Chapter 24
Biomaterials in Medicine: A Review

Swaralee Prabahwalkar
https://orcid.org/0009-0003-9794-8948
Ajeenkya D.Y. Patil University, India

Sanjana Pandey
https://orcid.org/0009-0005-6211-3304
Ajeenkya D.Y. Patil University, India

Ebaa Mubarak
https://orcid.org/0009-0004-3933-0530
Ajeenkya D.Y. Patil University, India

Susanta Das
https://orcid.org/0000-0002-9314-3988
Ajeenkya D.Y. Patil University, India

Nishakant Ojha
Ajeenkya D.Y. Patil University, India

ABSTRACT

Material science is essential to medical applications. Biomaterials are a class of materials studied under material science for healthcare. The initial known application of biomaterials was the use of animal intestines to suture wounds, wood as a missing limb in an amputation and glass as a substitution for an eye. Biomaterials impact a variety of applications like tissue engineering, implants, dentistry, drug delivery, etc. They are chosen based on their properties like biocompatibility, thermal conductivity, resistance to compression and corrosion, chemical stability, strength etc. This review broadly discusses biomaterials, their classification into ceramics, metals and polymers, their characteristics, current applications, properties which are vital for in-vivo material action prediction. A bibliometric analysis was done which identified information gaps like prolonged in-vivo studies, extensive interdisciplinary research and highlighted the future scope of biomaterials in healthcare and medicine for development of composite materials, bioprinting, AI and personalized medicine.

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I. INTRODUCTION

Material Science refers to the study of various materials, their properties, structure and composition (Patel et al.,2024). The application of material science spreads to a variety of fields like aerospace engineering, medicine and healthcare, energy production etc. Application of biomaterials in healthcare, especially, has skyrocketed in the past 2 decades (*Material Science in Healthcare - Pubmed*, n.d.). The field of healthcare requires surgical assistance. The quality of surgical instruments is crucial to the patients' health and thus the choice of material used for the same is vital because the tools are foreign bodies entering the human system. A research paper by Elizabeth D. Dominguez and Brett Rocos report that there may be as many as incidents a year of poor-quality surgical instruments causing harm. Dominguez and Brett Rocos report that there may be fifteen hundred incidents a year of poor-quality surgical instruments causing harm. One hundred and sixty-one incidents were reported in which instruments used in surgery were of inferior quality. Additionally, five reoperations were required. One hundred and nineteen incidents of no harm, thirty-five low harm incidents, six moderate harm incidents and one severe hard incident were also reported (Dominguez & Rocos, 2019). Furthermore, although the number of recorded cases where the material used in healthcare resulted in patient harm are low, the effects of such cases have often been long-term and/or fatal. For example, DePuy hip implants had to be recalled because of high revision rates of 12% and 13% in the ASR™ Hip Resurfacing System ASR™ Acetabular System respectively at five years. A major problem was the generation of metal debris from mechanical and corrosive wear. This is associated with higher metal ion concentrations in the patient's bloodstream (Hug et al., 2013). The implants caused metallosis, necrosis, osteolysis, systemic metallosis, pseudotumors, bone fractures, revision surgery or reconstructive surgery (*DePuy Hip Replacements*, n.d.). Another example is the Poly Implant Prothèse breast implants that had a high implant rupture rate due to the use of low-grade, highly permeable silicone (Bachour et al., 2018). The ruptured implants resulted in palpable lymph nodes in the axillae development, lump development, and pain (Wazir et al., 2015). There are also cases with failures in heart pacemaker implants due to biocompatibility issues. These records highlight the importance of well-researched use of materials in healthcare and medicine.

A major class of materials used in healthcare and medicine is broadly called 'biomaterials.' Biomaterials have been defined as 'as a non-biological material used in a medical device with the purpose to interact with biological systems' (Festas et al., 2019) by the European Society. The latest definition was proposed in United Kingdom in 1986 and approved afterwards in 1991 in a proceedings paper of Consensus Conference held by the European Society for Biomaterials: "Any substance or combination of substances, other than drugs, synthetic or natural in origin, which can be used for any period of time, which augments or replaces partially or totally any tissue, organ or function of the body, in order to maintain or improve the quality of life of the individual" (Feier et al., 2023). Biomaterials may be used to support, replace or enhance any biological function or tissue that has sustained damage. Biomaterials include synthetic and biological polymers, ceramics and metals etc. The development of biomaterials is generally multi and interdisciplinary. It requires not only materials scientists but also collaborations between engineers, pathologists, biomedical engineers, and clinicians (Kukich et at.,2024). Furthermore, their application is usually tailored with a certain function in mind. Biomaterials have a wide range of applications like medical implants, hearing loss implants, artificial joints, ligaments, tendon, dental implants, and devices that stimulate nerves. They are also used to promote healing of human tissues and are used in sutures, staples, clips and dissolvable dressings. Moreover, they are used in regeneration of