Advances in Biology & Earth Sciences
Vol.9, Special Issue, 2024, pp.5-10
https://doi.org/10.62476/abes.9s5

FUTURE PROSPECTS OF BIOMATERIALS IN NANOMEDICINE

Rovshan Khalilov[1], Afsana Bakishzade[1], Aygun Nasibova[1,2*]

[1]Department of Biophysics and Biochemistry, Baku State University, Baku, Azerbaijan
[2]Institute of Radiation Problems, Ministry of Science and Education, Baku, Azerbaijan

Abstract. Biomaterials are materials that temporarily or permanently replace injured/lost tissue/organ functions for any reason, are used directly or are included in systems developed for this purpose. It is divided into two: natural and synthetic. Biomaterials have chemical, physical, mechanical, etc. properties to compensate for the said loss. It must have certain properties and be biocompatible. Non-biocompatible materials can have many significant negative effects on the body; for example, they can range from mild to severe, cause irritation, be allergenic or toxic and even create very tragic situations, leading to tumor formation. Biomaterials are often used temporarily for soft and hard tissue injuries/losses. Our body has the knowledge and ability to repair itself; soft tissue can usually regenerate within a few weeks, while hard tissue can regenerate within a few months or even a year. During this period, it is necessary to protect and support the injured tissue to ensure healthy regeneration ("healing"). Biomaterials are used for this purpose.

Keywords: *Biomaterials, living system, environment, implants.*

[*]***Corresponding Author:*** *Aygun Nasibova, Institute of Radiation Problems, Ministry of Science and Education, Baku, Azerbaijan; Baku State University, Baku, Azerbaijan, e-mail:aygun.nasibova@mail.ru*

Received: *12 December 2023;* ***Accepted:*** *2 March 2024;* ***Published:*** *8 April 2024.*

Biomaterials: inanimate inhabitants of a living system

Humans are living organisms that naturally struggle with health problems. Despite having a protective immune system, there are times when the human body is susceptible to some disease-causing pathogens. For this reason, people have always looked for ways to overcome their inherent weaknesses and wanted to replace a lost tooth, leg or arm (Mammadova *et al*., 2022). In doing so, they aimed to use synthetic materials that are closest to the biological structure (Nasibova *et al*., 2021). Over time, the structure of biomaterials and their interaction with living systems have been better understood and significant advances have been made in the scientific field (Kumar *et al*., 2020). So what are biomaterials? Let's consider several definitions of biomaterials historically.

Biomaterial is any material that can be used as an implant

In 1967, Jonathan Cohen provided one of the earliest definitions of biomaterials. Despite lacking scientific confirmation, his definition closely resembles those provided by the scientific community decades later. While there is currently no established consensus on what distinguishes biomaterials from other materials (Maleki *et al*., 2021), Dr. Cohen, an orthopedic doctor, focused on their application in a narrow field.

How to cite (APA):
Khalilov, R., Bakishzade, A., & Nasibova, A. (2023). Future prospects of biomaterials in nanomedicine. *Advances in Biology & Earth Sciences*, *8*(Special Issue), 5-10 https://doi.org/10.62476/abes.9s5

According to Cohen, a material can only be classified as a biomaterial based on the results of previous experiments (Nasibova, 2020). However, he did not take into account the relationship between these materials and the biological environment.

Biomaterials are inert materials

In 1974, during the '6th Annual International Biomaterials Symposium' held in Clemson, South Carolina, the term 'biomaterial' was first defined. A biomaterial is a pharmacologically inert material that is intended to be implanted into or incorporated into a living system.

Biomaterials are both active and inert materials

Biomaterials are substances of synthetic or natural origin (excluding drugs) or combinations of substances that can be used for any period of time as a whole or as part of systems that treat, support or replace any tissue. This definition was first established in the Statement of the National Health Consensus Development Conference held in Bethesda, Maryland (USA) in 1982. In 1987, Professor David Franklin Williams confidently provided a unique and innovative definition of biomaterials.

Biomaterials are non-vital materials used in medical devices designed to interact with biological systems

Biomaterials, whether natural or synthetic, are used to support, enhance, or replace the biological function of damaged tissue (Ramburrun *et al*., 2022). In ancient times, the most widely used biomaterials were biomaterials made from animal tissues. Ceramics, metals, polymers and other composite materials are used today as the main components for the production of bioengineering materials (Rigano & Lionetti, 2016). Today, these materials are widely used in medical implants, human tissue healing and regeneration, cancer diagnosis and treatment, biosensors and drug delivery systems (Kumar *et al*., 2020).

