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Serum albumin and chondroadherin interact with graphene oxide coating of orthopedic implant; computational insights

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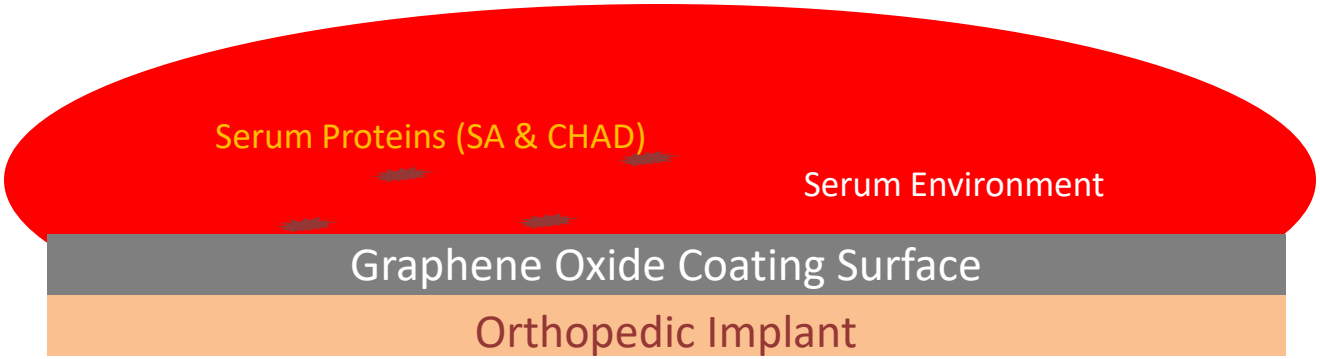
Graphical Abstract



Abstract:

The interactions of blood and joint components with the material of implants used in orthopedics are crucial. Orthopedic implants are widely used in knee and joint replacement surgeries. Ideally, implant surfaces should enhance osteoblast functions and simultaneously inhibit microbial infection, however, unfavourable serum protein-material interactions may cause clinically intractable infections and implant failure. Despite several attempts to overcome such consequences to physicochemical properties of materials, implant failures do exist significantly. Therefore, profiling molecular-level interactions between human serum proteins and implant material is vital in subsequent protein-material behaviour. Graphene oxide (GO) is one such orthopedic implant material that has been gaining attention in bio-tribology. Present molecular docking simulations report the interacting behavior of serum albumin (SA) and chondroadherin (CHAD) with the GO-based orthopedic implant coating. It was aimed to elucidate binding affinities and molecular-level interactions at the proteins-material interface. Considering the most stable conformations, the strongest binding affinities of SA-GO and CHAD-GO interactions were calculated to be -10.3 kcal/ mol and -12.3 kcal/ mol respectively. Analysis of all binding modes showed that CHAD has the highest overall affinity towards GO. Root mean square deviation was consistent with the modes. Only conventional hydrogen bonding was predominant in SA-GO complex while CHAD-GO complex is heavily influenced by both the hydrogen bonding and hydrophobic interactions involving π orbitals. Though CHAD seems competitive, it developed steric hindrance at the interacting surface while there were no such effects with SA interactions at the GO surface. These interaction trends establish the requirement for experimental analysis.

Keywords: Orthopedic; graphene oxide; human serum proteins; interactions

Introduction

- Serum protein-material interactions may cause clinically intractable infections and implant failure. Despite several attempts to overcome such consequences to physicochemical properties of materials, implant failures do exist significantly [1].
- Profiling molecular-level interactions between human serum proteins and implant material is vital in subsequent protein-material behavior.
- Orthopedic implant coating materials include; Calcium phosphate-based biocompatible materials, graphene oxide and other polymers [2]. Graphene oxide is gaining attention in bio-compatible materials industry targeting medical applications [3].
- Previous experimental studies have shown that GO coatings might be a good candidate as a coating material for orthopedic implants [4].

