**How to Cite**:
Chhaya, D., Vaidya, N., Patel, V., Chudasama, K., Doshi, S. H., & Shah, H. (2022). Dental implant biomaterials. *International Journal of Health Sciences*, *6*(S8), 1140–1152. https://doi.org/10.53730/ijhs.v6nS8.10115

# Dental implant biomaterials

**Dr. Deesha Chhaya**
M.D.S Periodontology, Senior lecturer, Department of Periodontics, Faculty of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat

**Dr. Naman Vaidya**
M.D.S Conservative Dentistry Endodontics, Senior lecturer, Department of Conservative dentistry and Endodontics, Faculty of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat

**Dr. Vasumati Patel**
M.D.S Periodontology, Professor and Head of department, Department of Periodontics, Faculty of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat

**Dr. Krutika Chudasama**
M.D.S Conservative Dentistry, Endodontics and Aesthetic Dentistry, Senior lecturer , Department of Conservative and Endodontics , College of Dental Sciences,Bhavnagar university , Gujarat

**Dr. Shivani H Doshi**
M.D.S Conservative Dentistry and Endodontics, Senior lecturer, Department of Conservative and Endodontics, College of Dental Sciences, Bhavnagar University, Gujarat

**Dr. Harita Shah**
B.D.S, Tutor, Department of Public Health Dentistry, Faculty of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat

***Abstract*---**Implants have been gaining popularity amongst the patients and frequently are being considered as a first treatment option. Modern dentistry is beginning to understand, realize, and utilize the benefits of biotechnology in health care. Appropriate selection of the implant biomaterial is a key factor for long term success of implants. The biologic environment does not accept completely any material so to optimize biologic performance, implants should be selected to reduce the negative biologic response while maintaining adequate function. Every clinician should always gain a thorough knowledge about the different biomaterials used for the dental implants.

International Journal of Health Sciences ISSN 2550-6978 E-ISSN 2550-696X © 2022.
*Manuscript submitted: 9 March 2022, Manuscript revised: 18 May 2022, Accepted for publication: 27 June 2022*

***Keywords*---**titanium, osteointegration, zirconia.

## Introduction

A biocompatible device placed within, or on, the bone of the maxilla or mandible, to provide support for a prosthetic reconstruction. (Glossary of Implant Dentistry).[1] "A prosthetic device made of alloplastic material(s) implanted into the oral tissues beneath the mucosal and/or periosteal layer and on or within the bone to provide retention and support for a fixed or removable dental prosthesis; a substance that is placed into and/or on the jaw bone to support a fixed or removable dental prosthesis." (According to Glossary of Prosthodontic term).[2] In an attempt to replace a missing tooth many materials have been tried as an implant. With all the advancements and developments in the science and technology, the materials available for dental implants also improved.[3]

The biomaterial surface chemistry (purity and surface tension for wetting), topography (roughness), and type of tissue integration (osseous, fibrous, or mixed) can be correlated with shorter and longer term in vivo host responses. The interaction at interface between recipient tissues and implanted material are limited to the surface layer of the implant and a few nanometers into the living tissues. The details of the interaction (hard or soft tissue) and force transfer that results in static (stability) or dynamic (instability or motion) conditions have also been shown to significantly alter the clinical longevities of intraoral device constructs.[4]

The Earliest dental implants of stone and ivory were reported in China and Egypt. Also Gold and Ivory dental implants were reported in the 16th and 17th centuries. Metal Implants of Gold, Lead, Iridium, Tantalum, stainless steel and cobalt alloy were also mentioned in the early 20th century. In the present era, due to the extensive research work and advancements in the field of biomaterials available for dental implants, newer materials came into being such as zirconia, roxolid, surface modified titanium implants. These materials not only fulfil the functional requirements but are also aesthetically pleasing.[5] The physical and chemical properties of implant materials are well-reported and documented factors that influence the clinical outcome and the prognosis of implant therapy. These properties include the microstructure of the implant, its surface composition and characteristics, as well as design factors. An ideal implant material should be biocompatible, with adequate toughness, strength, corrosion, wear and fracture resistance. The design principles of the implant should be compatible with the physical properties of the material. Materials used for the fabrication of dental implants can be categorized according to their chemical composition or the biological responses they elicit when implanted. From a chemical point of view, dental implants may be made from metals, ceramics or polymers (Table.1).[6]

Table.1:Materials used for the fabrication of endosseous dental implants[6]

| Implant Material | Common Name or Abbreviation |
|---|---|
| Metals | |
| Titanium | CpTi |
| Titanium Alloys | Ti-6A1-4V |

| | |
|---|---|
| Cobalt Chromium Alloy | Vitallium, Co-Cr-Mo |
| Stainless Steel | iron, chromium, nickel based alloy |
| Precious Metals | Au Alloys |
| Ceramics &Carbon | |
| Bioinert | $Al_2O_3$,$ZrO_2$, $TiO_2$ |
| Bioactive | HA |
| Resorbable | Calcium Phosphate Ceramic (Tricalcium Phosphate) |
| Glass Ceramics | $SiO_2/CaO/Na_2O/P_2O_5$ |
| Carbon-Silicon | C-Si |
| Polymers | |
| Polymethyl methacrylate | PMMA |
| Polytetrafluoro ethylene | PTFE |
| Polyethylene | PE |
| Composites | |
| Courtesy: Adopted from: Williams ,(1981);Lemons,(1990);Craig,(1993); Sagomonyants *et al.*, (2007); Berner *et al.*,(2009). | |

