Role of Hydroxyapatite (HA) Coatings in Implants : A Review

Abstract:
Biomaterials are the materials that are used for the restoration and reorganization of various tissues as well as organs. Some of the common materials presently used are organic, metallic, and composites. To increase the biocompatibility of these materials, some types of coatings are regularly applied. Hydroxyapatite is one of the materials which is mostly used for coating these materials. Hydroxyapatite acquires the same structural and chemical characteristics as human bone. In the present review, we discussed the various aspects of hydroxyapatite coatings that consist of rationale, coating process, various techniques, and coating failures.

Key-words: Hydroxyapatite, Implants, Coating

Introduction:

Hydroxyapatite the main inorganic component of human bone has been proven to be attractive materials for biological implants duo its biocompatibility of osteoconduction. It is a bone bonding ceramic capable of conducing bone formation and promoting bone apposition. Because of its poor mechanical properties Hydroxyapatite coating on metals have been developed. Hydroxyapatite coatings have been applied on Titanium substrates by a wide range of surface deposition techniques[1].

Several Hydroxyapatite coating implant systems have reported favorable clinical success rates over a varying number of years. Interest in Hydroxyapatite coated implants centers on findings of a more rapid complete and predictable bone contact (osseous integration) with Hydroxyapatite coated surface than with a metallic surface as seen on both light and electron microscopic level. Improvements are still needed in areas such as attachment, porosity and crystallinity[2].

Hydroxyapatite coatings were first applied to sub periosteal dental implants.Several publications documented the positive results. Afterwards endosseous cylindrical dental implants of many designs emerged.

Various forms of bioactive calcium phosphate are tested based on their chemical similarity to bone mineral. Examples are crystalline Hydroxyapatite, amorphous Hydroxyapatite, tricalcium phosphates, fluorapatite, octacalcium phosphates and brushite. Crystalline Hydroxyapatite is similar to the bone mineral apatite and it shows chemical bond with bone when implanted. Because not all Hydroxyapatite coatings are

Access this article online	
Website: www.ujds.in	Quick Response Code
DOI: https://doi.org/10.21276//ujds.2022.8.4.21	

[1]ANUPRIYA KOTHARI, [2]RAHUL A RAZDAN, [3]RICHA JAIN, [4]VEDANT PATEL, [5]NENCY PARIHAR, [6]DIVYA PANDEY
[1]Private Practitioner, Prosthodontics and Crown and Bridge, Indore
[2]Department of Prosthodontics and Crown & Bridge, Index Institute of Dental Sciences, Indore
[3]Department of Periodontology, College of Dental Sciences and Hospital, Indore
[4,5]Department of Prosthodontics and Crown and Bridge, Index Institute of Dental Sciences, Indore,
[6]Department of Conservative Dentistry and Endodontics, Chandra Dental College and Hospital, Barabanki

Address for Correspondence: Dr. Vedant Patel
MDS
Senior Lecturer, Department of Prosthodontics and Crown and Bridge,
Index Institute of Dental Sciences, Indore, Madhya Pradesh, India-452016
Indore, Madhya Pradesh-452016
Email : vedant879526@gmail.com

Received : 24 May, 2022, **Published :** 31 Dec., 2022

How to cite this article: Anupriya Kothari, Rahul A Razdan, Richa Jain, Vedant Patel, Nency Parihar, & Divya Pandey. (2022). Role of Hydroxyapatite (HA) Coatings in Implants : A Review. UNIVERSITY JOURNAL OF DENTAL SCIENCES, 8(4).

same there are guidelines to analyze the coatings according to chemical composition, density, crystallinity, levels of impurities, surface roughness and tensile and shear strength[3].

Rationale For Hydroxyapatite Coating:

Titanium and its alloys are tolerated when placed in the body. These are strong enough to carry significant loads and be formed into complex implant shapes. In light of the demonstrated ability of bone to initially bond with Hydroxyapatite and the fact that Hydroxyapatite alone cannot be made to support loads the rationale for an Hydroxyapatite coating was born. If a thin coat of Hydroxyapatite could be applied to a strong load bearing metal, the device could be held in place by biochemical means and could perhaps, eliminate a fibrous tissue formation with subsequent loosening and failure. Hydroxyapatite coating prevents the corrosion of the underlying material. Hydroxyapatite has the ability to cause the growth of bone up to the implant[4].

Indication of Hydroxyapatite coating :

Non coated metallic screw type implants have been highly successful in type I bone and type 2 bones. In type 3 and type 4 bones like in maxilla these implants have not been as successful. In maxilla Hydroxyapatite coated implants shows better results than noncoated ones. Bone to implant contact, shear strength and stability are more with Hydroxyapatite coated implants. Hydroxyapatite coated implants are more indicated in Low-density cancellous bone like that in maxilla[5].

Hydroxyapatite coating process :

Different procedures have developed for coating the implants. Plasma flames spray process.

