Original Article

BIOINERT AND BIOACTIVE MATERIALS – NARRATIVE REVIEW

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Abstract

Biomaterials and technologies are encouraging tissue regeneration strategies to replace missing or damaged tissues. They possess special qualities that enable direct contact with living tissue without triggering unfavourable immune rejection reactions. Dental biomaterials are utilized in surgical treatments, endodontic materials, dental implants, and other restorative procedures as well as in orthodontic devices.There is a dire need to identify molecular and cellular level of materials interaction with dental tissues.Recent advances in dental biomaterials pertain to cell and gene mediating properties. Formulation of newer biomaterials to fulfil the incessant need is the need of the hour.

Introduction

Biomaterials and technologies serve as potential tissue regeneration strategies in replacing missing or damaged tissues.[1] The goals of all these biomaterials and technologies is to encouraging tissue regeneration and replace missing or damaged tooth tissues.[2] Biomaterials are substances having special qualities that enable direct contact with living tissue to be made without triggering unfavorable immune rejection reactions. Dental biomaterials are utilized in surgical treatments, endodontic materials, dental implants, and other restorative procedures as well as in orthodontic devices.[3]

Dental anatomy and materials science are both involved in how restorative dental materials interact with tooth tissue. Many adhesive dental restorative solutions were formerly believed to interact passively with hard tissues based on their simple infiltration of the enamel or dentin they were used on. However, there is growing interest in identifying how materials interact with dental tissues, particularly when the former has an aggressive interaction while encouraging "bioactivity.[4]

Types of biomaterials

The word "bioinert" refers to any substance that, once placed into a human body, interacts only minimally with the surrounding tissue. Examples of such substances include metals (such as titanium and cobalt-chrome-based

alloys) and ceramics (such as alumina al2o3 and zirconia polymers) (silicone rubber, acrylic resins). A bioactive material is defined as a material that elicits a specific biological response at the interface of the material, which results in the formation of a bond between the tissue and that material[5], examples are bioactive glasses, hydroxyapatite ceramics.

Bioinert materials

Metals:

The key criteria for a metal to be used as a biomaterial is that it does not cause an undesirable reaction when used. Additionally, it requires excellent osseointegration, great corrosion resistance, and exceptional wear resistance. Furthermore, they ought to be nontoxic and prevent the human body from experiencing any inflammatory or allergic reactions[6]. The mechanical characteristics of a metallic material such as hardness, tensile strength, Young's modulus, and elongation are crucial in evaluating its type. Materials used to replace the tissue must have mechanical properties that are similar to those of tissue. [7-8] Numerous metals, including base metal alloys, noble metal alloys, and wrought metals, find use in dentistry are crowns and bridges, inlays orthodontics bands brackets and wires, cast post, and implants.

Ceramics

Dental ceramics are materials of systems created to make dental prostheses, which are then utilized to replace missing or damaged dental parts. Ceramics can be classified into one of four categories silicate, oxide, monoxide, and glassed-based ceramics [9] Glass-based systems are made from materials that are primarily silicon dioxide (commonly referred to as silica or quartz), which incorporates alumina in varying proportions. Feldspars are naturally occurring aluminosilicates with varying levels of potassium and sodium.Glass-infiltrated, partially sintered alumina was introduced in 1988 and marketed under the name In-Ceram. The technology, which was created as an alternative to traditional metal ceramics, has had excellent clinical results.

Monophasic, solid-sintered ceramics are made by directly sintering crystals together in the absence of a matrix to create a dense, air- and glass-free polycrystalline structure. It is possible to fabricate solid-sintered aluminous-oxide or zirconia-oxide frameworks using a range of different manufacturing methods[10]. The biocompatibility, long-term color stability, wear resistance, and ability to mold dental ceramics into exact designs make them appealing. Several of the core ceramics can be resin- bonded micromechanically to the tooth structure, and some of the materials can be shaped into inlays onlays, veneers, and crowns[9].

Polymers:

For more than 50 years, synthetic polymers have been employed extensively in both restorative and prosthetic dentistry. Applications for acrylic polymers based on functional methacrylates include temporary crowns and bridges, restorative materials, soft liners, relining and repair materials, and dentures. To create appliances outside of the mouth, elastomeric materials including silicones, polysulphides, and alginates are employed to record imprints of the hard and soft oral tissues[11].

