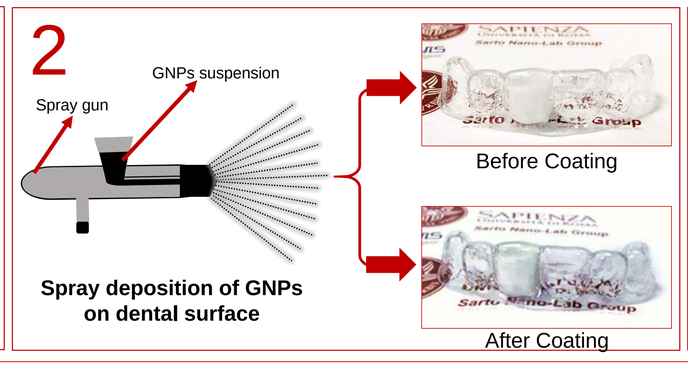
II. Production of Graphene Nanoplatelets (GNPs) and their Antibacterial Mechanism

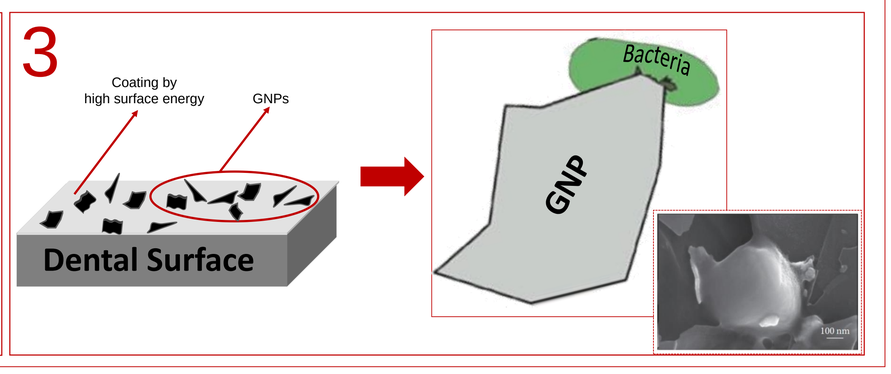
1. GNPs were produced starting through a thermal expansion of Graphite Intercalation Compounds(GICs) in a muffle furnace at 1050°C for about 30 seconds.[6] Then, the obtained thermal expanded graphite oxide (TEGO) was added to the solvent and tip sonicated for producing homogeneous GNPs suspension by using the ultrasonic probe sonicator.

2. The above resulting GNPs suspension was sprayed onto the dental surface for achieving antibacterial coating to reduce pathogens growth and Infections. Furthermore, there was a good adhesion between Graphene Nanoplatelets and dental surfaces observed by this simple spray coating deposition method.

3. The main antibacterial mechanism is the punction of bacterial cell membrane with GNPs sharp edges (nanoknife effect). Basically, the nanostructures adhere to the cell wall and penetrate its membrane to mechanically damage the membrane using their sharp edges. The inset Field Emission Scanning Electron Microscopy (FE-SEM) image is demonstrating that the Wrapping or trapping of bacterial membranes by flexible GNP thin film due to their antibacterial activity properties.



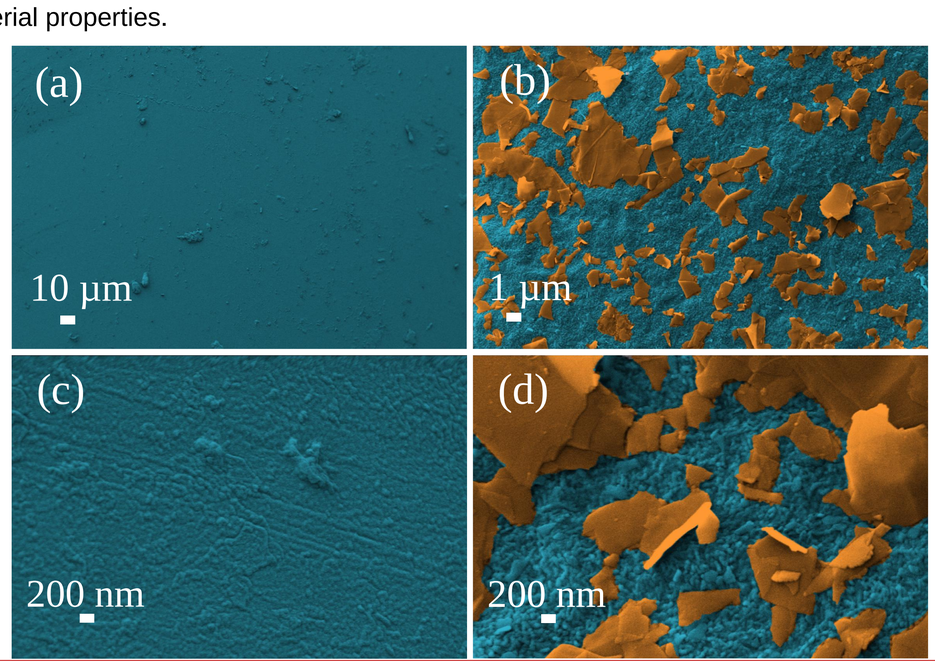




III. Surface Morphology Characterization

The morphology of treated and untreated dental surface was characterized through a FE-SEM using a Zeiss Auriga platform at (SNN-Lab). The untreated dental surface morphology at different magnifications was depicted in Fig (a) and (c). It reveals that the dental substrate has a very rough surface with small defects.

