Applications of Nano Structured Material in Tissue Regeneration

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If the surface structure or interior pores of a material are on the nanoscale, it is said to be nanostructured. Biomaterials are often used to replace or repair damaged or diseased bones. Materials used to replace bone typically consist of metals and alloys, ceramics, polymers, composites, and, more recently, nanocomposite. The increased mechanical characteristics, nanoscale porosity, biocompatibility, and bioactivity of nanostructured materials are attracting interest at the moment because they promote greater cell adhesion and proliferation, which leads to exceptional tissue integration. Nanoparticles, nanofibers, nanocomposites, nanoclusters, nanocrystals, nanotubes, nanowires, nanorods, nanofilms, and so forth are examples of nanomaterials. Nowadays, there are numerous top-down and bottom-up methods for creating nanomaterials or nanostructured materials with ordered or asymmetric nano topographies. These methods include electrospinning, phase separation, self-assembly processes, chemical vapour deposition, thin film deposition, chemical etching, nano-imprinting, photolithography, and lithographies using electron beams or nanospheres.

Keywords: public health, Nano technology, Nano structured material.

1. Introduction

The tissue engineering market is anticipated to expand at a healthy rate, with a 2016 valuation of approximately USD 5 billion. Over 900,000 procedures for bone replacement or reconstruction are carried out annually in the US, according to the Centres for Medicare and Medicaid. There are currently just a few nanotechnology-based solutions on the market for tissue regeneration applications. ActicoatTM Flex 3 and 7 (Smith & Nephew, UK) nano silver containing wound dressing, PolymemTM silver, and RegrenexTM gel are examples of these products [1]. Scaffolds built in nanostructured design have the capacity to imitate the ECM structure when compared to topical application. Nowadays, electrospinning technology is extensively employed to create nanofibrous scaffolds for bone tissue regeneration and wound healing that have better cell adhesion and proliferation. Because of their increased surface area and biomimetic properties, nanostructured materials allow for greater cell adherence than traditional materials—a necessary quality for materials employed in tissue engineering applications. In contrast to traditional materials, nanoparticles imitate the properties of the extracellular matrix (ECM) naturally occurring in the body to effectively stimulate the regeneration of new tissue by promoting higher levels of protein adsorption than the other [2]. There aren't many items based on nanotechnology available right now, and they're limited to tissue regeneration. The most popular uses of biodegradable materials are in tissue engineering and bone restoration. The materials that are most frequently utilised in tissue engineering are alloys, metals, polymers, ceramics, and composites. Polymeric materials can have their rate of deterioration modified by varying their production methods and structural makeup. Therefore, the goal of this research is to create nanostructured materials for applications such as bone tissue regeneration and wound healing.

