Editorial corner – a personal view

Designing biocompatible PEEK-based nanocomposites for load-bearing implant applications

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The need for orthopedic implants for load-bearing bone replacements is continuously increasing due to the increase of elderly population and traumatic injury. Bone grafts are commonly employed in reconstructive surgery of the hip, knee and long bones. The limited supplies of allografts or autografts and their associated donor-site morbidity as well as infection have led to research into biomaterials with excellent bioactivity, biocompatibility, osteoconductive and osteogenetic properties. Several non-resorbable materials such as stainless steels, cobalt-chrome and titanium alloys have been employed for the majority of fracture fixation devices and load-bearing implants. However, these metallic alloys exhibit much higher elastic modulus than human cortical bone, leading to stress shielding effect that can result in the bone resorption and subsequent implant loosening (<https://doi.org/10.1016/j.msar.2014.10.001>). In this respect, polymer composites with tunable mechanical properties are ideal bone graft substitutes for orthopedic applications. The successful development and use of the composite implants depend on the proper selection of polymers including reinforcements and fillers.

High performance polyetheretherketone (PEEK) finds useful application for orthopedic implants, such as skull plates, spinal cages and trauma fixation devices. This is due to its high elastic modulus (3.86 GPa), excellent thermal resistance and radiation stability. Thus it can withstand sterilization by steam or gamma irradiation. The elastic modulus of PEEK is still lower than that of human cortical bone ranging from 7–30 GPa. Bioinert PEEK is usually surface modified either with plasma (<https://doi.org/10.1039/C5RA03861H>) and <https://doi.org/10.1021/acsami.5b10881>), or added hydroxyapatite (HA) microparticles for enhancing its osseointegration. In the latter case, HA microparticles up to 40 vol% are added to PEEK for achieving desired mechanical properties. However, large HA microparticles usually fracture and debond from the PEEK matrix during tensile testing. The resultant composites experience premature failure due to poor tensile strength and reduced ductility ([https://doi.org/10.1016/S0142-9612\(03\)00028-0](https://doi.org/10.1016/S0142-9612(03)00028-0)). The recent emergence of nanohydroxyapatite (nHA) offers exciting new opportunities for fabricating biocomposites for load-bearing applications. Accordingly, 4–21.5 vol % nHA can be added to PEEK for enhancing its mechanical stiffness and biocompatibility. The modulus of PEEK-based composites increases with increasing nHA content. The PEEK-21.5 vol% nHA nanocomposite exhibits the highest modulus of 7.85 GPa, being slightly higher than the lower bound modulus of the cortical bone. This composite with a fracture elongation of 0.63% is very brittle, while cortical bone exhibits fracture strain of 1–3% (<https://doi.org/10.1039/C5RA22134J>). By reducing nHA content to 15 vol% and adding 1.8 vol% multiwalled carbon nanotubes, the resulting PEEK composite exhibits a modulus of 7.13 GPa and fracture elongation of 1.74%. This composite exhibits tensile properties similar to those of cortical bone, and also possess excellent biocompatibility (<https://doi.org/10.3390/polym8120425>). Therefore, filler hybridization provides an opportunity for designing polymer biocomposites with desired mechanical and biological properties for load-bearing orthopedic applications.

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