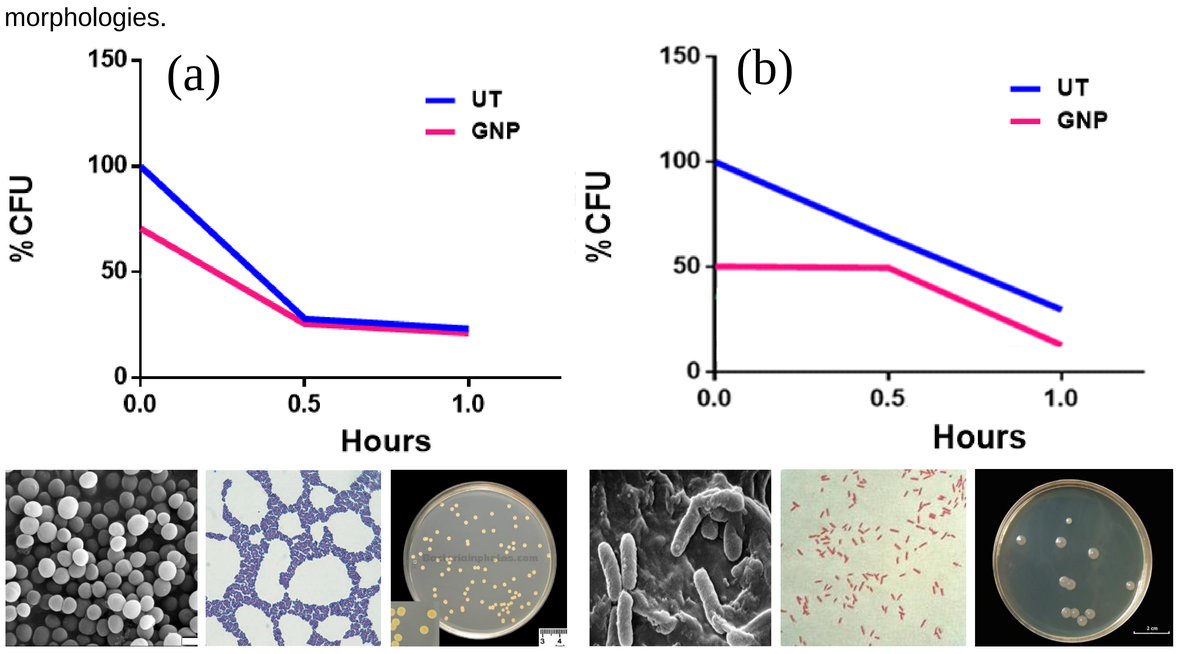
And also, the dental surface treated with GNPs surface morphology at two different magnifications were shown in Fig (b) and (d). It is clearly evident that the GNPs were well coated and uniformly dispersed on the surface of dental material. Furthermore, It is worth noticing that the sharp edge of GNPs has strongly appeared on the SEM images, which are main reason for antibacterial properties.



V. Cell Viability Test

The ability of bacterial survival was evaluated by the Colony Count Method (Colony Forming Units, CFU). The cell viability test is carried out by drop-casting of 200µL (6 x 105 cells/ml) on treated (spray-coated GNPs) and untreated (UT) dental surfaces. And then, the survival cells were calculated by %CFU for about 1-hour on both the dental surfaces.

From the results, It is clearly evident that comparatively due to their strong antimicrobial effect of GNPs treated on the dental surface shows initially significant-high reduction of %CFU gradually with time against the gram-positive Staphylococcus aureus bacteria as depicted in Figure (a) and gram-negative Pseudomonas aeruginosa bacteria reported in Figure (b) along with their surface morphologies.



Conclusions

The development of antibacterial coatings on dental substrates was achieved with GNPs by using a simple spray deposition method. The FE-SEM images show that the GNPs are uniformly dispersed on the surface of dental material for mechanical wrapping, puncturing and damaging the cellular membrane with their sharp edges (nanoknife effect). From the cell viability test, the antibacterial activity of GNPs against gram-positive and gram-negative bacteria demonstrates by significantly high reduction of %CFU with time. Therefore, the produced graphene-based antibacterial coating on dental substrates is suitable to reduce the risk of developing caries and periodontal problems during orthodontic treatment.

References

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