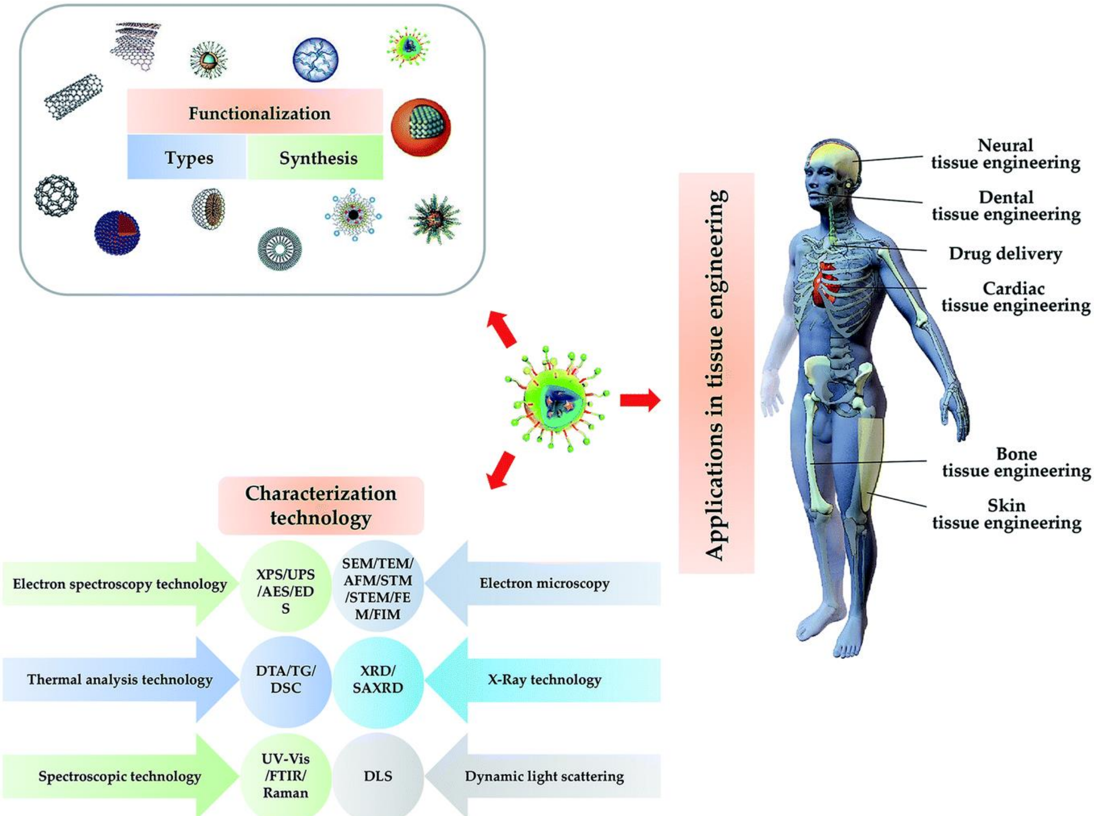

Figure 1: nanostructured material used in tissue regeneration

Nanostructured materials have many biomedical applications [3] as listed below

- Tissue engineering: this technique uses appropriate materials to meet the unique needs of damaged or wounded tissues, including skin, bones, cartilage, lymph nodes, blood vessels, muscle, and other tissues.
- Drug Delivery: By using a regulated drug delivery method, bioactive molecules or integrated drugs can be efficiently released from nanostructured materials by diffusion or degradation.
- Scaffolds: these structures promote enhanced cell adhesion, proliferation,

biocompatibility, and biodegradability due to their porous nature and increased surface area.

• Wound Healing: To promote tissue healing, innovative scaffolds for wound healing have been created using a variety of biopolymers and active ingredients.

Numerous in vitro investigations on nanofibrous scaffolds, drug delivery vehicles, and wound healing bandages have demonstrated that nanostructured materials perform better than their macro- or micro-architectured scaffold equivalents with comparable material composition. Thus, nanofibrous structures can be customised for specific tissue engineering uses.

In this instance, section 1 of the article examines the introduction, while section 2 examines the relevant literature. The purpose of the nano structured material is explained in Sections 3, and 4, the challenge of the proposed work is discussed in Section 5, and the project is concluded in Section 6.

2. Literature Review

The mechanical, optical, catalytic, magnetic, and cytocompatibility qualities that are needed are absent from conventional or micron structured materials [4]. The most popular tissue replacements for damaged tissue repair are autografts and allografts; nevertheless, they have drawbacks such as poor tissue availability, morbidity at the donor site, and expensive cost, which prevents them from meeting enhanced tissue regeneration [11]. On the other hand, the larger surface area of nanostructured material facilitates better cellular, protein, or active component adherence compared to the former [5]. Nanomaterials exhibit a biomimetic nature, akin to native bone tissue, and they promote improved protein adsorption in comparison to micron-sized materials, in contrast to conventional materials [6].

