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RESEARCH ARTICLE

ORAL TISSUE ENGINEERING

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Abstract

Oral tissue engineering is a progressive field aiming to regenerate damaged oral tissues, such as bone, gums, and salivary glands, by leveraging a combination of scaffolds, cells, and bioactive molecules. This multidisciplinary approach integrates principles from biology, materials science, and engineering to develop functional replacements for lost or injured oral tissues. Recent advancements have focused on optimizing scaffold materials to mimic the natural oral environment, identifying suitable cell sources for regeneration, and applying growth factors to enhance tissue repair and integration. These innovations offer promising avenues for improving dental and craniofacial reconstructive treatments, significantly impacting patient care in dentistry and oral surgery.

Introduction:-

Tissue engineering is “the application of the principles and methods of engineering and the life sciences towards the fundamental understanding of structure–function relationships in normal and pathologic mammalian tissues and the development of biologic substitutes that restore, maintain, or improve tissue function”. For the oral and maxillofacial surgeon, the reconstruction of maxillofacial defects in hard and soft tissues is an ongoing challenge. While autologous grafts and vascularised free flaps are the current gold standard, they are not without complications at both the donor and reconstructed sites. Tissue engineering, which aims to create tissue-matched, prefabricated, prevascularised bony or soft tissue composite grafts, or both, therefore has the potential to revolutionise practice in maxillofacial surgery.[2]

Goal Of Tissue Engineering

The goal of tissue engineering and regenerative medicine is to promote healing and ideally, true regeneration of a tissue’s structure and function more predictably, more quickly and less invasively than allowed by previous techniques. The desire for such improved patient outcomes is shared across medical disciplines and geographic divides. Many approaches and materials have been proposed over the past 20 years, as researchers have sought to better understand the cellular and molecular mechanisms involved in healing and regeneration in order to optimize treatments. However, the ability to regenerate tissues lost to disease, trauma, or congenital deformity with predictability and precision has been elusive, and today many clinicians sceptically approach new regenerative therapeutics as promise without predictability.

Priniciple Of Tissue Engineering

The basic principle of tissue engineering is a plagiarism of natural tissue regeneration and healing. That is, both require three elements:

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1. Cells
2. A Signal
3. A Matrix

This concept is often represented in the form of a triangle, indicating that absence or dysfunction of one element will halt tissue regeneration.

Stem Cells
They are defined as immature or undifferentiated cells capable of generating daughter cells identical to themselves or of differentiating into diverse cellular phenotypes. In the adult, stem cells contribute to homeostasis of the tissues and regeneration after injuries.

Cellular Signaling
Cellular signalling is initiated by generation of a ligand; i.e. a molecular entity generated by a sending a cell to bring about a change in the physiology of a responding cell. A central paradigm can be recognized in most events of cellular signalling, which consists of three distinct steps: signal initiation, signal transduction, and gene activation.

Use Of Prp In Oral And Maxillofacial Surgery
The widespread application and acceptance of PRP are the result of its efficacy, safety and cost effectiveness. The advantage of PRP over other growth factors is that it contains seven native growth factors in their neutral ratios in a concentrated form. In addition, PRP contains concentrated vitronectin and native levels of fibronectin and fibrin, which are the essential cell adhesion molecules for cell migration, capillary growth and bone deposition. It is safer because it is derived from the patient's own blood.

Craniofacial Bone Tissue Engineering
Large bone defects resulting from trauma, tumor resection, nonunion of fractures, and congenital malformations are common clinical problems in craniofacial surgery, which have proven difficult to remedy.[30] In situations where insufficient autogenous bone exists, use of allogeneic bone may also be used. This approach, however, is also beset with a multitude of concerns, chief among which include infection, immunologic rejection, and graft-versus-host disease. Alternative materials have therefore been developed to assist in bone reconstruction, with metal alloys, glass, plaster of paris, polymethylmethacrylate, and, more recently, biodegradable scaffolds all being investigated.[131] Discouragingly, none of these modalities have yet to prove a consummate tool for craniofacial bone reconstruction.