[1] González-García, C., Cantini, M., Ballester-Beltrán, J., Altankov, G. and Salmerón-Sánchez, M., 2018. The strength of the protein-material interaction determines cell fate. *Acta Biomaterialia*, 77, pp.74-84.
[2] Hussain, M., Askari Rizvi, S., Abbas, N., Sajjad, U., Shad, M., Badshah, M. and Malik, A., 2021. Recent Developments in Coatings for Orthopedic Metallic Implants. *Coatings*, 11(7), p.791.
[3] Paik, P., 2017. Graphene Oxide for Biomedical Applications. *Journal of Nanomedicine Research*, 5(6).
[4] Zhao, C., Lu, X., Zanden, C. and Liu, J., 2015. The promising application of graphene oxide as coating materials in orthopedic implants: preparation, characterization and cell behavior. *Biomedical Materials*, 10(1), p.015019.

Introduction (continued)

- Human serum albumin (SA) and chondroadherin (CHAD) are blood proteins which are recently studied for the effects of their potential interactions with the implant material surface in surgeries. Cytocompatibiity and osteogenic activity are investigated in materials like silicate bioceramics [5].

- Hexagonally arranged network of C atoms forms two-dimensional (2D) graphene sheet. This creates a space for the C atoms to interact with surrounding environment [6]. The present study employs three dimensional modelling techniques, stereo-chemical quality validations, blind docking simulations and molecular level interaction analysis to profile how these serum proteins interact with the GO surface.

[5] Deng, F., Zhai, W., Yin, Y., Peng, C. and Ning, C., 2021. Advanced protein adsorption properties of a novel silicate-based bioceramic: A proteomic analysis. *Bioactive Materials*, 6(1), pp.208-218.[2] Hussain, M., Askari Rizvi, S., Abbas, N., Sajjad, U., Shad, M., Badshah, M. and Malik, A., 2021. Recent Developments in Coatings for Orthopedic Metallic Implants. *Coatings*, 11(7), p.791.
[6] Armano, A. and Agnello, S., 2019. Two-Dimensional Carbon: A Review of Synthesis Methods, and Electronic, Optical, and Vibrational Properties of Single-Layer Graphene. *C — Journal of Carbon Research*, 5(4), p.67.

Results and discussion

- Conventional hydrogen bonding was predominant in SA-GO complex.