**Metals**

**Titanium**

Titanium has a good record of being used successfully as an implant material and this success with titanium implants is credited to its excellent biocompatibility due to the formation of stable oxide layer on its surface. It is the gold standard in implant materials. According to the American Society for Testing and Materials (ASTM), there are six distinct types of titanium available as implant biomaterials .Amongst these six materials, there are four grades of commercially pure titanium (CpTi) and two titanium (Ti) alloys. The mechanical and physical properties of CpTi are different and are related chiefly to the oxygen residuals in the metal.[6]

**Composition of commercially pure titanium**

Titanium99.75%, Iron0.05%, Oxygen0.1%, Nitrogen0.03%, Hydrogen0.012%, Carbon0.05% Commercially pure titanium occurs in 4 grades, grade I II III IV, according to oxygen content (0.18%to 0.40%) &iron content (0.20 to0.50 wt%). These Consists of 2 phases α and β. The general engineering properties of the metals and alloys used for dental implants is that, titanium shows a relatively low modulus of elasticity and tensile strength (110 Gpa) when compared with most other alloys. The strength values for the wrought soft and ductile metallurgic condition, are appropriately 1.5 times greater than the strength of compact bone. In most designs, this magnitude is adequate because fatigue strengths are normally 50% weaker or less than the corresponding tensile strengths. Implant designs criteria are decidedly important. Sharp corners or thin sections must be avoided for regions loaded under tension or shear conditions. The modulus of elasticity is 5 times greater than that of compact bone, and this property places emphasis on the importance of designing the proper distribution of mechanical stress transfer. The alloy of titanium most often used is titanium-vanadium. The wrought alloy condition is approximately 6 times stronger than compact bone and thereby affords more opportunity for designs with thinner sections (eg. plateaus, thin interconnecting regions, implant to abutment connection screw housing, irregular scaffolds, porosities). The modulus of alloy is slightly greater than that of titanium being about 5.6 times that of compact bone. The alloy and the primary element (titanium) both have titanium oxide (passivated) surfaces. In general, titanium and alloys of titanium have demonstrated interfaces described as "osteointegrated" for implants in humans. Also, surface conditions where the oxide thickness has varied from hundreds of angstroms of amorphous oxide surface to 100% titania (tio2 rutile form ceramics) have demonstrated osteointegration. Although extensive literature has been published on the corrosion rate of titanium within local tissue fluids and the peri-implant accumulation of "black particles", few adverse effects have been reported. Increased titanium concentrations were found in both peri implant tissues and parenchymal organs, mainly the lungs and much lesser concentrations in the liver, kidney, and spleen. However, alloy compositions were not well defined or controlled. Corrosion and mechanical wear have been suggested as possible causes. Authors who still caution about the applicability of these results to the presently available titanium alloys have developed other alloys using iron, molybdenum, and other elements as primary alloying agents, and more recently several new titanium alloys of higher strength have been introduced.[7-10]

**Properties**

**Biocompatibility**[6]

- Titanium is one of the most biocompatible material due to its excellent corrosion resistance. The corrosion resistance is due to formation of biologically inert oxide layer.
- Three different oxides are:
- TiOAnastase, $TiO_2$Rutile, $Ti_2O_3$Brookite
- $TiO_2$ rutile is the most stable and mostly formed on titanium surface. This oxide layers is self healing i.e. if surface is scratched or abraded during implant placement it repassivates instantaneously.
- Good yield strength, tensile strength, fatigue strength.
- Modulus of elasticity (110GPa) is half of other alloys and 5 times greater than bone. This helps in uniform stress distribution
- Good strength, but less than Titanium alloys.
- Ductile enough to be shaped into implant by machining.
- Low density4.5g/$cm^3$light weight.
- Titanium allows bone growth directly adjacent to oxide surface.
- Inspite of excellent corrosion resistance peri-implant accumulation and also accumulation in lung, liver, spleen of Titanium ions is seen. However since it is in traces, it is not harmful.[6]

**Dental applications**

Titanium pins and posts are used to secure dental implants. They use threaded fixtures to secure them into the jaw. Titanium superstructures are now being investigated as an alternative to other metals such as gold for implants such as polymer based dentures.

*ADVANTAGES: High passivity, controlled thickness, ability to repair itself, resistance to chemical attack, modulus of elasticity compatible with that of bone*
DISADVANTAGE: There is an aesthetic issue due to grey colour of titanium which is more pronounced when soft tissue is not optimal. Reports related to titanium toxicity are spares but concur that cationic are relatively non-toxic in amounts and forms that are normally ingested.