Can any material be applied in living systems as a biomaterial?

The biomaterial intended to be introduced into the body must meet a number of requirements. Biomaterials must be biocompatible, that is, safe for the host organism (Reinke *et al*., 2020). This means that they should not cause adverse effects at the implantation site or other tissues and organs. Biocompatibility is traditionally a characteristic of implantable materials intended to remain in the living body for a long time (Nasibova *et al*., 2023). From the development of the first generation of implantable materials between the 1940s and 1980s, it became clear that the least chemically active materials would exhibit the best biological performance (Smijs & Pavel, 2011).

Materials used as implants are required to be non-toxic and not cause any inflammatory or allergic reactions in the human body. The patient's body areas or tissues in contact with the implants should not be exposed to any physical irritation, inflammation, toxicity, carcinogenic or mutagenic effects (Kiran & Ramakrishna, 2021). It is decided whether the biomaterial is biocompatible with the body or not, based on the opinion given after testing in vitro in laboratory conditions and in vivo in animals, whether it is applied in humans or not (Tüylek, 2017).

Mechanical biocompatibility is just as important as biological biocompatibility for long-term implantation (Lens, 2009). It refers to the appropriate mechanical properties required for the function and area of implantation. Bio-implants must also possess sufficient mechanical strength to withstand all forces and additional effects (Kiran & Ramakrishna, 2021).

Corrosion resistance is a crucial requirement for biomaterials, especially in the case of metal implants (Yang *et al*., 2011). The fluid environment of the living organism can cause metal ions to accumulate in the tissues surrounding the implants and release them into other parts of the body. Corrosion is a significant process that affects the performance and lifespan of orthopedic materials made of metals and alloys used as implants in the body (Khalilov & Nasibova, 2022). Biomaterials are frequently exposed to environments with critical humidity levels and the released ions have been found to cause allergic and toxic reactions. Corroded implants in the human body release excessive amounts of harmful and toxic metal ions, such as Fe, Cr, Ni, Co and Ti, into the body fluid (Kiran & Ramakrishna, 2021).

The release of wear debris from the implant into surrounding tissues can cause inflammation, osteolysis, infection, pain and osteoporosis due to low wear resistance. The proper functioning of the biomaterial is dependent on its wear resistance (Kiran & Ramakrishna, 2021).

Osseointegration is the state in which an implant is firmly attached to the bone without breaking. When an implant is integrated into the bone, there is no progressive relative mobility between the directly contacting bone, ensuring the long-term stability of the osseointegrated implant (Kiran & Ramakrishna, 2021).

Sources of biomaterials

Biomaterials are easily obtained from a diverse range of natural sources such as animals, minerals, and metals using conventional methods.

Biomaterials from animals. Spider silk, egg shells, corals, fish bones are the main animal resources used for the production of biomaterials. They show high biocompatibility and have mechanical stability. The presence of amino acids such as glycine and polyalanine in spider silk strengthens its mechanical stability and biomaterials made from spider silk are widely used for tissue engineering, drug delivery systems, etc. In the production of biomaterials, another biomaterial - eggshells - obtained from animal resources is used. Calcite ($CaCO_3$) is the primary component of eggshells. Eggshell is commonly used in tissue engineering as a calcium source for hydroxyapatite synthesis (Khomutov *et al*., 2014). Additionally, fish bones are an excellent source of calcium carbonate and phosphate content (Marin *et al*., 2020), making them a valuable resource for biomedical purposes. Fish bones are an excellent biomaterial for treating bone diseases due to their similar chemical composition and pore size to human bones. Coral biomaterials, including coral granules, coral calcium and coral hydroxyapatite, are highly stable and ideal for use in orthopedic, craniofacial and dental treatments (Kumar *et al*., 2020).

Metallic Biomaterials

The application of metal biomaterials is intended for the purpose of providing internal strength to biological tissues. Metal implants are divided into two categories, permanent and biodegradable. Permanent metal implants are permanently implanted in the human body. Such implants are made of metals such as stainless steel, titanium and cobalt. Stainless steel is a corrosion-resistant material, examples of stainless steel-based permanent implants include stainless steel tubes, artificial heart valves, etc. (Kumar *et *al*., 2020). However, the presence of an allergic structure such as Ni in stainless steel is considered a limiting factor for its use (Tüylek, 2017). Titanium (Ti) is a lightweight material that exists in its pure alpha phase at temperatures below 882°C. It is an allotropic metal. The oxide coating that protects this material from corrosion and acts as a stable layer is watt (Kavetskyy *et al*., 2018). This coating prevents diffusion of oxygen from the environment to the biomaterial. Titanium is used as a permanent metal implant in dental implants, joint replacement, artificial heart valves, etc. (Kumar *et al*., 2020). Ti is also applied as a functional coating (Tüylek, 2017).