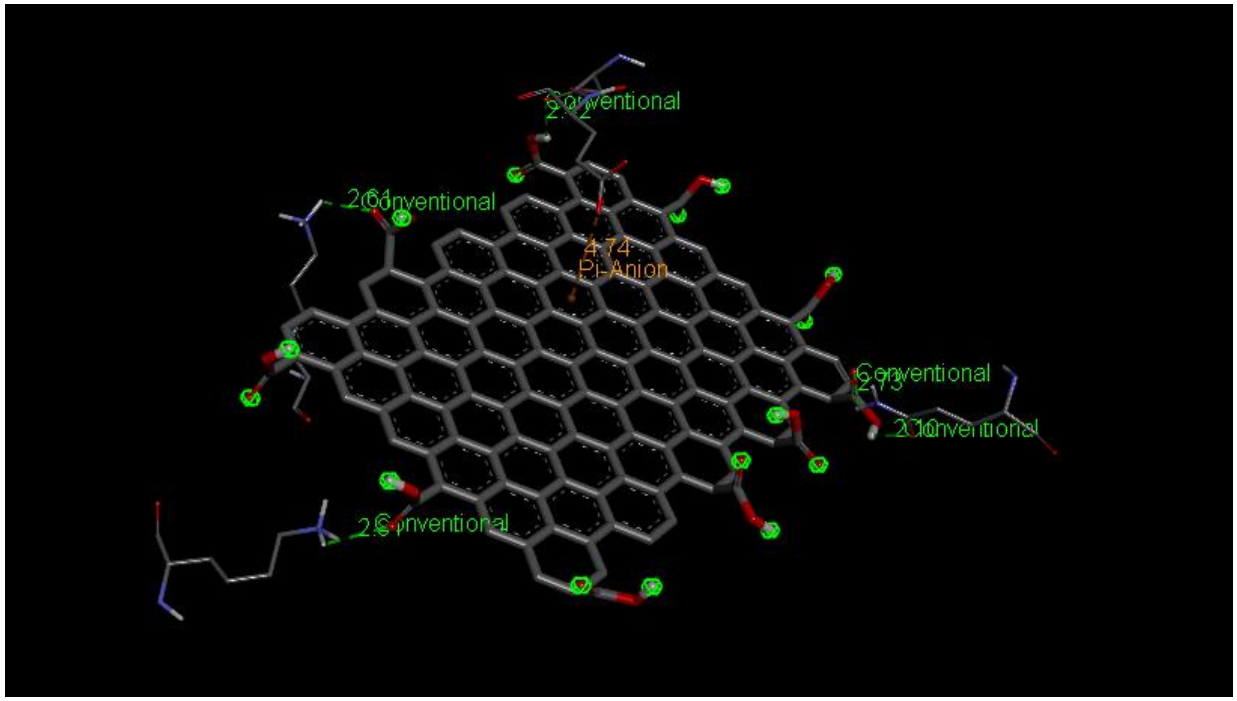


Figure 2: Three dimensional view of SA-GO complex with interactions

Results and discussion

- CHAD-GO complex is heavily influenced by both the hydrogen bonding and hydrophobic interactions involving π orbitals.

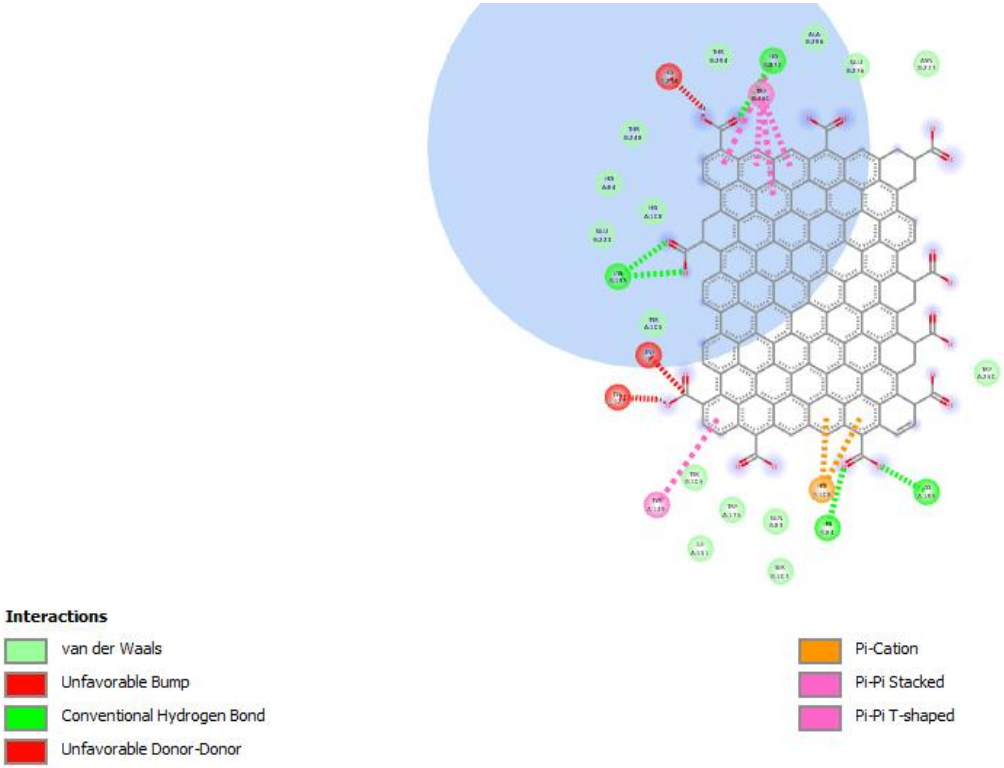


Figure 2: Two dimensional view of CHAD-GO complex with interactions

Conclusions

- Considering the most stable conformations, the strongest binding affinities of SA-GO and CHAD-GO interactions were calculated to be -10.3 kcal/ mol and -12.3 kcal/ mol respectively.
- Analysis of all binding modes showed that CHAD has the highest overall affinity towards GO. Root mean square deviation was consistent with the modes.
- Only conventional hydrogen bonding was predominant in SA-GO complex while CHAD-GO complex is heavily influenced by both the hydrogen bonding and hydrophobic interactions involving π orbitals.
- Though CHAD seems competitive, it developed steric hindrance at the interacting surface while there were no such effects with SA interactions at the GO surface.
- These interaction trends establish the requirement for experimental analysis.