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NANO HYDROXYAPATITE: BONE GRAFT INNOVATION

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ABSTRACT

Nanocrystalline hydroxyapatite (n-HA) is the primary inorganic constituent found in hard tissues.. The development of commercial synthetic analogues, known as 'biomimetic' materials, has garnered significant attention due to their ability to closely replicate the physicochemical characteristics of biological apatite compounds. With enhanced osseointegrative properties, nano-hydroxyapatite (n-HA) stands out as a promising class of bone graft materials, offering improved compatibility and functionality for regenerative applications. Nano-hydroxyapatite (n-HA) exhibits a strong affinity for bone tissue, where it promotes bone healing by stimulating osteoblast activity and enhancing the expression of local growth factors. Clinical studies using nanocrystalline hydroxyapatite bone grafts in the treatment of human periodontal intrabony defects have demonstrated significant benefits, including reductions in pocket depth and osseous lesion depth, as well as statistically significant gains in clinical attachment levels. n-HA presents multiple benefits for periodontal tissue regeneration, such as low patient morbidity, excellent biocompatibility, and a non-toxic profile. These qualities make it a highly favorable option for promoting effective and safe tissue repair.

KEYWORDS: Nanocrystalline hydroxyapatite, promote, bone grafts, tissue regeneration, tissue repair.

INTRODUCTION

Periodontitis is a long-term inflammatory disease that targets the supporting structures of the teeth, leading to the gradual breakdown of the periodontal ligament and the alveolar bone surrounding the teeth. This condition can result in various forms of bone deficiency, posing significant challenges for clinicians, particularly in cases of periodontal osseous defects. Bone regeneration potential is significantly higher in cases of angular defects than in instances of horizontal bone loss, as long as the remaining bone structure and the number of osseous walls provide a favorable environment for regeneration.[1]

Bone grafting has been a cornerstone in reconstructive and regenerative medicine, playing a vital role in treating bone defects, fractures, and degenerative conditions.

Hydroxyapatite is the primary inorganic component of human bone, making it an ideal candidate for bone regeneration. The introduction of nanotechnology has further refined its application, leading to improved bioactivity, biocompatibility, and mechanical properties. Unlike conventional hydroxyapatite, nano-sized hydroxyapatite particles possess a high surface-to-volume ratio, allowing enhanced interaction with bone cells and better integration with surrounding tissues.

Bone grafting is an essential procedure in both orthopedic and dental surgeries, used to promote the regeneration and repair of bone defects. Among various graft materials, nano-hydroxyapatite (nHAp) has emerged as a promising innovation due to its biocompatibility, osteoconductivity, and structural similarity to natural bone. Hydroxyapatite (HAp), a calcium phosphate compound, is extensively utilized in bone coatings and cements owing to its outstanding biocompatibility.

A proven approach to restoring the lost attachment apparatus in deep intra-bony defects is the grafting of

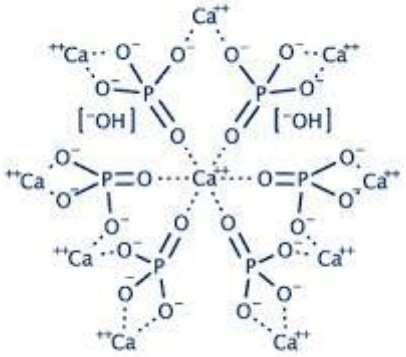
bone substitute biomaterials, which facilitates tissue regeneration and structural repair.[2]

The hydroxyapatite (HA) with the chemical formula of Ca10(OH) 2(PO4) 6 is almost identical to the inorganic portion of the bone matrix. Due to its strong structural resemblance to natural bone, extensive research is being conducted to explore the use of hydroxyapatite (HA) as a bone graft material. Due to its excellent osteoconductive and osseo-integrative properties, it is commonly used as a bone graft in dental surgeries.[3]

