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Drug Delivery Systems in the Oral Cavity Using Biocompatible and Biomaterials

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Abstract

In response to environmental limits and conditions, biological organisms develop sophisticated and effective methods for producing materials that frequently surpass synthetic materials with a same composition. It is essential to have a thorough grasp of the characteristics, make-up, and hierarchical organisation of biological materials in order to synthesise and develop innovative bio-inspired materials with similar traits. These biomaterials are increasingly being used in the medical field, such as as drug delivery vehicles or as skin and soft tissue substitutes for the treatment of wounds. According to this theory, a number of researchers have been asked to submit unique research findings and reviews that may inspire further research into novel biomaterials with immediate clinical uses in the related disciplines of medication delivery, wound care, and transportation.

Based on the following keywords stem cells, bone tissue engineering, functional biomaterials, scaffolds, and implants this special issue is organised into different areas. Applications for biomaterials have quickly spread to various scientific disciplines. Dentistry is one of the key areas where biomaterials are used. These materials can help with implant placement, surgery, and the treatment of oral disorders such peri-implantitis, periodontitis, and other dental issues. Drugs are released into target tissues of the oral cavity with the fewest possible side effects thanks in large part to drug delivery devices made of biocompatible materials. In order to increase the effectiveness and acceptability of therapy techniques for dental issues and oral disorders, researchers have examined a variety of delivery systems. Additionally, biomaterials might be used in biocompatible medication delivery systems as carriers. For instance, several delivery systems are made using natural polymeric materials such gelatin, chitosan, calcium phosphate, alginate, and xanthan gum. Additionally, several alloys are used in medication complexes for transportation purposes.

Keywords: Biomaterials applications; Drug delivery; Natural polymer; Transportation; Biocompatible; Therapeutic

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Introduction

With a broad antibacterial range, potent antibacterial activity, and low effective inhibitory concentration, ciprofloxacin (CPFX), one exceptional fluoroquinolone antibiotic of the third generation, has produced a number of positive therapeutic outcomes. It is common practise to provide CPFX in the form of a capsule, pill, or injectable. However, these common administration techniques demonstrate that the drug's greatest bioavailability is around 52%. Additionally, the usable CPFX's half-life is too short to achieve extended drug release. Although many pathogens can enter cells directly, most medications first breakdown in the lysosome before they can kill bacteria. Typically, this condition causes low intracellular drug concentrations. The infected cells operate as a vast reservoir for the growth and amplification of dangerous microorganisms. Recurrence of suppressed infectious symptoms is frequently caused by the release of harmful microorganisms [1].

In the pharmaceutical industry, chitosan, a good biodegradable, naturally derived substance is frequently employed as a sustained drug-release carrier. By replacing an amine group with a tiny alkyl group in a carboxylation reaction, carboxymethyl chitosan (CMC) is produced. CMC is easily degradable and biocompatible. In comparison to chitosan, CMC has better water solubility without the help of an acid component, protecting the pH-sensitive drug's antibacterial activity. Ionic cross-linking was used to create carboxymethyl chitosan nanoparticles in this study to increase the drug's effectiveness in cells and extend its acting period [2].

Nowadays, dental implant therapy, which is widely accepted, is one of the reliable procedures for replacing missing teeth. 60 years ago, Bothe et al. demonstrated that titanium has the potential to be a biocompatible material for surgical implantation after initially explaining the fundamental notion of metallic instrument implantation in bone in the 1940s. Finding out the fundamental characteristics of the tissue response to dental implantation is necessary in order to determine the successful outcome and purposes of dental implants. Early implant failures have typically been attributed to altered or insufficient wound healing, which prevents osseointegration. Early implantation failures have also been attributed to other issues such poor bone quality, a variety of surgical techniques, occlusal loading, and postoperative inflammation and infection. Dissection in osseointegration, which commonly occurs after the practical loading of implant-supported prostheses, is the primary cause of delayed implant failures. Additionally, peri-implantitis and occlusal overload, a biomechanical failure, have been linked to delayed implant failures frequently [3].

