Japan Journal of Research

Short Communication

Bioceramics - A Medical Revolution

Dr. Samson Emmanuel[1], Dr. Jadhav Pradnya[2], Dr. Gangurde Lata[3], Dr. Ambhore Sangeeta[4], Dr. Bidve Anant[5], Dr. Kambli Vinod[6]

[1]Professor and Head, Department of Dentistry, Government Medical College & Hospital, Miraj, India.
[2]Assistant Professor, Department of Public Health Dentistry, Government Dental College & Hospital, Aurangabad, India.
[3]Professor and Head, Department of Dentistry, Grant Government Medical College, Mumbai, India.
[4]Assistant Professor, Department of Conservative Dentistry & Endodontics, Government Dental College & Hospital, Mumbai, India.
[5]Dental Surgeon, Conservative & Endodontics, Department of Dentistry, Grant Government Medical College & JJ Hospital, Mumbai, India.
[6]Associate Professor, D.Y. Patil Dental School, Charholi, Pune, India.

Correspondence
Dr. Emmanuel Samson
Professor Govt. Medical Collage, Miraj, India

- Received Date: 24 May 2024
- Accepted Date: 15 June 2024
- Publication Date: 02 July 2024

In ancient text a Greek word Keranika is refer as ceramic, which means burnt stuff.

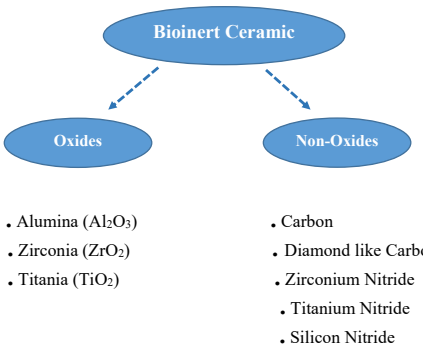
This ceramic derived from heat treated clayed raw material through process of firing, these ceramics are either, glasses, whitewares, structural clay, refractories, cements, abrasives, or advance ceramics [1,2].

Bioceramic its prefix Bio, which being referred to biocompatible, these materials are specifically designed and used for medical and dental purpose, also known as Biomaterial.

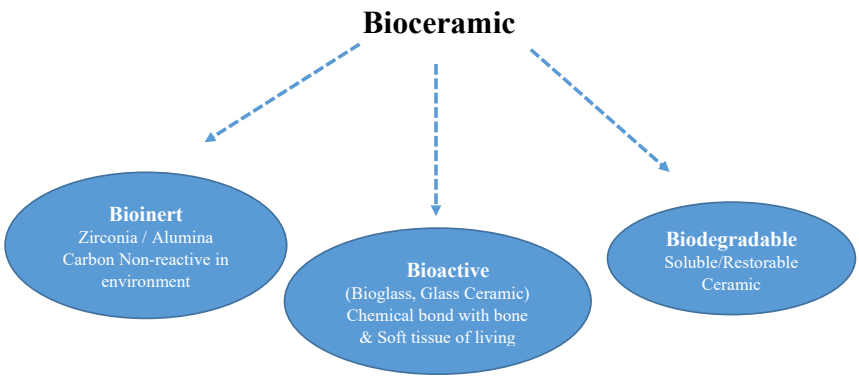
Bioceramics are chemically classified according to their composition as ceramics, metallic, polymeric, composite, and can also be derived biologically [3].

- First Generation - Alumina and Zirconia
- Second Generation – Bioglass (Hydroxyapatite & Calcium phosphate cements)
- Third Generation Biomaterials (Cell and Gene-Activating Materials)

Bioinert: Bioinert are the first generation ceramic of bioceramics, they are defined as a biologically inert in nature, material consist of two most important ceramics that is Alumina (AL_2O_3) and Zirconia (ZrO_2), these material are biocompatible and it has excellent wear resistance, thus used in orthopedics cases such as hip joint repair or replacement , keen arthroplasty ,dental implants ,crowns [4].



