ISAKOS CONGRESS 2025 | MUNICH GERMANY June 8–11

Graphene in Orthopedics

From an Emerging Promise to Real-World Application

Saulo Afonso de Almeida Filho, PhD, São Paulo, SP, Brasil

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- Saulo Afonso de Almeida Filho, PhD, São Paulo, SP, Br
- Deissy Johanna Feria Garnica, PhD, São Paulo, SP, Br
- Caio Roberto Soares Braganca, PhD, Passos, MG, Br
- Marcelo Nelson Páez Carreño, PhD, São Paulo, SP, Br
- Inés Pereyra, Profa, PhD, São Paulo, SP, Br
- Mateus Saito, PhD, São Paulo, SP, Br
- Tiago Lazzaretti Fernandes, PhD, São Paulo, SP, Br

Faculty Disclosure Information

I DO NOT have a financial interest or other relationship with a commercial company or institution.

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Graphene in Orthopedics - From an Emerging Promise to Real-World Application

Universidade de São Paulo, SP, BRAZIL

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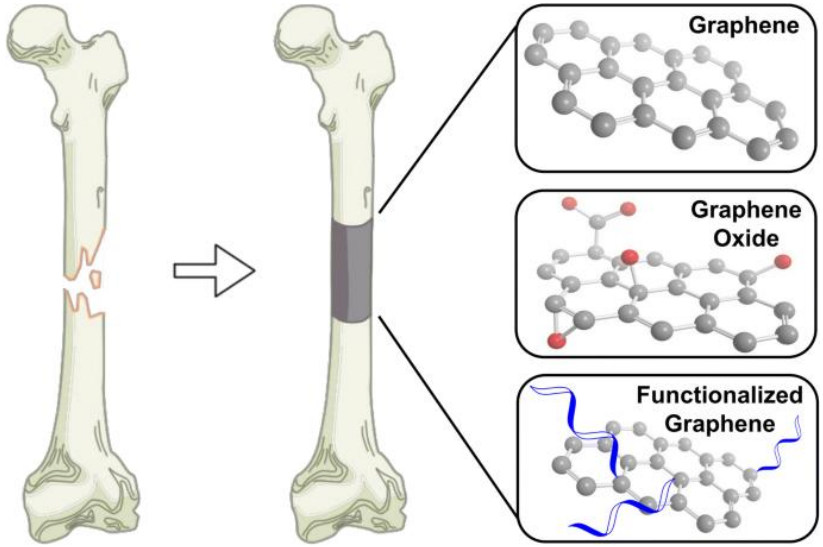
Introduction

Graphene and other carbon nanomaterials (rGO, CNTs) are revolutionizing the biomedical field due to their mechanical strength, conductivity, and biocompatibility. In orthopedics, their integration into implants aims to enhance osseointegration, reduce infections, and improve durability.



Adapted from Wright et al., Regen Eng Transl Med, 2019

Objective

To evaluate the potential of graphene in the development of interference screws and anchors for orthopedic and sports medicine applications. This research aims to enhance osseointegration, reduce the risk of infection, and promote tissue regeneration through both in vitro experiments and in vivo animal models

Methods

Graphene was deposited onto cylindrical 316L surgical steel implants using Atmospheric Pressure CVD (CH_4-based). This technique allowed uniform coating across the entire surface.

The material was characterized by:

- **Raman spectroscopy** (graphene quality),
- **SEM/EDS** (surface morphology and elemental analysis),
- **XPS** (surface chemistry).

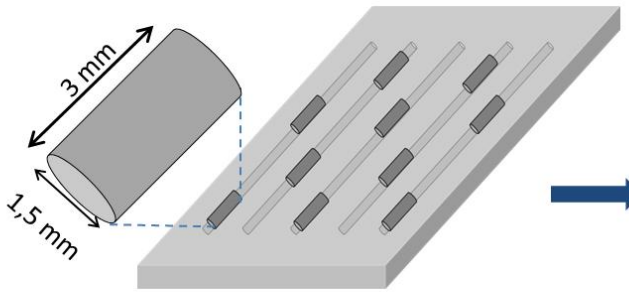
Biological evaluation included:

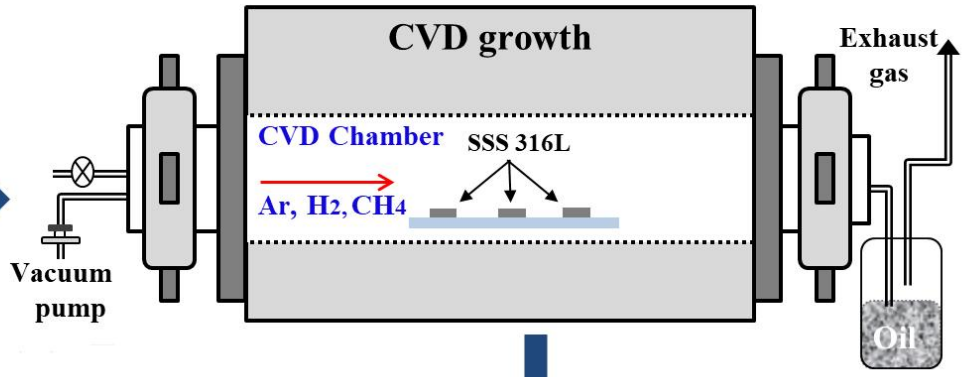
- **In vivo implantation** in *Rattus norvegicus* Wistar rats,
- **In vitro microbiological assays** with *S. aureus* and *P. aeruginosa*.

Methods

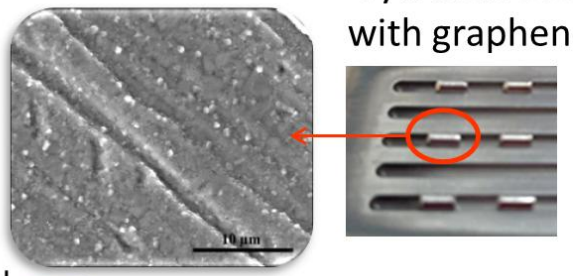
Cylinders measuring 1.5 previously cleaned and placed in the sample holder.

APCVD reactor at 950°C depositing graphene on the surface of cylinders

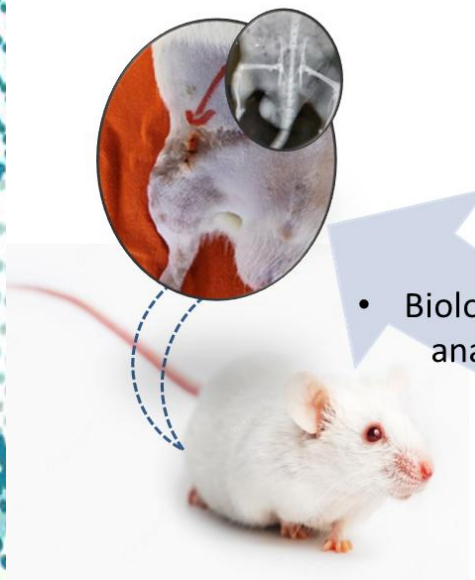




Cylinders SSS with graphene



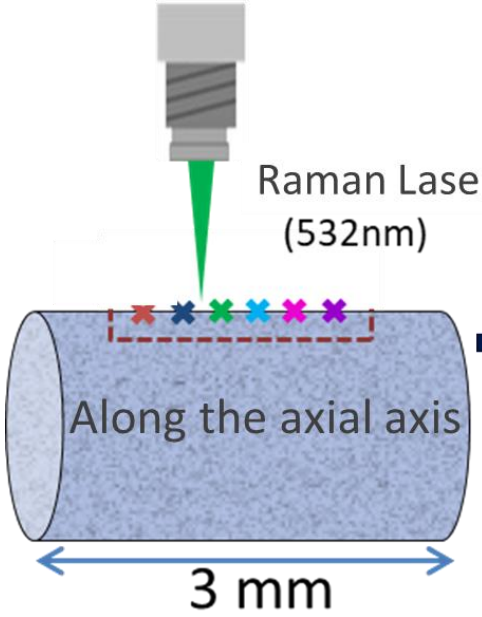
- Biological analysis
- Chemical characterization
- Structural characterization



