Chapter 11

Functionalization and Targeting Strategies of Solid Lipid Nanoparticles

Vidya Umesh Patil[1]*, Smita V. Nhawkar[1], Rajanikant B. Ghotane[1]
[1]Ashokrao Mane College of Pharmacy, Peth Vadgaon, Maharashtra, India

Abstract

Solid lipid nanoparticles (SLNs) have shown great promise as drug delivery vehicles because of their capacity to encapsulate a variety of therapeutic agents, controlled release behavior, and biocompatibility. By facilitating site-specific delivery, increasing bioavailability, and lowering systemic toxicity, functionalization and targeting techniques have further expanded their potential. Recent developments in SLN surface modification, such as PEGylation, ligand conjugation, and bioinspired coating methods, are thoroughly reviewed in this chapter. Important targeting strategies are covered in detail, including active targeting with ligands like folic acid, transferrin, aptamers, and peptides and passive targeting through the enhanced permeability and retention (EPR) effect. The chapter also discusses stimuli-responsive systems, which enable precise and environment-specific drug release by responding to pH, redox conditions, or enzymatic activity.Functionalized SLN applications are being investigated in a number of therapeutic domains, such as gene delivery, microbial infections, cancer, and disorders of the central nervous system. Their function in improving intracellular uptake and overcoming biological barriers such as the blood-brain barrier is emphasized. Additionally

***Author for Correspondence:** *Email:* vidyapatil480480@gmail.com

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emphasized are difficulties with drug loading, formulation stability, scale-up, and regulatory compliance. Future directions are outlined as transformative tactics, including theranostic SLNs, AI-assisted formulation design, modular platforms for combination therapy, and personalized nanomedicine. SLNs are in a position to be crucial in the creation of next-generation precision therapies by fusing cutting-edge functionalization methods with developments in biomedical science.

Keywords: Active targeting, Aptamers, Bioinspired coatings, Cancer therapy, Controlled release, Drug delivery, Functionalization, Gene delivery, Ligand conjugation, Modular SLNs, Nanomedicine, Passive targeting, PEGylation, Personalized medicine, Redox-responsive systems, SLNs, Stimuli-responsive delivery, Surface modification, Theranostics, Transferrin.

1. INTRODUCTION

1.1 Importance of Targeted Drug Delivery in Modern Therapeutics

In recent decades, targeted drug delivery has emerged as a pivotal strategy in the development of more efficient and patient-friendly therapeutic systems. Unlike conventional therapies, which often suffer from off-target effects and systemic toxicity, targeted delivery aims to direct therapeutic agents precisely to diseased tissues, thereby enhancing efficacy and minimizing side effects. This approach is especially critical in treating complex conditions such as cancer, neurological disorders, and chronic inflammatory diseases, where localized delivery significantly improves clinical outcomes [1].

1.2 Brief Overview of Solid Lipid Nanoparticles (SLNs)

Solid Lipid Nanoparticles (SLNs) are submicron-sized colloidal carriers composed of biocompatible and biodegradable lipids that remain solid at room and body temperatures. Solid lipid nanoparticles are the preliminary type of nanocarriers that are composed of lipids, that transform into solid at human body warmth along with solidified by emulsification submicron (those smaller than 1000 nm) sizes apply to solid lipid nanoparticle [2]. Typically stabilized by surfactants in