Uses of Bioinert Bioceramics	
1.	As bone plates and screws
2.	As drug delivery devices
3.	In the reconstruction of orbital rims
4.	In the form of ceramic-ceramic composites
5.	In the form of ceramic- polymer composites
6.	As components of total and partial hips.
7.	In the form of sterilization tubes
8.	As femoral heads
9.	As middle ear
10.	As ventilation tubes
11.	In the repair of the cardiovascular area



Citation: Samson E. Bioceramics: A Medical Revolution. Japan J Res. 2024;5(5):037.

Bioactive Glass - It was Hench in 1969, discovered bioactive glass it has the ability to form hydroxyapatite layers when it comes in contact with calcium and phosphate rich tissue fluid [5].

It contains Na_2O-CaO-SiO_2-P_2O_5 in specific proportion with main composition silica more than ≤ 50 mol % [6], when used in bone defect there is a release of critical concentration of soluble Ca, Si, P and Na ions inducing a favorable intercellular and extracellular response there by leading to rapid bone formation thus forming silica rich,which reacts when comes in contact with body fluid.

Thus resulting in formation of (Hap)-like on bioglass surface. (7) Its properties are osteoconductive and osteoinductive [8].

Use of Bioactive Bioceramics in Dentistry (Endodontic)
Putty: MTA (ProRoot MTA, MTA Angelus, NeoMTA Plus, etc.), Biodentie, BC Putty, Bioaggregate, CEM, TheraCal LC, etc.
Paste: BC Sealer, MTA Fillapex, BioRoot RCS, Tech BioSealer, Endoseal MTA, etc.

Bioresorabable /Biodegradable - Combination of bioactive glass and composites of bioactive salts (Calcium silicate, Ca-Ps) along with polymers designed to induce biological reaction at molecular level to stimulate tissue regeneration [9].

Uses of Biodegradable/Resorbable Bioceramics	
1.	As drug delivery devices
2.	For repairing bone damaged due to disease
3.	For filling space vacated by bone screws, donor bone, excised tumors, & diseased bone loss
4.	For repairing and fusion of spinal & lumbo-sacral vertebrae
5.	For repairing herniated discs
6.	For repairing maxillofacial and dental defects
7.	Hydroxyapatite ocular implants

Calcium Orthophosphates -These are bioceramics such as hydroxyapatite (HA, Ca_{10} $(PO_4)_6$ $(OH)_2$ and Tricalcium phosphate (TCP, $Ca_3(PO_4)_2$), these a inorganic apatite's having common formula $Ca_5(PO_4)_3X_2$ where X can be either fluoride – fluorapatites, chloroapatite containing chlorine, its main mineral structure is hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$ present in bone and teeth.

Calcium Phosphate - Calcium phosphate was first published in dentistry by Dorozhkin [10] who used in remineralization formula in a toothpaste to reduce sensitivity. Its commonly used commercial products are B-TCP and HA [11-14] such as Durapatil (HA) [15-18], Alvograft (HA) [19]. White composite nanobone consist of nanocrystalline HA containing silver gel matrix with embedded HA particles.

Calcium silicate - The oldest known calcium silicate bioceramic used in dentistry was MTA [20] its main basic components are Ca_3Sio_2 and $CaSiO_4$, which induce bioactive activity in endodontic [21, 22].

MTA cement introduce in dental literature in 1993, Food and Drug Administration (FDA) approval in 1998 known as MTA Angelus, calcium silicate hydrophilic cement is basically Portland cement. Revisited by Torabinejad et al. [23].

It is widely used in dentistry due to its superior biological and physical property like, root perforation repair, pulp capping, pulp dentin regeneration, pulpotomy, root end filling, apical barrier formation and calcium silicate endodontic sealers have also been introduced [24,25].

In 2007 first calcium silicate-based sealer know as, iRoot SP was introduce by Innovative Bioceramix, Vancouver, Canada [26].

