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Clay nanoparticles for regenerative medicine and biomaterial design: a review of clay bioactivity

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Abstract: Clay nanoparticles, composites and hydrogels are emerging as a new class of biomaterial with exciting potential for tissue engineering and regenerative medicine applications. Clay particles have been extensively explored in polymeric nanocomposites for self-assembly and enhanced mechanical properties as well as for their potential as drug delivery modifiers. In recent years, a cluster of studies have explored cellular interactions with clay nanoparticles alone or in combination with polymeric matrices. These pioneering studies have suggested new and unforeseen utility for certain clays as bioactive additives able to enhance cellular functions including adhesion, proliferation and differentiation, most notably for osteogenesis. This review examines the recent literature describing the potential effects of clay-based nanomaterials on cell function and examines the potential role of key clay physicochemical properties in influencing such interactions and their exciting possibilities for regenerative medicine.

1. Introduction

Recent studies have shed new light on the potential of clay nanoparticles and composites for biomaterial design and regenerative medicine[1–3]. Clay nanoparticles are biocompatible at doses significantly higher than most other nanomaterials [4,5] and their degradation products are non-toxic, absorbable and of relevance to osteogenic cell function[6,7,8]. Furthermore, several studies have convincingly demonstrated direct, beneficial, concentration-dependent effects of clay nanoparticles on cellular adhesion, proliferation and differentiation [4–6,9–12]. These new observations combined with the well-established utility of clay nanoparticles to impart attractive mechanical or rheological properties to polymeric hydrogels and scaffolds [9–12,13, 14], and the opportunities afforded by their classic use as drug delivery modifiers[15,16], suggest the striking potential of clays for the creation and development of new bioactive scaffolds.

Clay minerals, also called sheet-silicates or phyllosilicates, are a family of inorganic layered nanomaterials classically defined as “minerals which impart plasticity to clay and which harden upon drying or firing”[17]. Based on archaeological and written records, clays have played an important role in medicine from the dawn of mankind, ranging from oral ingestion for therapeutic purposes (geophagy) to wound healing and haemorrhage inhibition[18,19]. Clays are still widely applied as active ingredients in pharmaceutical formulations, typically administered either orally as antacids, gastrointestinal protectors, and anti-diarrheic or topically as dermatological protectors and anti-inflammatories[20]. Clays also play an important role in pharmaceutical preparations as excipients functioning as disintegrants, diluents and binders, emulsifying, thickening and anticaking agents, flavour correctors and delivery modifiers of active agents [21,22].

Extensive research has been undertaken to investigate the role of clay minerals in drug/gene delivery and in the development of polymer-clay nanocomposites (PCNs). This interest is due