Fibrous or fibrosis encapsulation is the repairing reaction to biocompatible materials. Following implantation, there are typically 2 techniques used to treat the damage: connective tissue regeneration and replacement (contains fibrous capsule). The ability of cells to proliferate and the tissue framework permanence of the implant location determine the operations. Dental implants are more compatible with osseous tissue than soft tissue. Dental implants also have a strong ability to bind to bone, despite their unsatisfactory ability to bond to soft tissue, which might result in the encapsulation of fibres. Dentistry uses a wide variety of materials, including intracanal fillings, liners, and medications as well as subgingival implants, restorative products, mouthwashes, and prosthetic materials [4].

Since dental implant surfaces are vivaciously related with essential soft and hard tissue and adapted to chemical as well as mechanical features, dental implant systems produce numerous dental devices and materials that are essential necessities. To set essential tissues, at least some requirements might include morphological compatibility, mechanical compatibility, and biological compatibility. Biomaterials are sometimes referred to as biological or synthetic materials that are used to repair a section of a live structure so that it can continue to interact with living tissues. The responses of the local and systemic tissues reveal vital aspects of biocompatibility. Additionally, biomaterials incorporating dental implants and associated components can be defined as any materials, whether synthetic or natural, that can be used for any amount of time to benefit biological systems [5].

Any kind of biocompatible substance can be made into nanoparticles, which can improve the material's characteristics over its bulk counterpart. Additionally, according to study, nanoparticles can be applied as particle coatings to the dental implant's surface to promote soft tissue integration and enhance implant outcomes. Basic characteristics of tissue reaction following biomaterial implantation include acute and chronic inflammation, damage, blood material interactions, creation of the provisional matrix, formation of granulation tissue, advancement of the fibrous capsule, and responses to foreign bodies. Materials for bone grafts are traditionally classed as bioactive, biotolerant, or bioinert in terms of biocompatibility. Due to the response, biotolerant implant materials are sustained in the body with fibrous encapsulation [6].

The bone tissue adjacent to implants made of bioinert materials is connected to it without any chemical reactions. The chemical linkages that bioactive implants form with the bone tissue result in the direct deposition of bone matrix on the implant material. On the basis of histological analysis of local impacts following implantation into bone tissue, this theoretical classification was developed. Stainless steel, stabilised zirconia, titanium, ultrahigh molecular weight polyethylene, and alumina are examples of bioinert materials that bind with the surrounding tissue the least. The capability of biochemical and biophysical responses with regard to tissues has been established by other materials. In various bioactive ceramics, such as bioactive glasses of particular constitutions, a real chemical interaction capability with soft tissues has been demonstrated. However, owing to their greater elasticity and lower strain-to-failure, flexural strength, and toughness of fracture than bone, bioactive ceramics (in bulk form) are not recommended for load-bearing applications. Ceramics made of calcium phosphate are thought to be osteoconductive and bioactive. An active carbonate hydroxyapatite layer that is similar to the mineral phase in bone is formed on the implant as a result of ion exchange reactions between the surrounding bodily fluids and the bioactive implant. Depending on where the body is, Bioresorbable bioactive components also begin to resorb and are gradually replaced by developing tissue. These biomaterials include tricalcium phosphate [Ca_3 $(PO_4)_2$ and polylactic-polyglycolic acid copolymers. This review covered the impacts of biocompatible materials and how they support dental implant prosthetics [7].

Materials and Method

The following databases were used to conduct the current review: PubMed, SciFinder, Science Direct, and Google Scholar. In the first section of the investigation, extensive bibliographic research was conducted using the terms "drug delivery system," "biomaterials," "dental disorders," "oral cavity," and "biocompatible" and each of the associated materials. A total of 487 articles were discovered, 81 of which were accepted for the writing phase and 135 of which were rejected because they were irrelevant because of the emphasis placed on the distribution method, included redundant information, or lacked verifiable data. The emphasis of the chosen readings is on the assessment of polymeric substances, administration, delivery system characteristics, and their effects in the sectors of medicine and dentistry. The English language has been used for both articles and patents. The second stage of the bibliographic investigation focused on every biomaterial and biocompatible substance. Chitosan, calcium phosphate, alginate, hyaluronic acid, gelatin, silver nanoparticle, titanium, and gold nanoparticle are the keywords chosen. From June 2021 to July 2020, a process of bibliographic research was carried out, including works from 1999 to 2021 [8].