- **Group 1** – Calcium phosphate silicate-based bioceramic sealers (BioRoot).
- **Group 2** – Tricalcium silicate- and resin-based bioceramic sealers (MTA).
- **Group 3** – Pure tricalcium silicate-based bioceramic sealers (iRoot) [27].

Advance Bioceramic

Drugs - Drugs like aspirin /Ibuprofen, amoxicillin either have carboxyl group or (COOH) or hydroxyl (OH) group can effectively absorbed by surface bond Ca^{2+} ions [28] Thus material with Ca-Si are widely used also on basis of related profile bioceramic composite show sustain drug released capacity, Ca-Si has shown long drug released time usually weeks, thus extending drug therapeutic efficiency [27,29].

Nanocomposites- Nihara in 1991 proposed nanocomposite a structural ceramic, which is a multiphase material, consisting of at least one constitutes phase less than 100um, nanocomposites consist of one or more dimensions of the reinforcing phase ranging from nanometer (1mm= 10A), which may range up to 100nm [30], to improve its compressive strength, fracture toughness, fatigue résistance and biocompatible nanocomposites are being engineered specially for dentistry [31].

Bioceramic Coating- In recent decade plasma spray HA coating, especially in implant which comes in contact with blood, Diamond like carbons have outstanding antithrombogenic properties.Oxidized Zirconium (Oxinium) due to its high or superior wear resistance thus used in hip and knee implants.

Genetic Control and Activated- Third generation biomaterials, which involves molecular tailoring of polymer generating specific cellular response. This promising result induced by specific protein, peptides and biomolecules, thus mimic the extracellular environment, which will provide multifunctional adhesive surface. This cell specific recognized factor like protein fibronectin incorporated in restorable polymer, can be tailored with protein that influence interaction with endothelium [32], neurite stimulation [33] and synaptic development [34].