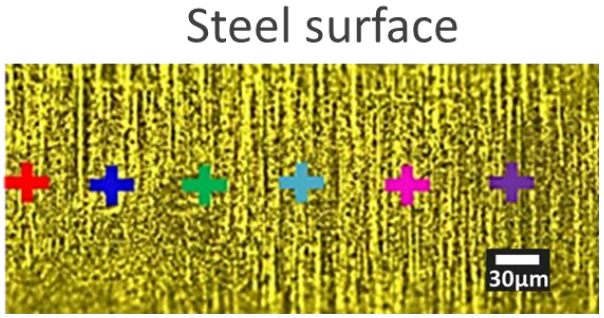
Feria, D. J. et al., *Diamond and Related Materials* 2024

Results

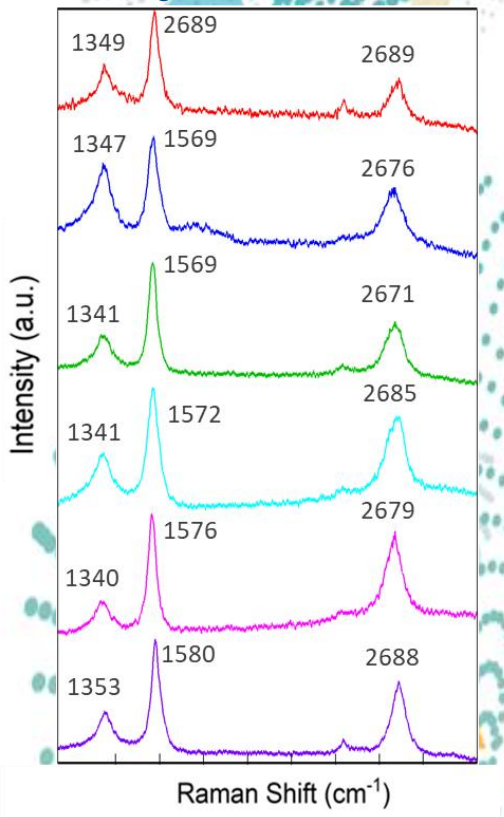
Characterization by Raman spectroscopy



Raman measurements were performed using a WITec Confocal Raman Microscope Alpha300 R, equipped with a green laser (532 nm) and 10× and 50× objectives.



Optical image of surgical steel. the crosses indicate the points where the Raman spectra were extracted



Raman spectrum of a surgical steel , the three characteristic bands of graphene are identified.

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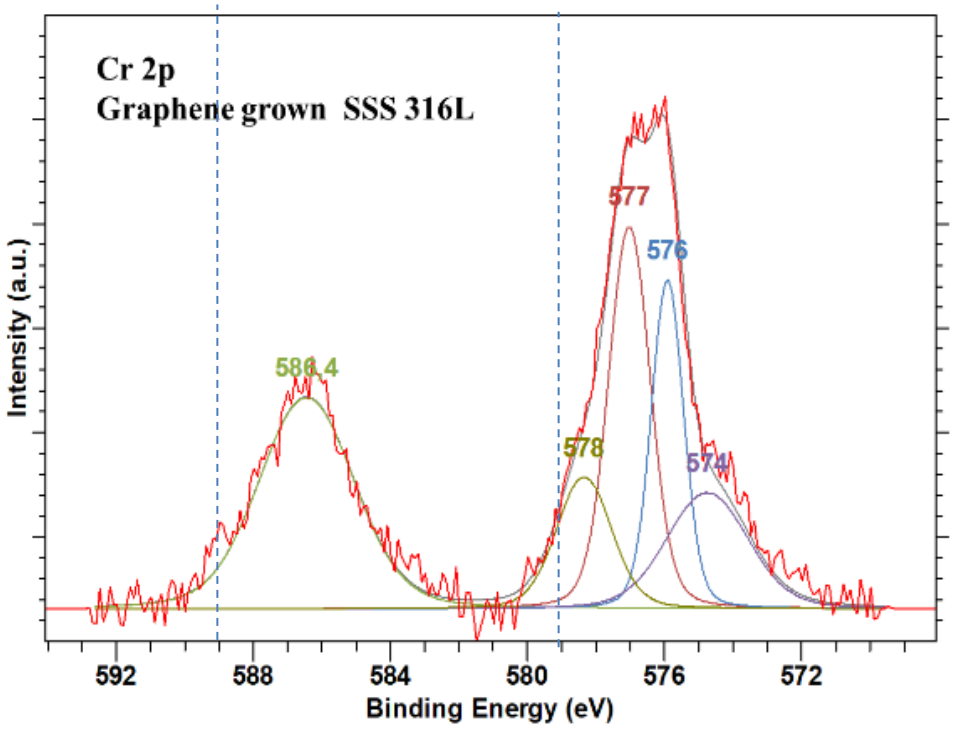
XPS Characterization

