frontiers | Frontiers in Materials

TYPE Editorial
PUBLISHED 14 February 2025
DOI 10.3389/fmats.2025.1549972

OPEN ACCESS

EDITED AND REVIEWED BY
Nicola Maria Pugno,
University of Trento, Italy

*CORRESPONDENCE
Egemen Avcu,
avcuegemen@gmail.com
Mert Guney,
mert.guney@nu.edu.kz

RECEIVED 22 December 2024
ACCEPTED 05 February 2025
PUBLISHED 14 February 2025

CITATION
Avcu E, Avcu YY, Armağan M, Abakay E, Yousif BF and Guney M (2025) Editorial: Tribological behavior of biomaterials. *Front. Mater.* 12:1549972. doi: 10.3389/fmats.2025.1549972

Editorial: Tribological behavior of biomaterials

Egemen Avcu[1,2]*, Yasemin Yıldıran Avcu[1], Mustafa Armağan[3], Eray Abakay[4], B. F. Yousif[5] and Mert Guney[6,7]*

[1]Department of Mechanical Engineering, Kocaeli University, Istanbul, Kocaeli, Türkiye, [2]Department of Machine and Metal Technologies, Kocaeli University, İzmit, Kocaeli, Türkiye, [3]Department of Mechanical Engineering, Istanbul Medeniyet University, Istanbul, Türkiye, [4]Department of Metallurgy and Materials Engineering, Sakarya University, Sakarya, Türkiye, [5]School of Engineering, University of Southern Queensland, Toowoomba, QLD, Australia, [6]The Environment and Resource Efficiency Cluster (EREC), Nazarbayev University, Astana, Kazakhstan, [7]Department of Civil and Environmental Engineering, Nazarbayev University, Astana, Kazakhstan

KEYWORDS

biomaterials, biomedical coatings, lubrication, polymers, surface engineering, titanium alloy, wear behavior

Editorial on the Research Topic
Tribological behavior of biomaterials

Introduction

Stents, joint and dental implants, orthopedic fixation devices, internal support, and the replacement of biological tissues are only a few of the many medical applications that depend extensively on biomaterials. In these applications, biomaterials frequently experience mechanical forces that entail tribological interactions. One of the main factors affecting these materials' long-term performance and durability is their tribological characteristics, which include frictional behavior, lubrication, and wear resistance. Numerous studies have been carried out to comprehend the mechanical properties of the innovative biomaterials that have developed in the current context. However, there is an urgent necessity to further investigate their tribological properties to confirm their suitability for medical applications. The literature on the tribological evaluation of biomaterials under various functioning conditions (including load, counter body properties, duration, and especially lubricating media) is insufficient. The primary aim of this Research Topic is to elucidate recent developments in the study of the tribological properties of biomaterials, providing a forum for researchers to share their latest findings, thorough reviews, methodological advancements, and illustrative case studies in the specific field of "tribological behavior of biomaterials". The present Research Topic focuses on (Abakay et al.) the current understanding of the wear of biomaterials, (Imran et al.) the relationship between their mechanical-microstructural and tribological behaviours, and (Ouerfelli et al.) recent advances in the tribological behaviour of biomaterials. The Research Topic is structured to offer a platform for researchers in biomaterials, featuring three core contributions (Abakay et al.; Imran et al.; Ouerfelli et al.).

Contribution highlights

The review "Advances in improving tribological performance of titanium alloys and titanium matrix composites for biomedical applications: a critical review" presents recent advancements and strategies for enhancing wear resistance in metallic implants for biomedical applications. Life expectancy has been globally rising, and more patients require biomedical implants. Consequently, permanent implants serving for extended durations require rigorously engineered tribological properties. Additionally, today's patients stay younger and more active, putting higher demands on the implants (Sonntag et al., 2013). In case of failure, implants need more challenging and painful revisions than the initial replacement. Revision surgeries place an economic burden on both patients and healthcare systems. Therefore, introducing novel concepts and technological innovations to improve the tribological performance of metallic biomaterials is essential for patient wellbeing and economic reasons.