References

1. Blum IR, Jagger DC, Wilson NH. Defective dental restorations: To repair or not to repair? Part 2: All-ceramics and porcelain fused to metal systems. Dent Update. 2011; 38:150-158.
2. Callister WD Jr. Materials Science and Engineering: An Introduction. 7th ed. New York, NY: John Wiley & Sons, Inc.; 2007.
3. Hench LL, Thompson I. Twenty-first century challenges for biomaterials. J R Soc Interface. 2010; 7(Suppl 4).
4. Vaiani L, Boccaccio A, Uva AE, et al. Ceramic materials for biomedical applications: An overview on properties and fabrication processes. J Funct Biomater. 2023; 14:146.
5. Hench LL. The story of Bioglass®. J Mater Sci Mater Med. 2006; 17:967-978.
6. Hench LL. The story of Bioglass®. J Mater Sci. 2006; 17:967-978.
7. Xynos ID, Edgar AJ, Buttery LDK, Hench LL, Polak JM. Gene expression profiling of human osteoblasts following treatment with the ionic products of Bioglass 45S5 dissolution. J Biomed Mater Res. 2001; 55:151-157.
8. Hench L, Splinter R, Allen W, Greenlee T. Bonding mechanisms at the interface of ceramic prosthetic materials. J Biomed Mater Res. 1971; 5(6):117-141.
9. Hench L, Polak J. Third-generation biomedical materials. Science. 2002; 295:1014-1017.
10. Dorozhkin SV. Calcium orthophosphates in dentistry. J Mater Sci Mater Med. 2013; 24:1335-1363.
11. Braly TE Jr. The use of Synthograft in periodontal bony defects. J Oral Implantol. 1983; 10:611-618.
12. Hoexter DL. The use of tricalcium (Synthograft). Part I: Its use in extensive periodontal defects. J Oral Implantol. 1983; 10:599-610.
13. Louise F, Fourel J, Roig R. Bioceramics in periodontal bone surgery. Clinical trial of Synthograft. J Parodontol. 1985; 4:277-285.
14. Shen TC. Tricalcium phosphate (Synthograft) in a vital homogeneous tooth transplant. Gen Dent. 1985; 33:518-519.
15. Rothstein SS, Paris D, Sage B. Use of durapatite for the rehabilitation of resorbed alveolar ridges. J Am Dent Assoc (1939). 1984; 109:571-574.
16. Greenstein G, Jaffin RA, Hilsen KL, Berman CL. Repair of anterior gingival deformity with durapatite. A case report. J Periodontol. 1985; 56:200-203.
17. Koslen RH. Two-stage maxillary ridge augmentation using durapatite. J Oral Implantol. 1987; 13:428-441.
18. Yukna RA, Mayer ET, Amos SM. 5-year evaluation of durapatite ceramic alloplastic implants in periodontal osseous defects. J Periodontol. 1989; 60:544-551.
19. Kwon HJ. Ridge augmentation with hydroxylapatite (Alveograf). CDS Rev. 1984; 77:29-33.
20. Pajor K, Pajchel L, Kolmas J. Hydroxyapatite and fluorapatite in conservative dentistry and oral implantology—A review. Materials (Basel). 2019; 12:2683.
21. Jimenez-Sanchez MDC, Segura-Egea JJ, Diaz-Cuenca A. Higher hydration performance and bioactive response of the new endodontic bioactive cement MTA HP repair compared with ProRoot MTA white and NeoMTA plus. J Biomed Mater Res B Appl Biomater. 2019; 107:2109-2120.
22. Parirokh M, Torabinejad M, Dummer PMH. Mineral trioxide aggregate and other bioactive endodontic cements: An updated overview—Part I: Vital pulp therapy. Int Endod J. 2018; 51:177-205.
23. Hench LL, Splinter RJ, Allen WC, Greenlee TK. Bonding mechanisms at the interface of ceramic prosthetic materials. J Biomed Mater Res. 1971; 5:117-141.
24. Parirokh M, Torabinejad M. Mineral trioxide aggregate: A comprehensive literature review—Part I: Chemical, physical, and antibacterial properties. J Endod. 2010; 36:16-27.
25. Darvell BW, Wu RC. "MTA"—an hydraulic silicate cement: Review update and setting reaction. Dent Mater. 2011; 27:407-422.
26. Gottschalck TE, McEwen GN, Cosmetic Toiletry and Fragrance Association. International Cosmetic Ingredient Dictionary and Handbook. 11th ed. Cosmetic Toiletry and Fragrance Association; 2005.
27. Reddy PM, Lakshmi R, Dass FP, Sasikumar S. Synthesis, characterization and formulation of sodium calcium silicate bioceramic for drug delivery applications. Sci Eng Compos Mater. 2016; 23:375-380.
28. Donnermeyer D, Bürklein S, Dammaschke T, Schäfer E. Endodontic sealers based on calcium silicates: A systematic review. Odontology. 2019; 107:421-436.
29. Ricardo S, Marissa C, Usmani M, et al. Comparison of three bioceramic sealers in terms of dentinal sealing ability in the root canal. International Journal of Applied Pharmaceutics. 2020; 12(2):1-7.
30. Díez-Pascual AM. Inorganic-nanoparticle modified polymers. Polymers (Basel). 2022; 14:1979.
31. Fugolin APP, Pfeifer CS. New resins for dental composites. J Dent Res. 2017; 96:1085-1091.
32. Hubbell JA, Massia SP, Desai NP, Drumheller PD. Endothelial cell-selective materials for tissue engineering in the vascular grafts. Biotechnology (N Y). 1991; 9:568.
33. Patel N, Padera R, Sanders GH, et al. spatially controlled cell engineering on biodegradable polymer surfaces. FASEB J. 1998; 12(14):1447-1454.
34. Hunter DD, Cashman N, Morris-Valero R, Bulock JW, Adams SP, Sanes JR. An LRE (leucine-arginine-glutamate) - dependent mechanism for adhesion of neurons to S-laminin. J Neurosci. 1991; 11(12):3960-3971. Doi: 10.1523/JNEUROSCI.11-12-03960.1991.