The study also indicated that it could be used as a potential defect filling biomaterial for bone tissue regeneration at the fracture site. Hence, the current study has focused on the development of nanotechnology based degradable scaffolds with biomimetic nature which opens up multiple avenues for potential wound and bone tissue regeneration applications.

3. Need for Biodegradable Materials

Biocompatible and biodegradable scaffolds must be created for tissue engineering and drug delivery applications [7]. The tissue's rate of degradability and healing must be equal. Any scaffold utilised in tissue engineering applications must also be biocompatible; it must be free of toxins, promote cell adhesion and proliferation, permit the interchange of gas and nutrients from the blood, and have a sufficient mechanical strength. As seen in Figure 2, the most often utilised biodegradable materials for tissue engineering are polymers, ceramics, composites, metals, and alloys. A tissue-engineered scaffold's controlled, slow disintegration rate prevents the stress shielding effect by transferring the mechanical strain to the surrounding tissue and bone. The most widely employed biomaterials in tissue engineering and drug delivery applications are biodegradable polymers. It is possible to modify the polymer's rate of degradation by varying the materials and scaffold construction methods used. A biodegradable scaffold that is ideal should not cause any harm to the surrounding tissues and should not have any toxicity or cancer-causing properties. Degraded scaffold products should also be biocompatible and unaffected by the healing tissue.

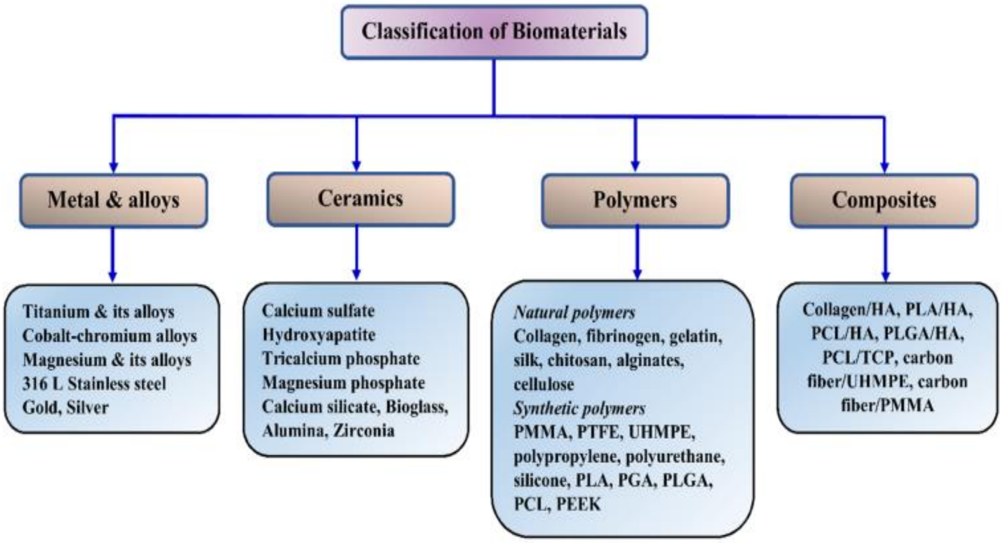

Figure 2: Classification of various biodegradable materials used for tissue regeneration

When using scaffolds for tissue regeneration, their design is very crucial. The surface of the scaffold should promote cell adhesion and proliferation and offer a networked porous structure to facilitate tissue ingrowth. In comparison to typical materials utilised in tissue engineering applications, electrospun nanofibrous polymeric scaffolds, nanostructured composite scaffolds, and scaffolds including bioactive molecules and delivered by nanoparticles are dramatically increasing the cell responses. Thus, poor cytocompatibility, mechanical qualities, and the lack of linked holes can be addressed by creating biomaterials with nanoscale structures. For improved functionality, tissue-engineered scaffolds are therefore usually made to resemble the ECM. By creating the biomaterial as nanofibers and nanocomposite, which can be applied to tissue and bone regeneration, these qualities can be obtained [8].