High temperature melting of Hydroxyapatite ceramic particles and accelerating them towards the surface prepared metal implant. They cool and attach to the implant in the form of a thin coating applied by multiple layers. During this process some chemical changes occur to Hydroxyapatite which are not favorable. It alters the crystalline state to available percentage of amorphous phase. A dense coating with high crystallinity has been listed as desirable to minimize in vivo resorption[6].

Functionally Graded Coating (FGC):

The drawbacks of plasma sprayed Hydroxyapatite are solved by plasma spraying of a composite powder of Hydroxyapatite and Ti6A 4V. It improves the mechanical properties of HA, the bonding between HA and underlying substrate, and prevention of oxidation of corrosion of Ti6AL4V. A functionally graded coating comprising of a mechanically strong, bioinert, biocompatible alloy (Ti6AL4V) and a bio active ceramic (Hydroxyapatite) may be developed[4].

Ratio Frequency Sputtering (RF) technique:

The use of RF sputtering technique for the deposition of Hydroxyapatite thin film coatings has gained significant momentum in the last few years. RF sputtered coatings are more retentive and their structure can be precisely controlled. These coatings are very thin (few microns) and give complete substrate coverage and can be applied to fine implant structures such as threaded implants without comprising their essential design. Hydroxyapatite by sputtering being a vaccum based process, can easily and substantially adapted for incorporating bonds coats such as titanium and silica for realizing composite implant/bond coat/ Hydroxyapatite structures[7].

Antibiotic Coating :

Porous Titanium surfaces can be coated with Gentamycin containing layers of Hydroxyapatite. The release of the drug into the elution fluid is reliable and reproducible. The gentamycin coating opens the way to a local prophylaxis or treatment with antibiotics for rough titanium implants in dental surgery[8].

Laser ablation technique

Crystalline Hydroxyapatite and amorphous calcium phosphate with different morphologies can be deposited onto Ti6AL4V substrates by means of laser ablation technique. Hydroxyapatite coatings with granular morphology have higher resistance to delamination[7].

Magnetron Sputtering:

Hydroxyapatite coating on Titanium powder by magnetron sputtering shows strong Hydroxyapatite Titanium bonding associated with an outward diffusion of Titanium into Hydroxyapatite layer and formation of TiO_2 at the interface[7].

Pulsed Laser Deposition (PLD):

This is one method of placing a thin Hydroxyapatite coating on implant. It allows control over chemistry and structure of the coating[9].

Coating Characterization:

Surface characterization of Hydroxyapatite coated implants changes due to the surface treatment with various chemotherapeutic modalities like citric acid, Chlorhexidine gluconate, hydrogen peroxide etc. Implants surfaces were evaluated macroscopically, Microscopically (SEM) and spectrometrically. All treatments left either microscopic residues or a loss of surface roughness when viewed on SEM. More of Hydroxyapatite coating is removed. The treatment did not alter the crystallinity of the Hydroxyapatite[10].

The chemical and mechanical stability of Hydroxyapatite coating is affected by its micro structural characterization. Hydroxyapatite coating dissolve in soft tissue. Physical and chemical characterization include chemical composition, level of impurity, porosity, substrate coverage, surface roughness of both substrate and coating and the degree of solubility. Mechanical characterization includes tensile strength, shear strength etc. Histological analysis of coated and non-coated implants from various models demonstrated common characteristics. For uncoated metal smooth surface – a thin fibrous tissue separate implant from bone. Isolated areas of osseointegration have been observed[11].

When macrotextures such as threads, grooving or porosities are used, osseo-integration increases. But observation of high magnification revealed mechanical adaptation of bone. High crystallinity Hydroxyapatite coating have shown faster adaptation of bone. Bone contact is intimate with bio-integration regardless of the substrate metal type[8].

Clinical Evaluations:

Intimate and abundant bone to implant contact was observed in maxillary implants with augmented sinus after two and half year of loading. Active remodeling occurred in all threads. Both the nature and thickness of the coating hardly changed even after two and half year of loading. The Hydroxyapatite coated implants used achieved excellent osseointegration and must be considered clinically safe and effective in maxillary grafted bone.

Another study of two Hydroxyapatite coated implants. In one case Hydroxyapatite coating was degraded as SEM revealed a resulted rough Titanium surface. Histology showed Hydroxyapatite particles and inflammation near the implant. Second case showed Hydroxyapatite coating was intact but scattered Hydroxyapatite particles were found embedded in bone. These results shows Hydroxyapatite coating may become loose during clinical function.More evaluation of clinical cases and causes of failures are to be corrected like improvement in coating strength, Chemical integrity of the coating material and substrate. And surface texture of the coating etc[12,13].

Hydroxyapatite coating failures :

As the clinical experiences with Hydroxyapatite coating has increased some short-term successes and failures of quality or inferior coating have emerged[14].

Mechanisms of failures:

Displacement and Dissolution: Displacement occurs when the coating is not intact. Loss of integration and particulate debris are potential consequences. Dissolution causes an instability problem to the implant if it is rapid. In many cases failures of Hydroxyapatite coated implants are due to the placement factors.