Mg and its alloys have physical and mechanical compatibility with human bone and differ from other biomaterials. They can eliminate the elastic inconsistencies between bone tissue and biomaterial. While metal implants usually have to be removed from the body with a second surgical procedure shortly after insertion-after a healing process-Mg-based implants degrade easily after serving a specific function. As a result, there is no need for a second additional operation to remove the implant (Kumar *et al*., 2020).

The compatibility of metals with the biological environment is crucial, as it directly affects their corrosion resistance. Unfortunately, corrosion can lead to the loss of several metal properties due to the formation of oxygen and hydroxides through unwanted chemical reactions with surrounding metals (Koutsopoulos, 2012). It is worth noting that the human body contains dissolved oxygen, water and hydroxide ions that create a corrosive environment for metals (Kumarage *et al*., 2020). As a result, corrosive products can enter tissues and damage cells, which highlights the importance of selecting the right metals for biomedical applications (Kumar *et al*., 2020). In the early 1900s, metal was a popular choice for implant materials (Amrahov *et al*., 2023). This breakthrough opened up new possibilities for implant materials and paved the way for further research in the field. It is important to consider the benefits and drawbacks of different implant materials to ensure the best possible outcomes for patients. However, as researchers discovered the potential for metal implants to wear out, they began exploring alternative materials, such as ceramics. In 1969, a highly biocompatible, corrosion-resistant and hard ceramic material was synthesized (Tüylek, 2017).

Ceramic biomaterials

Ceramic biomaterials are corrosion- and heat-resistant, hard materials and because of these properties, they have a wide range of applications. Ceramic biomaterials are classified into two groups, bioactive and bioinert (Kim *et al*., 2018). Bioactive ceramic biomaterials can be attached directly to human tissues without the need for connective tissue (Aliyeva *et al*., 2023). Bioinert ceramics are those that do not interact with the body's environment (Kandanapitiya & Kottegoda, 2022). Bioinert materials are used in hip prostheses and other clinical ceramic operations, for example Al_2O_3 and ZrO_2. ZrO_2 and Al_2O_3 show excellent biocompatibility and when the surface is polished, they gain wear resistance (Kumar *et al*., 2020).

References

Aliyeva, N., Nasibova, A., Mammadov, Z., Eftekhari, A. & Khalilov, R. (2023). Individual and combinative effect of NaCl and γ-radiation on NADPH-generating enzymes activity in corn (Zea mays L.) sprouts. *Heliyon*, *9*(11), e22126.

Amrahov, N.R., Allahverdiyev, V.Y., Agharzayeva, Y.I., Mammadova, R.B., Omarova, S.N., Khudayev, F.A. & Mammadov, Z.M. (2023). Effect of verticillium wilt on the antioxidant system and formation of iron nanoparticles in cotton genotypes. *JAPS: Journal of Animal & Plant Sciences*, *33*(6), 1322-1332.

Gobbi, S.J., Reinke, G., Gobbi, V.J., Rocha, Y., Sousa, T.P. & Coutinho, M.M. (2020). Biomaterial: Concepts and basics properties. *European International Journal of Science and Technology*, *9*(2), 23-42.

Kavetskyy, T.S., Khalilov, R.I., Voloshanska, O.O., Kropyvnytska, L.M., Beyba, T.M., Serezhenkov, V.A. & Voloshanska, S.Y. (2018). Self-organized magnetic nanoparticles in plant systems: ESR detection and perspectives for biomedical applications. In *Advanced Nanotechnologies for Detection and Defence against CBRN Agents*, 487-492. Springer Netherlands.

Khalilov, R., Nasibova, A. (2022). The EPR parameter's investigation of plants under the influence of radiation factors. *Acta Bot. Caucasica*, 1, 48-52.