4. Significance of the Nano Structured Materials

Owing to its exceptional biocompatibility and biodegradability, poly (lactic acid) (PLA) is a great biopolymer for use in tissue engineering, regenerative medicine, drug administration, gene transfer, and surgical suture manufacturing [9]. Dressings made of PLA nanofibers may have application in regenerative medicine. Nanofibers made of PLA and curcumin have demonstrated good wound healing and blood compatibility. The chemical compound known as curcumin, or 1,7-bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione, is the biologically active component of turmeric and is a polyphenol that was isolated from the dry rhizomes of Curcuma Longa L, a member of the Zingiberaceae family of ginger plants. Unfortunately, because curcumin is hydrophobic and not soluble in water, it has limited bioavailability and in vivo stability, which restricts its usage in wound healing applications. For enhanced solubility and regulated release, hyperbranched polyglycerol (HPG), a highly hydrophilic polymer with strong blood compatibility, water solubility, and nonimmunogenic nature, can be coupled with curcumin.

The most effective method for creating nanofibers is electrospinning, which has a number of medical uses such as tissue engineering, medication delivery, and enzyme immobilisation. Additionally, through their ability to replicate the extracellular matrix of different biological tissues, nanofibers enhance cell adhesion and proliferation. In the current study, a novel curcumin-loaded nanofibrous dressing with a PLA and HPG blend was created using the electrospinning technique and tested in vitro to address issues including wound infection, poor bioavailability and stability of curcumin, and uncontrollable release of the active component.

The most often employed bone healing biomaterials are tricalcium phosphate (TCP) and nano hydroxyapatite (nHA), because of their remarkable capacity for bone repair and biocompatibility. However, their usage in bone-related applications has been limited due to their drawbacks, which include weak mechanical strength and degradability. Magnesium phosphate (MgP) has excellent adhesive properties, a high initial strength, quick breakdown, and a quick setting time. Calcium phosphate (CaP) on nHA and MgP combined can combine the benefits of both for applications involving bone tissue regeneration. The goal of the current work is to create a fibrous nanocomposite structure that will resemble the extracellular matrix (ECM) for use in bone tissue engineering. There isn't a report on calcium-magnesium nanocomposite fibrous scaffolds made using electrospinning yet. In a similar vein, there haven't been any reports on the utilisation of magnesium phosphate in the nano range with flakes' shape.

In orthopaedic practice, the lengthy bone segmental defect is difficult to repair. For the correction of these deformities, autologous bone transplants are regarded as the gold standard material. For reconstruction, synthetic bone grafts and allografts are also utilised. Limited tissue availability, longer recovery times following surgery, donor site morbidity (autografts), high costs, unpredictable bone healing, the possibility of disease transmission, and an unfavourable host immune response are only a few of the problems related to the use of these bone transplants (allografts). Magnesium-based materials are an effective scaffold material for bone tissue creation because they are biocompatible and totally disintegrate following tissue regeneration [10]. The primary drawback of magnesium implants is their rapid deterioration rate, which produces hydrogen gas and a localised alkaline environment.

5. Conclusion

The benefits of nanofibrous degradable scaffolds include increased surface area, porous structure, and ECM that resembles natural processes. Numerous biological tissues, including bone, tendon, ligaments, muscle, nervous system, and teeth, have tubular and densely packed fibre structures. Therefore, there are several uses for electrospun nanofibrous assemblies in tissue engineering to restore or repair a variety of tissues. To accomplish the regeneration of the particular tissue, the parameters such as mean fibre diameter, linked pores, distribution, and degradation can be customised through the employment of various materials. The native tissues of bone and dentin are nanocomposite structures made of nano-hydroxyapatite crystals (3-5 nm) encased in a matrix of nanofibrous collagen. The collagen and hydroxyapatite in this nanostructured form provide the bone greater mechanical strength and biofunctionality.

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