Nanohydroxyapatite is widely utilized in dentistry due to its excellent biocompatibility and bioactivity. One of its most valuable properties is its ability to facilitate re-mineralization, making it particularly beneficial in the early stages of caries. It supports the direct restoration of lost minerals or serves as a carrier for mineral ions, aiding their integration into the collagen network for enhanced structural repair.[4]

STRUCTURE AND CHEMICAL COMPOSITION

Nano-hydroxyapatite (n-HA) is the hydroxyl-rich end member of the apatite group, composed primarily of calcium and phosphate ions.. The structure of HA crystals belongs to the hexagonal symmetry group with ten Ca2+, six PO43−, and two OH − ions contained in a single unit cell.[5]



PROPERTIES OF NANO-HYDROXYAPATITE

Bone is primarily composed of hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$), which serves as its main inorganic constituent.

Enhanced surface area: Nano particle provides a much larger surface area compared to bulk hydroxyapatite, which can enhance their interaction with cell and other biomolecule.

High biocompatibility and bioactivity: Encourages osteoblast proliferation and differentiation.

Osteoconductivity: Serves as a scaffold for bone ingrowth.

Resorbability: Depending on formulation, nHA can be bioresorbable, reducing the need for surgical removal.[6]

DRUG DELIVERY SYSTEMS

Serving as a carrier for antibiotics or growth factors. Commercially available nHA-based products (e.g., NanoBone®, Ostim®, and others) have demonstrated positive outcomes in clinical trials, with reduced inflammation and faster bone regeneration.[7]

APPLICATIONS OF NANOHYDROXYAPATITE IN DENTISTRY

Nano-hydroxyapatite (nHA) is an innovative material with a wide range of applications in dentistry. It is used in a diverse array of dental applications like Bone grafting, intrabony defect, ridge augmentation, peri implantitis, tissue enginerring.[8]

Nanohydroxyapatite in Periodontal Tissue Regeneration

Recently, nano-hydroxyapatite (nHA) has emerged as a viable alternative to autogenous bone grafts for periodontal and alveolar tissue regeneration, owing to its excellent biocompatibility, minimal patient morbidity, and lack of toxicity.[9]

The nHA graft has demonstrated promising clinical outcomes in periodontal regeneration and can therefore be effectively utilized in the treatment of intrabony defects.[10]

Bone Grafting and Implantology

n-HA serves as a grafting material in periodontal and oral-maxillofacial surgeries, aiding in bone regeneration and enhancing implant osseointegration due to its osteoconductive properties.

Intrabony defect

Kumar et al. (2013) demonstrated that n-HA grafts significantly improved clinical attachment levels, probing depth reduction, and radiographic bone fill in periodontal intrabony defects.

Ridge Augmentation

Studies suggest that combining n-HA with collagen or platelet-rich fibrin (PRF) improves outcomes in ridge preservation and augmentation procedures, offering predictable regeneration with minimal complications.[11]

FUTURE PERSPECTIVES

Nano-hydroxyapatite is extensively used in dentistry due to its remarkable properties and effectiveness. Since hydroxyapatite naturally occurs in bones and teeth, it boasts excellent biocompatibility, making it highly versatile across various medical fields. A key advantage of nano-hydroxyapatite is its ability to be combined with different substances to enhance its functionality, such as incorporating antimicrobial agents. In treatments focused on tissue regeneration, minimizing the risk of infection is

particularly critical, as it plays a vital role in ensuring successful healing and recovery.[12]

With ongoing advancements in nanotechnology and biomaterials, nano-hydroxyapatite is set to revolutionize bone grafting. Researchers are working on optimizing its composition for better mechanical strength, faster healing, and multifunctional applications.[13]

CONCLUSION

Nano-hydroxyapatite has emerged as a promising alternative to autogenous bone grafts for periodontal tissue regeneration. Its increasing use in recent years can be attributed to several key advantages, such as minimal patient morbidity, excellent biocompatibility, and an absence of toxicity. Moreover, when combined with active particles or biological mediators, nano-hydroxyapatite demonstrates enhanced regenerative potential, stimulating periodontal tissue repair more effectively than when used alone.[1]

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