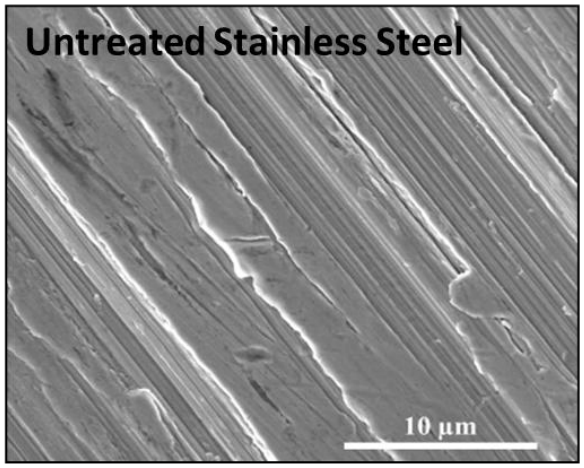
X-ray Photoelectron Spectroscopy (XPS) analysis was conducted to evaluate the chemical composition and bonding states of the graphene layers deposited on the stainless steel surface. This technique provides detailed information about the elemental composition and the presence of functional groups or contaminants at the surface level.

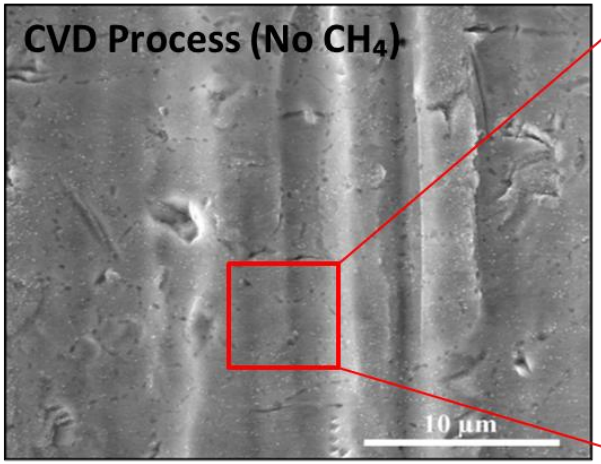
No detectable presence of hexavalent chromium (Cr VI) at 589 eV and 579 eV

