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# Nanomedicine and advanced technologies for burns: Preventing infection and facilitating wound healing

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ABSTRACT

According to the latest report from the World Health Organization, an estimated 265,000 deaths still occur every year as a direct result of burn injuries. A widespread range of these deaths induced by burn wound happens in low- and middle-income countries, where survivors face a lifetime of morbidity. Most of the deaths occur due to infections when a high percentage of the external regions of the body area is affected. Microbial nutrient availability, skin barrier disruption, and vascular supply destruction in burn injuries as well as systemic immunosuppression are important parameters that cause burns to be susceptible to infections. Topical antimicrobials and dressings are generally employed to inhibit burn infections followed by a burn wound therapy, because systemic antibiotics have problems in reaching the infected site, coupled with increasing microbial drug resistance. Nanotechnology has provided a range of molecular designed nanostructures (NS) that can be used in both therapeutic and diagnostic applications in burns. These NSs can be divided into organic and non-organic (such as polymeric nanoparticles (NPs) and silver NPs, respectively), and many have been designed to display multifunctional activity. The present review covers the physiology of skin, burn classification, burn wound pathogenesis, animal

*Abbreviations:* 2ABI, 2-Aminobenzimidazole; Ang-2, Angiopoietin = 2; ASC, Adipose-derived stem cell; ATP, Adenosine triphosphate; AuNP, Gold nanoparticles; BALO, *Bdellovibrio* and like organisms; BC, Bacterial cellulose; BLT, Blue light therapy; CNF, Carbon nanofibers; CNP, Carbon NP; CNT, Carbon nanotubes; CrHFC, Crypreserved human cultured fibroblasts; CRISPR, clustered regularly interspaced palindromic repeats; CS, Chitosan; DC, Dendritic cell; DOTAP, N-(2,3-Dioleoyloxy-1-propyl) trimethylammonium methyl sulfate; ECM, Extracellular matrix; EGF, Epidermal growth factor; EPS, Exopolysaccharide; ERK, Extracellular regulated kinase; FDA, US Food and drug administration; FGF, Fibroblast growth factor; FIR, Far infrared; GMCSF, Granulocyte macrophage colony stimulating factor; GO, Graphene oxide; GQD, Graphene quantum dots; IGF, Insulin-C12like growth factor; iPSC, Induced pluripotent stem cell; KGF, Keratinocye growth factor; IL, Interleukin; LED, Light emitting diode; LLLT, Low-level laser (light) therapy; LPL, Low power laser; mAb, Monoclonal antibody; MNP, Magnetic NP; MRSA, Methicillin resistant *Staphylococcus aureus*; MSC, Mesenchymal stem cells; MSN, Mesoporous silica nanoparticle; NE, Nanoemulsion; NGF, Nerve growth factor; NHDF, Normal human dermal fibroblasts; NHEK, Normal human epidermal keratinocytes; NIR, Near infrared; NO, Nitric oxide; NP, Nanoparticle; NS, Nanostructure; OP-GEL, Oxidized pectin gelatin; PcrV(A), *P. aeruginosa* V(A) antigen; PDGF, Platelet-derived growth factor; PDMS, polydimethylsiloxane; PDT, Photodynamic therapy; PEG, Polyethylene glycol; PGLA, Poly-lactic-*co*-glycolic acid; Phyto-AuNP, Phytochemical decorated AuNP; PMN, Polymorphonuclear neutrophil; PS, Photosensitizer; Psl, Polysaccharide synthesis locus; PTT, Photothermal therapy; PVPI, Povidone iodine complex; QD, Quantum dot; rhEGF, Recombinant human EGF; ROS, Reactive oxygen species; siRNA, Small interfering RNA; SLBN, Solid lipid-based NP; SSD, Silver sulfadiazine; SWCNT, Single wall CNT; TGF, Transforming growth factor; TiO2 NP, Titanium dioxide NP; TLR, Toll-like receptor; TNF, Tumor necrosis factor; TTSS, Type III secretion system; VEGF, Vascular endothelial growth factor.

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Stimulus-responsive drug delivery
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models of burn wound infection, and various topical therapeutic approaches designed to combat infection and stimulate healing. These include biological based approaches (e.g. immune-based antimicrobial molecules, therapeutic microorganisms, antimicrobial agents, etc.), antimicrobial photo- and ultrasound-therapy, as well as nanotechnology-based wound healing approaches as a revolutionizing area. Thus, we focus on organic and non-organic NSs designed to deliver growth factors to burned skin, and scaffolds, dressings, etc. for exogenous stem cells to aid skin regeneration. Eventually, recent breakthroughs and technologies with substantial potentials in tissue regeneration and skin wound therapy (that are as the basis of burn wound therapies) are briefly taken into consideration including 3D-printing, cell-imprinted substrates, nano-architectured surfaces, and novel gene-editing tools such as CRISPR-Cas.



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