

Biomedical Engineering in Dentistry

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Abstract

Biomedical engineering is a developing field that includes engineering principles in the field of biomedicine for diagnosis, treatment as well as preventive procedures. The introductions of new technologies provide new and advanced treatment options than the usual practices. Thus, research in coordination & amalgamation can help biomedical engineers to contribute to dentistry through research, discovery and advancements in dental practice. This article enumerates the utility of biomedical engineering in various dental procedures and the need for research in this field.

Keywords: *Biomedical engineering, Regeneration, Stem cell.*

Introduction

Dentistry is under colossal evolution by the introduction of latest technologies like restorative biomaterials, cell culture, stem cell & gene therapy for regenerative procedures. Regenerative Medicine has tissue engineering that aims in repairing or replacing damaged tissues. These procedures initiate biocompatible scaffolds, cells and growth factors that can in total replace tissues and organs. Bioengineered tissues are created using autologous cells from the patient that is cultured in vitro. These processes are dependent on precise identification of cells, scaffold material, fabrication and inductive factors.¹

Bioprinting of tissue engineering scaffolds: Bioprinting uses additive manufacturing techniques for the production of three-dimensional structures which consist of living cells, biomaterials & active

biomolecules that produces a homogeneous distribution of cells. The current techniques used in bioprinting are inkjet, laser-form that create a hydrogel arrangement that is utilized for cellular encase and assistance.²

Bioprinting techniques use bio-ink which is the basis of printing called hydrogels. These are three-dimensional molecular networks with high water intake. This ensures cell entrapment and containment without damaging the cells. The bio-ink is reinforced depending on the choice of substance, concentration and chemical properties.³

Biomedical materials in Dentistry: The Object of manufacture of biocompatible biomedical materials is to substitute the perished tissues and restore the functioning of the tissues. These improvised materials should enhance the dental treatment and have finer properties. But this requires a thorough understanding of the material with its interaction with the dental structures to obtain an optimum result.⁴ These materials are broadly classified under the following materials.

- 1. Metallic biomaterials:** such as titanium, dental amalgam, and alloys for metallic restorations Metal are not popular materials and could be either noble (Gold, palladium, iridium, platinum, rhodium, etc) and base metal (silver, titanium, copper, tin, zinc, etc) that are cheaper. These materials have good

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compatible properties and marginal fit. These metals are usually used for indirect restorations, post & core, crown etc.⁵

- 2. Polymeric and hydrogel biomaterials:** In recent days new materials are being produced that simulates the natural biomaterials. These polymers are primarily used for complete dentures, denture liners, resin cements etc.⁶

Polymethylmethacrylate is the most popular polymer used because of its low price, its lighter, has low water solubility and water resorption., creates great contour enhancing the esthetics. But the drawback of this material is its fragility that breaks on to a slight impact. With the inclusion of copolymer, glass and metal fibers, etc The polymers are used in dental regeneration and tissue engineering. The use of ploy (lactic-glycolic acid) before implants improved in repair of the alveolar socket and enhanced bone formation. They are even used as delivery vehicles by incorporating it with regenerative growth factors.^{7,8}

- 3. Ceramicbiomaterials** such as hydroxyapatite, bioactive glasses, endodontic filling materials, and

zirconia. Ceramics are a blend of metal and non-metallic materials like oxides, nitrides and silicates. It can appear in solid crystalline, amorphous solid & glass. The interatomic ionic & covalent bonding makes it hard, stiff & brittle with good compressive stresses and less shear and tensile stress. Porcelains are biocompatible material made at the laboratory with excellent biocompatibility, natural chemically, esthetic and high strength.⁹

- 4. Composite biomaterials** such as resin-based composites, giomer composite, and bone augmentation materials. These materials are commonly used in tooth building because of its color, easy contouring and esthetics. Composites are divided into two types: according to size fine and micro-fine & according to the type of fillers micro-hybrid and microfilmed. The composites are at an edge over other materials for its esthetics, bonding, easy to repair, reducing extensive preparation of the tooth. A limitation of this material is polymerization shrinkage & secondary caries. Commonly used resins are dimethacrylate or urethane dimethacrylate oligomers.^{10,11}

3D imaging with oral tissue engineering:

Table 1. The different three-dimensional imaging modalities used in tissue engineering.

Xray/Computed Tomography	These modalities have outstanding penetration depth that is helpful in the diagnosis of bone defects & morphological changes in bone with time. Thus bone ingrowth into scaffolds with mineral accumulation at organic mineral junction is observed. The osteogenic function of mesenchymal stem cells, bone deposition can be visualized by this determining the progression of disease process. ^{12,13}
Single-photon emission computed tomography (SPECT) and positron emission tomography (PET)	PET/SPECT are established Nuclear medicine imaging techniques with detection of radiations from isotopes used to monitor the stem & progenitor cells function and estimate location within the body also within a scaffold. The polymeric scaffolds release kinetics growth factor that can be evaluated with SPECT. ¹⁴
MRI	MRI is one of the essential modalities for soft tissues. Contrast agents are used to amplify lesions and tracking that primarily is Gadolinium. This is useful in labeling a scaffold and enhances the visibility of the implanted scaffold. ¹⁵
Multimodal Imaging	Multimodal imaging has its advantages as we can remove the limitations of every modality and utilize a single modality to obtain necessary results. ¹⁶ Imaging and subsequent analysis provides information about morphological & functional alterations of tissue-engineered scaffolds and regenerating tissue by release of growth factors & cell incorporation within scaffolds and tissue.

Maxillo facial rehabilitation: Tissue engineering prospects replacement of tissues lost post-surgery, concern arises while treating large defects. This is done by the use of autologous bone grafts or tissue free flaps.

As an alternative treatment tissue engineering with stem cell and gene therapy evolve forming cells, scaffolds & cell signaling molecules to regenerate normal cells thereby healing of such defects.^{18,19}

Periodontal regeneration: Periodontium is an intricate structure with distinctive features making healing complicated. Tissue engineering suggests laboratory constructed periodontal tissues under controlled conditions which is later on implanted onto the surgical site. These periodontal cell sheets cultured when implanted reports to regenerate the periodontal tissues.²⁰

Oral mucosal grafting in ophthalmology - The ocular surfaces are complicated with sensitive structures like eyelids, tear film, conjunctiva, and cornea. Minor damage to either of these structures complicates the corneal clarity. Oral mucosa is considered as the best graft material to replace conjunctiva. Oral mucosa is highly vascularized that is effective in rapid healing. They are without any hair follicles & resistant to microbial agents. The oral mucosal grafts are obtained from buccal mucosa, labial mucosa, and lingual mucosa. They are utilized during symblepharon release and fornix reconstruction, cover large conjunctiva defects. It is used for ocular resurfacing and in conjunctivodacryocystorhinostomy & osteo-odonto-keratoprosthesis.^{21,22}

Whole tooth bioengineering - should imitate the function, development and functioning of natural tooth. The use of a scaffold when embedded with postnatal dental cells and it was gelatin-chondroitin-hyaluronan tri co polymer which was later implanted into a healed extraction socket of an adult pig produced all the tissues of tooth that resembled the enamel, dentin, cementum & roots. The bioengineered tooth should be vascularized and would be a bio-hybrid of artificial and living cells.^{23,24}

Conclusion

Biomedical engineering/regenerative dentistry has been crucial in developing signal pathways for functional replacement of dental tissues. To upgrade the biological presentation of scaffolds it's vital to select relevant material. From the selection of biomaterials, appropriate computing to printing is essential. But there has to remarkable research in the field of biomedical engineering for better comprehension & future evolution.

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