Advantages :

1. Stable coating with good crystalline structure of Hydroxyapatite give long term success to implants.
2. Hydroxyapatite coated implants shows more bone to implant contact than metallic implants.
3. Increased success rate is noticed in Hydroxyapatite coated implants in maxilla.
4. Hydroxyapatite coated implants shows increased surface activity and more bone deposition is noticed because of the osteo conducive property.

Disadvantages :

1. Rough surface predispose to plaque retention
2. Fracture of Hydroxyapatite coating causing failure of implants.
3. Dissolution of Hydroxyapatite coating when there is a low pH
4. Porosity can occur during the coating process.
5. Fatigue and fracture of the coating leads to the failure of the implants[15,16].

Conclusion:

Implants are Hydroxyapatite coated for maximum bone to implant contact, quicker fixation and stabilization, better shear strength under function and implants not depend on mechanical retention for stabilization. Hydroxyapatite coated implants are more indicated in maxilla where bone is less dense and cancellous in nature. Hydroxyapatite coated screw implant may be indicated in posterior mandible or anterior maxilla where D3 bone is present. Posterior maxilla cylindrical implants with Hydroxyapatite coating may be better. Situations where shorter implants are used Hydroxyapatite coated implants give better results. Hydroxyapatite coated implants manufactures with strict quality controls can provide fast, reliable and maintainable bone implant interface. Good Hydroxyapatite coating shows faster healing, stronger attachment to bone and resist flaking and dissolution. Proper oral hygiene and professional maintenance is essential for the success of an implant.

References:

1. Li P. Biomimetic nano-apatite coating capable of promoting bone ingrowth. J Biomed Mater Res A. 2003 Jul 1;66(1):79-85
2. Wheeler SL. Eight-year clinical retrospective study of titanium plasma-sprayed and hydroxyapatite-coated cylinder implants. Int J Oral Maxillofac Implants. 1996;11:340–350
3. Kay, M. E., Young, R. A., and Posner, A. S., Crystal structure of hydroxyapatite, Nature, 1964; 204:1050–1052
4. Liao H, Fartash B, Li J. Stability of hydroxyapatite-coatings on titanium oral implants (IMZ). 2 retrieved cases. Clin Oral Implants Res. 1997 Feb;8(1):68-72
5. Watson CJ, Tinsley D, Ogden AR, Russell JL, Mulay S, Davison EM. A 3 to 4 year study of single tooth hydroxylapatite coated endosseous dental implants. Br Dent J. 1999 Jul 24;187(2):90-4
6. Yoshinari M, Ozeki K, Sumii T. Properties of hydroxyapatite-coated Ti-6Al-4V alloy produced by the ion-plating method. Bull Tokyo Dent Coll. 1991;32:147–156
7. Eom TG, Kim JH, Cho IH, Jeong CM, Cho YS, Kim YK. Experimental study about the bony healing of hydroxyapatite coating implants. J Korean Assoc Oral Maxillofac Surg. 2011;37:295–300
8. Søren Overgaard (2000) Calcium phosphate coatings for fixation of bone implants: Evaluated mechanically and histologically by stereological methods, Acta Orthopaedica Scandinavica, 71:6, 1-74
9. Nancollas, G. H. and Tucker, B. E., Dissolution kinetics characterization of hydroxyapatite coatings on dental implants, J. Oral Implantol., 1994; 20:221–226
10. Lee JJ, Rouhfar L, Beirne OR. Survival of hydroxyapatite-coated implants: a meta-analytic review. J Oral Maxillofac Surg. 2000 Dec;58(12):1372-9; discussion 1379-80.
11. Guttenberg SA. Longitudinal report on hydroxyapatite-coated implants and advanced surgical techniques in a private practice. Compend. 1993:S549–S553
12. Ogiso M, Yamashita Y, Matsumoto T. The process of physical weakening and dissolution of the HA-coated implant in bone and soft tissue. J Dent Res. 1998 Jun;77(6):1426-34.
13. Yang BC, Weng J, Li XD, Yang ZJ, Feng JM, Chen JY, Zhang XD. Preliminary study on HA coating percutaneously implanted in bone. Int J Artif Organs. 1999 Oct;22(10):713-8
14. Ducheyne, P., van Raemdonck, W., Heughebaert, J. C., and Heughebaert, M., Structural analysis of hydroxyapatite coatings on titanium, Biomaterials, 1986; 7:97–103
15. Tufekci, E., Brantly, W. A., Mitchell, J. C., and McGlumphy, E. A., Microstructures of plasmasprayed hydroxylapatite-coated Ti-6A1-4V dental implants, Int. J. Oral Maxillofac. Implants, 1997; 12:25–31.
16. Bharati S, Sinha M.K.and Basu D. (2005), “Hydroxyapatite coating by biomimetic method on titanium alloy using concentrated SBF”, Buletin. Material. Science, Vol. 28, pp 617–621