In the treatment of dental and oral illnesses, biocompatible materials and systems have shown promise. All things considered, biomaterial carries out a component of a system that comes into direct contact with biological tissues and enhances or replaces any organ, tissue, or body function. Additionally, because to their capabilities, such as those of native tissue, biopolymers such hyaluronic acid, gelatin, chitosan, and collagen being investigated in dentistry. Numerous techniques have demonstrated how to make nano- or micro composites with various technological and biological features. The use of biomaterials as materials or delivery systems in dentistry, as well as recent studies on biocompatible and biomaterials as carriers in drug delivery systems, are of great interest and appeal [9].

Different strategies have been developed to direct antibiotics from implant materials to specific regions. Some of the solutions under investigation are beneficial for dentistry and involve biocompatible materials. Because these biomaterials are absorbable drug carriers, several researches stressed the employment of biocompatible alloys with other biomaterials such silica sol-gel, polylactic acid, chitosan, and gelatin. The surfaces of implants still need to hypothetically achieve osseointegration as the covering deteriorates, infections are eradicated. Antimicrobial coatings also effectively treat infections without any strain resistance against a wide variety of bacterial species [10].

Antibiotics can be delivered via biomaterials at the implant-tissue interface, in conjunction with systemic antibiotics, and to create a novel therapy method for eradicating chronic biofilm infections. Drug delivery systems are also employed to enhance drug release control, customised target area, prolonged period of contact, dose reduction, and administration times. Additionally, medication delivery systems make good transporters for genes, peptides, proteins, active components, and vaccines. Alginate, chitosan, calcium phosphate, gelatin, and hyaluronic acids are only a few examples of the biodegradable biomaterials that are available in drug-loaded natural polymeric forms. These materials have prospective applications as drug delivery methods [11].

Discussion

Box-Behnken response surface approach not only ensures measurement accuracy, but also explores interacting effects among several actors. In contrast to formulation optimization by employing uniform design method which attempts to investigate effects of single factor on the manufacture of nanoparticles, the results indicate that the constructed mathematical model employing the Box-Behnken response surface approach has strong predictability because the anticipated OD value of the optimal formulation is similar to the actual result. In each step, CCC NPs displayed a varied releasing pattern. It was implied that pharmaceuticals absorbed on nanoparticle surfaces quickly dissociated into the releasing medium, causing the initial burst release of drug. Drug slowly passed via the pores inside nanoparticles and diffused into the medium as new holes were created by the medium's continued degradation and dissolution of CMC.

It is believed that the primary mechanism for cellular uptake of CCC NPs is endocytosis. Opsonin mediation allowed for the recognition of nanoparticles, which were then bound to cell plasma membranes. A portion of the plasma membrane invaded to create vesicles, in which nanoparticles were wrapped before being released into the interior of the cell and detached from the plasma membrane. Drug in the vesicles was released into the cytoplasm by enzymatic hydrolysis when they came into additional contact with the lysosome [12].

Conclusion

Numerous biocompatible materials are employed in dental implants and prostheses because of their potential to have anti-inflammatory properties. Although they can be physically and chemically altered, peri-implantitis cannot be cured by dental prostheses. Peri-implantitis and peri-implant mucositis are routinely treated and prevented with biocompatible antimicrobial treatments. The promotion of dental implant surface modification and dental pulp regeneration is another way that various types of biocompatible materials, such as metal implants, polymer-based implants, and naturally bioactive materials, display their role in the bone and wound healing process. More research is needed to create the ideal dental implant.

Conflicts of Interest

None

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