The longevity of metallic biomaterials, especially those employed in tribological applications, is dictated by their tribological performance. Titanium alloys and their composites are among the most widely used biomaterials among metallic implants (e.g., stainless steel, Co-Cr-Mo alloys) in tribological applications. According to this critical review, the current cutting-edge research on enhancing tribological behaviour of titanium implants focuses on i. Developing new titanium alloys and their composites; ii Implementing mechanical surface treatment methods; iii. Developing biomedical coatings; iv. Developing functional (e.g., self-lubricating, self-adaptive, self-healing) materials; v. Implementing new tribological testing/characterization methods; and vi. The application of tribo-informatics (e.g., machine learning, deep learning, data-driven methodologies). The prevailing challenges in this domain are: i. Achieving precise control over the alloy's microstructure to attain the required mechanical and biological properties, ii. Reducing wear debris generation, iii. Employing advanced instruments such as electron microscopy and optical profilometry to clarify the fundamental causes of the tribological behavior of these materials, iv. Rectifying defects, such as porosity and cracks, arising from surface modification techniques (e.g., biomedical coatings and chemical/mechanical treatments), and v. Modeling studies aimed at predicting tribological properties, including the coefficient of friction and wear rate (Abakay et al.).

The original research "Electrophoretic deposition of polyetheretherketone/polytetrafluoroethylene on 316L SS with improved tribological and corrosion properties for biomedical applications" focuses on the implementation of polyetheretherketone (PEEK) and polytetrafluoroethylene (PTFE) coatings on metallic implants (i.e., stainless steel) to improve their tribological properties. When tested in a physiological setting with phosphate-buffered saline (PBS), 316L stainless steel (316L SS) exhibits lower corrosion and wear resistance than Cp-Ti and Ti-6Al-4V implants. However, they are reasonably priced. The application of biocompatible coatings could enhance their resistance to wear and corrosion. This study utilises electrophoretic deposition to apply a polymer coating of PEEK and PTFE on 316L SS at optimal processing conditions. They investigated the performance of PEEK and hybrid PEEK/PTFE coatings through scratch testing, corrosion testing, and scanning electron microscopy. Their adhesion strength and wear resistance tests verified that the PEEK/PTFE coating is appropriate for coating orthopedic implants and can withstand implementation loading (Imran et al.).

The original research "Rheological behavior of the synovial fluid: a mathematical challenge" presents solutions to the governing equations for the partial differential equations pertaining to the synovial fluid (SF), which sheds lights on the viscous flow along the articular surfaces of the knee joints. SF is frequently utilized for diagnostic and research objectives as it mirrors the local inflammatory environment. Due to its intricate composition, particularly the inclusion of hyaluronic acid, SF is viscous and heterogeneous. The presence of high-molecular-weight hyaluronan in this fluid imparts the necessary viscosity for its role as a lubricant. Viscosity is the predominant hydraulic property of the SF in articular cartilage. This work examined the flow of a non-Newtonian fluid applicable for modeling SF flow. The study concludes that the rheological behavior of SF transitions gradually from non-Newtonian to a Newtonian profile. The results of this study may provide novel insights for diagnosis, criteria, and prediction of diseased case types by comparing new parameter values subjected to identical experimental settings as hyaluronidase injection (Ouerfelli et al.).

Concluding remarks

This Research Topic addresses challenges in the field of tribological behavior of biomaterials and offers a summary of some of the most promising developments with diverse publications. The published work shows that an effective translation of new biomaterials into clinically successful implants strongly depends on overcoming the challenges related to wear and friction. This requires a change in our comprehension of tribological interactions within the complex biological context. Addressing the tribological challenges encountered by biomaterials in biomedical applications often necessitates a multidisciplinary approach crucial for transforming innovative solutions into clinically viable advancements. Research is needed with a focus on developing new metallic biomaterials and biomedical coatings with improved wear resistance and biocompatibility, investigating advanced surface modification methods, and enhancing predictive models that properly represent the *in vivo* tribological performance of these biomaterials.

Author contributions

EgA: Conceptualization, Funding acquisition, Resources, Supervision, Validation, Writing–original draft, Writing–review and editing. YA: Writing–original draft, Writing–review and editing, Conceptualization, Validation, Supervision. MA: Writing–review and editing. ErA: Writing–review and editing. BY: Writing–review and editing. MG: Writing–original draft, Writing–review and editing, Conceptualization, Validation, Supervision.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Reference

Sonntag, R., Reinders, J., Gibmeier, J., and Kretzer, J. P. (2013). Fatigue strengthening of an orthopedic Ti6Al4V alloy: what is the potential of a final shot peening process? *Biomaterials and Medical Tribology*. 217–37. doi:10.1533/9780857092205.217

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note