Bioactive material

Hench introduced the concept of bioactivity in 1969. A bioactive material evokes a specific biological reaction at the material's interface, resulting in the establishment of a link between the tissues and the material[12] In osteoproductive materials, Osteogenic stem cells colonize the bioactive surface of materials that promote bone growth. A material is said to be bioactive when it causes an extracellular and intracellular reaction at its interface eg: 45S5 Bioglass. The osteoconductive materials provide biocompatible interfaces along which bone migrates.

osteoconductive bioactivity occurs when the extracellular reaction is elicited at its contact.: Eg; Synthetic hydroxyapatite (HA)[13]

Mineral trioxide aggregate (MTA)

Torabinejad introduced mineral trioxide aggregate (MTA) in 1990. The composition of MTA are dicalcium silicate, tricalcium, gypsum, aluminate, silicate, tricalcium, and tetra calcium aluminoferrite. Mineral trioxide aggregate is utilized for root-end filling material in

apicoectomy procedures, vital pulp therapy, apexification, and apexogenesis, as well as for the correction of procedural errors. It causes cytologic and functional alterations in pulpal cells, which results in the formation of reparative dentin on the exposed dental pulp. When inserted, it promotes odontoblast-like cells' migration, differentiation, and proliferation which produce a collagen matrix. The production of tertiary dentin after the initial mineralization of this unmineralized matrix by osteodentin.[14]

Calcium hydroxide

Calcium hydroxide dissociates into calcium and hydroxyl ions. These released calcium ions decrease the capillary permeability by decreasing the serum flow and the levels of inhibitory pyrophosphates that result in mineralization. These released calcium ions decrease the capillary permeability by decreasing levels of inhibitory pyrophosphates that result in mineralization and serum flow. The acid released by osteoclasts is neutralized by the hydroxyl ions, keeping the pH at the ideal level for pyrophosphatase activity.[15]

Doxadent

It is a calcium aluminate material that can be obtained in liquid or powder form. used as a permanent restorative material. It is made up of zirconium dioxide, water, calcium oxide, alumina, and other alkali oxides.When a powder and a liquid are combined, the calcium aluminate powder is dissolved by the water. This causes the calcium, aluminum, and hydroxyl ions to form, which then causes katoite and gibbsite to form.[16]

Biodentine

It is a bioactive substance with qualities similar to that of dentin and has a favorable impact on pulp cells, helping in the production of tertiary dentin.[17]

Bioaggregate

It is a calcium silicate material that is available in liquid and powder form. It can be used for root perforation, pulp capping, apexification, root resorption, and root capping.[16]

MTYA1-Ca filler

It is used as a direct pulp-capping agent made of resin. It is composed of liquid (67.5% tri ethylene glycol dimethacrylate, 30.0% glyceryl methacrylate, 1.0% O-methacryloyl tyrosine amide, 1.0% dimethylamino ethyl methacrylate, and 0.5% camphorquinone) and powder (89.0% microfiller, 10.0% calcium hydroxide, and 1.0% benzoyl peroxide).[18]

Ceramir

It's a cement made of calcium aluminate which is used as a luting agent. It follows the principle of two types of cement calcium aluminate and glass ionomer cement. it helps in luting of Inlays and Onlays made of gold, prefabricated metal, and cast dowel and cores, high-strength all- zirconia or all alumina crowns, fixed partial dentures, and permanent crowns[19]

Resin Impregnation with Titanium Oxide (TiO2)

TiO2 nanoparticles can be impregnated in dental resins, such as dentin-bonding adhesives and dental monomers. It has been discovered that this method of restoration promotes the formation of hydroxyapatite, which improves the strength and bactericidal properties. nanoparticles promote the remineralization of both enamel and dentin. By filling in the marginal gaps.[20]

EndoSequence Root Repair Material

It contains proprietary fillers, thickening agents, zirconium oxide, tantalum oxide, monobasic calcium phosphate, and calcium silicates. They have a high pH, are hydrophilic, insoluble, radiopaque, and aluminum-free hardens in the presence of moisture.
Endosequence root repair materials simulate tissue fluid and phosphate-buffered saline and result in the precipitation of larger apatite crystals with increased immersion times, concluding to be bioactive. [21]

Theracal

It is a light-cured, resin-modified calcium silicate–filled liner insulating and protecting the dentin–pulp complex. It can be used as a protective base or liner under composites, amalgams, cements, and other base materials, as well as in direct and indirect pulp capping. Calcium release was shown to be higher and its solubility to be lower when compared to ProRoot MTA and Dycal.[22]

Bioactive root canal sealers :

The most recent generation mineral-based root canal sealer, Bio Root RCS (Saint Maur des Fosses, France), uses a tricalcium silicate setting technique. Zirconium oxide serves as a biocompatible radiopacifier in the powder component, and a hydrophilic biocompatible polymer improves adherence. The liquid contains calcium chloride as a setting modifier, and a water reduction agent. It stimulates the physiological processes of bone and the mineralization of the dentinal structure, It creates a favorable environment for periapical healing and bioactive qualities such as biocompatibility, hydroxyapatite production, mineralization of dentinal structure, alkaline pH, and sealing capabilities.[23]

Conclusion

Pulp regeneration and stem cell technology are emerging areas of study, and new horizons for the use of biomaterial in dentistry are being investigated. The current usage of biomaterial in dentistry is studied with cell and gene-activating material that is being introduced into dentistry.