Distraction Osteogenesis
Distraction osteogenesis is a powerful form of endogenous tissue engineering, promoting bone formation through the gradual separation of osteogenic fronts.

As elaborated by Ilizarov, distraction osteogenesis incorporates rigid fixation with a several days latency period, followed by gradual distraction and stable fixation until radiographic and clinical assessment demonstrates the formation of a robust, mineralized regenerate. Fibrous nonunion, permanent inferior alveolar nerve injury, and relapse of the original condition typically within the first 6 months following distraction remain significant considerations in the postoperative period. In the face of such concerns, however, overall results remain acceptable, with surgeons reporting good or excellent results in over 86% of patients.

Salivary Gland Gene Therapy
Why consider gene transfer to salivary glands? Two primary reasons have motivated us. First, no adequate treatment is available for irreversibly damaged salivary glands, such as found in patients receiving therapeutic irradiation (IR) for a head and neck cancer or in patients with the autoimmune exocrinopathy SjÖgren's syndrome (SS). Second, salivary glands can produce and secrete large amounts of protein locally to the oral cavity and gastrointestinal (GI) tract or into the bloodstream systemically, making them attractive targets for gene therapeutics (ie, using genes as drugs). However, and importantly, as of mid- 2005, there have been no approved clinical trials involving salivary gland gene transfer.

Application Of Tissue Engineering In Periodontitis
In the near future, third-generation periodontal therapies will involve nanoscale science [64] and moldless manufacturing technology commonly known as rapid prototyping (RP) or solid free-form fabrication (SFF). These

scientific and technologic innovations will make it possible to fabricate complex scaffolds that mimic the different structures and physiologic functions of natural fibro-osseous tissues, including those, such as periodontium, which consist of hard and soft tissues.

Bone Tissue Engineering-
For clinical applications, it is necessary to develop manufacturing processes that guarantee an automated and controlled bone production. The main drawback is that as the similarity to native bone tissueincreases in cell-seeded scaffolds, the readiness for clinical applicationdecreases compared to cell-free scaffolds.[57]

Cartilage Tissue Engineering
Theoretically, autologous chondrocytes would be the ideal donor cell type for cartilage repair due to their intrinsic properties in terms of function and immune compatibility. Therefore, alternative cell sources are being considered. Since chondrogenesis is initiated by a condensation phase of mesenchymal precursor cells, MSCs collected from different sources, such as adipose tissue or bone marrow have generated great interest. MSCs have a vast proliferative capacity, can be easily cultured in vitro and have the ability to differentiate towards osteogenic, adipogenic, chondrogenic and myogenic lineages.

Tissue Engineering Within Cleft Surgery
Tissue engineering within **cleft surgery** is a "promising technique" that results in a shorter operating time and hospital stay, absence of donor site morbidity, and reduced cost.

Conclusion:-
Tissue engineering is a rapidly advancing discipline that combines the attributes of biochemical and biomaterial engineering with cell transplantation to create bioartificial tissues and organs. For the oral and maxillofacial surgeon, the reconstruction of maxillofacial defects in hard and soft tissues is an ongoing challenge. While autologous grafts and vascularised free flaps are the current gold standard, they are not without complications at both the donor and reconstructed sites. Tissue engineering, which aims to create tissue-matched, prefabricated, prevascularised bony or soft tissue composite grafts, or both, therefore has the potential to revolutionise practice in maxillofacial surgery.[160]

Hence, oral and maxillofacial tissue engineering is an interdisciplinary science involving researchers in stem cell biology, bioengineering, polymer chemistry, mechanical engineering, robotics, etc. A thorough clinical knowledge of dental, oral and craniofacial disorders is needed to advance this novel field further.

The aim of regenerative medicine is to stepwise recreate in-vitro all the mechanisms and processes that nature uses during initiation and morphogenesis of a given organ. Regenerative medicine has become a fashionable field and the isolation and manipulation of ES and ASC for the creation of new functional organs will replace the missing or defective organs constitutes an enormous challenge.

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