Khomutov, G.B., Potapenkov, K.V., Koksharov, Y.A., Trubitsin, B.V., Tikhonov, A.N., Mamedov, M.D. & Khalilov, R.I. (2014). Magnetic nanoparticles in biomimetic and biological systems: Generation of iron oxide magnetic nanoparticles in DNA complexes, isolated chloroplasts and high plants. *XII International Conference on Nanostructured Materials* (Nano-2014), Moscow, Russia.

Kim, J., Grate, J.W. & Wang, P. (2008). Nanobiocatalysis and its potential applications. *Trends in Biotechnology*, *26*(11), 639-646. https://doi.org/10.1016/j.tibtech.07.009

Kiran, A.S.K., Ramakrishna, S. (2021). *An Introduction to Biomaterials Science and Engineering*. World Scientific. https://doi.org/10.1142/12038

Koutsopoulos, S. (2012). Molecular fabrications of smart nanobiomaterials and applications in personalized medicine. *Advanced Drug Delivery Reviews*, *64*(13), 1459-1476.

Kumar, S., Nehra, M., Kedia, D., Dilbaghi, N., Tankeshwar, K. & Kim, K.H. (2020). Nanotechnology-based biomaterials for orthopaedic applications: Recent advances and future prospects. *Materials science and engineering: C*, 106, 110154. https://doi.org/10.1016/j.msec.2019.110154

Kumarage, V., Siriwardane, I.W., Sandaruwan, C., Kandanapitiya, M.S., Kottegoda, N. & Jayewardenepura, G. (2022). Nanotechnology Applications in Biomaterials. *A Review*, 3, 32-54.

Lens, M. (2009). Use of fullerenes in cosmetics. *Recent Patents on Biotechnology*, *3*(2), 118-123. https://doi.org/10.2174/187220809788700166

Maleki Dizaj, S., Eftekhari, A., Mammadova, S., Ahmadian, E., Ardalan, M., Davaran, S. & Mostafavi, E. (2021). Nanomaterials for chronic kidney disease detection. *Applied Sciences*, *11*(20), 9656.

Mammadova, S., Nasibova, A., Khalilov, R., Mehraliyeva, S., Valiyeva, M., Gojayev, A.S. & Eftekhari, A. (2022). Nanomaterials application in air pollution remediation. *Eurasian Chemical Communications*, *4*(2), 160-166.

Marin, E., Boschetto, F. & Pezzotti, G. (2020). Biomaterials and biocompatibility: An historical overview. *Journal of Biomedical Materials Research Part A*, *108*(8), 1617-1633. https://doi.org/10.1002/jbm.a.36930

Nasibova, A., Khalilov, R., Abiyev, H., Kavetskyy, T., Trubitsin, B., Keskin, C. & Eftekhari, A. (2021). Study of Endogenous paramagnetic centers in biological systems from different areas. *Concepts in Magnetic Resonance Part B*, 2021, 1-5.

Nasibova, A., Khalilov, R., Bayramov, M., Mustafayev, I., Eftekhari, A., Abbasov, M. & Selakovic, D. (2023). Electron Paramagnetic Resonance Studies of Irradiated Grape Snails (Helix pomatia) and Investigation of Biophysical Parameters. *Molecules*, *28*(4), 1872.

Nasibova, A.N. (2020). Formation of magnetic properties in biological systems under stress factors. *Journal of Radiation Researches*, *7*(1), 5-10.

Ramburrun, P., Khan, R.A. & Choonara, Y.E. (2022). Design, preparation, and functionalization of nanobiomaterials for enhanced efficacy in current and future biomedical applications. *Nanotechnology Reviews*, *11*(1), 1802-1826.

Rigano, L., Lionetti, N. (2016). Nanobiomaterials in galenic formulations and cosmetics. In *Nanobiomaterials in Galenic Formulations and Cosmetics*, 121-148. William Andrew Publishing. https://doi.org/10.1016/B978-0-323-42868-2.00006-1

Smijs, T.G., Pavel, S. (2011). Titanium dioxide and zinc oxide nanoparticles in sunscreens: focus on their safety and effectiveness. *Nanotechnology, Science and Applications*, *4*(1), 95-112. https://doi.org/10.2147/nsa.s19419

Tüylek, Z. (2017). Nanomedicine and Biomaterial Usage. *Journal of Engineer Brains*, *1*(2), 41-52. (In Turkish).

Yang, L., Zhang, L. & Webster, T.J. (2011). Nanobiomaterials: State of the art and future trends. *Advanced Engineering Materials*, *13*(6), B197-B217. https://doi.org/10.1002/adem.201080140