References

1. Del Corso M, Vervelle A, Simonpieri A, Jimbo R, Inchingolo F, Sammartino G, M Dohan Ehrenfest D. Current knowledge and perspectives for the use of platelet-rich plasma (PRP) and platelet-rich fibrin (PRF) in oral and maxillofacial surgery part 1: Periodontal and dentoalveolar surgery. Current Pharmaceutical Biotechnology. 2012 Jun 1;13(7):1207-30.

2. Tuna EB, Oshida Y, Ozen B, Gjorgievska E, Tuzuner T. Biomaterials for Dental Applications. BioMed research international. 2017 Mar 15;2017.

3. Bhat S, Kumar A. Biomaterials and bioengineering tomorrow's healthcare. Biomatter. 2013 Jul 19;3(3):e24717.

4.Hench LL, Splinter RJ, Allen WC, Greenlee TK Jr.; Bonding mechanisms at the interface of ceramic prosthetic materials. J BiomedMater Res., 1972; 2:117-141.

5. Jones JR. Reprint of: Review of bioactive glass: From Hench to hybrids. Actabiomaterialia. 2015 Sep 1;23:S53-):43-6082.

6. de Viteri VS, Fuentes E. Titanium and titanium alloys as biomaterials. InTribology- Fundamentals and advancements 2013. InTech

7. Black J, Hastings G, editors. Handbook of biomaterial properties. Springer Science & Business Media; 2013 Nov 27.

8. Katz JL. Anisotropy of Young's modulus of bone. Nature. 1980 Jan 3;283(5742):106-7.

9. Shenoy A, Shenoy N. Dental ceramics: An update. Journal of conservative dentistry: JCD. 2010 Oct;13(4):19518.

10. Kelly JR. Dispersion strengthened composite. US Patent 4978640 Issued Dec 18th, 1990

11. Krishnan V, Lakshmi T. Bioglass: A novel biocompatible innovation. Journal of advanced pharmaceutical technology & research. 2013 Apr;4(2):78.
1. Hench LL, Splinter RJ, Allen WC, Greenlee

12 TK Jr.; Bonding mechanisms at the interface of ceramic prosthetic materials. J Biomed Mater Res., 1972; 2:117-141.

13. HENCH LL; Bioactive ceramics: Theory and clinical applications. In Andersson OH, Yli- Urpo A editors; Bioceramics. Volume 7, Butterworth-Heinemann, Oxford, 1994: 3-14

14. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review – Part III: Clinical applications, drawbacks, and mechanism of action. J Endod 2010 Mar;36(3):400-413.

[15]Chandra BS, Krishna VG, editors. Vital pulp therapy, pulpotomy, and apexification. In: Grossman's Endodontic Practice. 12th ed. New Delhi: Wolters Kluwer; 2010

16. Jefferies S. Bioactive and biomimetic restorative materials: a comprehensive review. Part II. J EsthetRestor Dent 2014 Jan-Feb;26(1):27-39.

17. Laurent P, Camps J, De Méo M, Déjou J, About I. Induction of specific cell responses to a Ca(3)SiO(5)-based posterior restorative material. Dent Mater 2008 Nov;24(11):1486-1494.

18. Niinuma A. Newly developed resinous direct pulp capping agent containing calcium hydroxide (MTYA1-Ca). IntEndod J 1999 Nov;32(6):475-483.

19. Doxa Dental AB. 510(k) summary. Ceramir® Crown & Bridge, K100510, March 25, 2010.

20. Welch K, Cai Y, Engqvist H, Strømme M. Dental adhesives with bioactive and on-demand bactericidal properties. Dent Mater 2010 May;26(5):491-499.

21. Damas BA, Wheater MA, Bringas JS, Hoen MM. Cytotoxicity comparison of mineral trioxide aggregates and EndoSequencebioceramic root repair materials. J Endod 2011 Mar;37(3): 372-375.

22. Gandolfi MG, Siboni F, Prati C. Chemical-physical properties of TheraCal, a novel light- curable MTA-like material for pulp capping. IntEndod J 2012 Jun;45(6):571-579.

23.Siboni F, Taddei P, Zamparini F, Prati C, Gandolfi MG. Properties of BioRoot RCS, a tricalcium silicate endodontic sealer modified with povidone and polycarboxylate. International Endodontic Journal. 2017 Sep 7