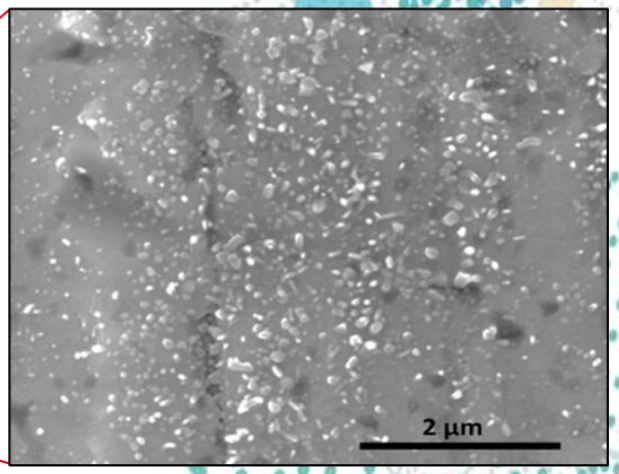


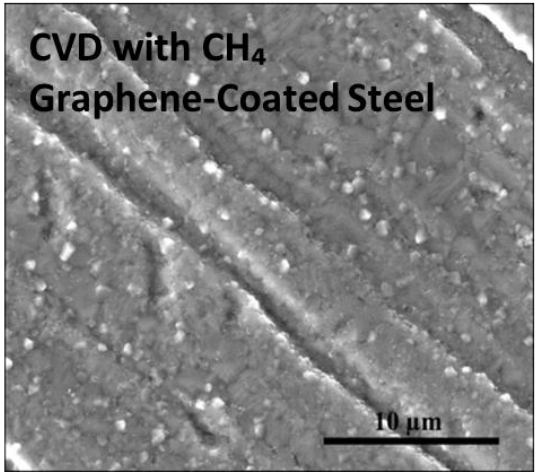
Results

SEM Characterization





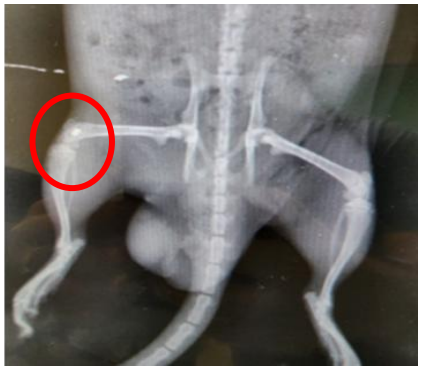




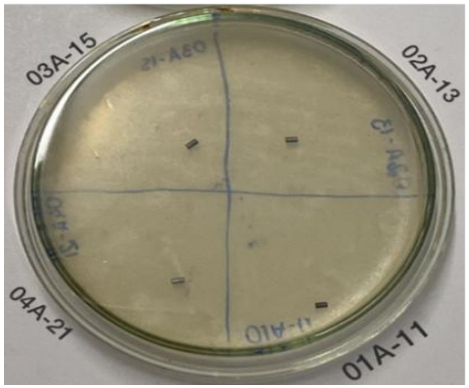
Rat implants and microbiological analysis

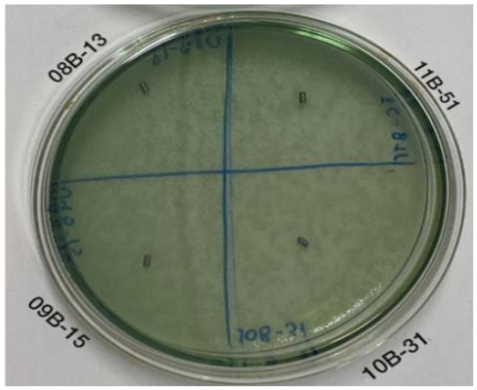
Surgical procedure test for insertion of graphene-coated 316L steel cylinder

Cylinders implanted in Rattus norvegicus.



Did not stimulate bacterial growth





Interaction with *Staphylococcus aureus* and *Pseudomonas aeruginosa*

Results and Conclusion

Our results demonstrate the feasibility of uniformly coating orthopedic implants with graphene and reveal favorable biological interactions.

While some challenges remain:

- The toxicity of graphene is still under investigation, with ongoing animal studies.
- The efficient and affordable production of high-quality graphene.
- Clinical translation requires continued validation and development.

Nonetheless, current progress highlights graphene's potential as a groundbreaking material in orthopedics, with promising future applications in bone regeneration and smart prostheses, poised to transform musculoskeletal care.

References

Wright, B., De Bank, P. A., & Luetchford, K. A. (2019). *Scalable expansion of human mesenchymal stem cells in 3D culture system using microcarriers: Growth and metabolism*. *Regenerative Engineering and Translational Medicine*, *5*(3), 276-285. https://doi.org/10.1007/s40883-019-00102-9

Feria, D. J., Almeida Filho, S. A., Lopes, A. T., Saito, M., Fernandes, T. L., Carreño, M. N. P., & Pereyra, I. (2024). Direct CVD graphene growth onto surgical stainless steel for orthopedic implants. *Diamond and Related Materials, 147,* 111548. https://doi.org/10.1016/j.diamond.2024.111548