**Titanium alloys(Ti-6Al-4V)[4]**

Titanium alloys of interest to dentistry exist in three structural forms: alpha (α), beta (β) and alpha-beta. The alpha (α) alloys have a hexagonal closely packed (hcp) crystallographic structure, while the beta alloys (β) have a body-centred cubic (bcc) form. These different phases originate when pure titanium is mixed with elements, such as aluminium and vanadium, in certain concentrations and then cooled from the molten state. Aluminium is an alpha-phase stabilizer and increases the strength of the alloy, while it decreases its density. On the other hand, vanadium is a beta-phase stabilizer. Allotropic transformation of pure titanium (Ti) from the α to β phase occurs at 882 °C. With the addition of aluminium or vanadium to titanium, the α-to-β transformation temperature changes over a range of temperatures. Depending on the composition and heat treatment, both the alpha and beta forms may coexist. The alpha-beta combination alloy is the most commonly used for the fabrication of dental implants.[6]

COMPOSITION: Titanium, 6% Aluminium–alpha stabilizer, 4% Vanadium– beta stabilizer

**Properties**

- Excellent corrosion resistance, Oxide layer formed is resistant to charge transfer thus contributing to biocompatibility.
- Modulus of elasticity is 5.6 times that of the bone, more uniform distribution of stress. Ductility is sufficient.
- Its strength is greater than pure titanium 6 times that of bone hence thinner sections can be made.
- Exhibits osseointegration.

USES : Extensively used as implant material due to its excellent biocompatibility, strength and osseointegration.
ADVANTAGES: Its modulus of elasticity is slightly higher, being about 5-6 times than that of compact bone Its yield strength increases over 60% to 795 GP as compared with 483GP for Cp titanium

**Cobalt, chromium, molybdenumalloy**

The cobalt-based alloys are most often used in and as cast or cast-and-annealed metallurgy condition. This permits the fabrication of implants as custom designs such as sub-periosteal frames. The elemental composition of this alloy includes cobalt, chromium, and molybdenum as the major elements.[4]

**Composition**

- 63%Cobalt, 30%Chromium (CrO provides corrosion resistance), 5%Molybdenum(strength)

**Properties**

- High mechanical strength,
- Good corrosion resistance,
- Low ductility,
- Direct apposition of bone to implant is seen.

USES: Limited for fabrication of custom designs for subperiosteal frames due to ease of castability and low cost.
ADVANTAGES: Chromium adds for the strength and corrosion by the means of passivation. It is possible to fabricate the implant as custom design. Excellent biocompatibility
DISADVANTAGE: It’s melting range is significantly higher, which makes it’s manipulation difficult in laboratory. It is a least ductile alloy system used for dental implant.

**Iron, chromium, nickelbasedalloy**

These are surgical steel alloys or Austenitic steel. They have a long history of use an orthopedic and dental implant devices.

**Composition**

Iron, Chromium –18%-corrosion resistance, Nickel– 8%-stabilize austenitic steel.

**Properties**

- It has high mechanical strength and high ductility.
- Pitting and crevice corrosion and hypersensitivity to nickel has been seen.
- Bone implant interface shows fibrous encapsulation and ongoing foreign body reactions.

USES: It has limited usage.
ADVANTAGES: It has high strength and high ductility making it helpful in casting, thinner copping and framework. These have higher elastic modulus
DISADVANTAGE: It has a galvanic potential and corrosion resistance that could result in concerns about galvanic coupling and bio-corrosion if interconnected with titanium, cobalt, zirconium or carbon implant biomaterial. Nickel present in its constituents may cause allergic reaction. These alloys have lower yield strength than noble metal alloy.

**Preciousmetals**

Many other metals and alloys have been used for dental implant device fabrication. Early spirals and cages included tantalum, platinum, indium, gold, palladium, and alloys of thesemetal.More recently, devices made from zirconium, hafnium, and tungsten have been evaluated.[11] Some significant advantages of these reactive group metals and their alloys have been reported, although large numbers of such devices have not been fabricated. Gold, platinum, and palladium are metals of relatively low strength, which places limits on implant design. Also, cost-per-unit weight and the weight-per-unit volume (density) of the device along the upper arch have been suggested as possible limitations for gold and platinum. These metals, especially gold because of nobility and availability, continue to be used as surgical implant materials. For example, the Bosker endosteal staple design represents use of this alloy system.[12]

**Properties**

- Noble metals are unaffected by air, moisture, heat and most solvents.
- They do not depend on surface oxides for their inertness.

They have low mechanical strength.
Possess very high ductility.
It does not demonstrate osseointegration

USES: They are not used currently.
ADVANTAGES: It has a good corrosion resistance. The biocompatibility of material is good.
DISADVANTAGE: These are expensive and have lower mechanical strength.

**Ceramics and carbon**

**Ceramics**

Ceramics are inorganic, nonmetallic, non polymetric materials manufactured by compacting and sintering at elevated temperatures. They can be divided into metallic oxides or other compounds. Oxide ceramics were introduced for surgical implant devices because of their inertness to biodegradation, high strength, physical characteristics such as color and minimal thermal and electrical conductivity, and a wide range of material specific elastic properties. In many cases, however, the low ductility or inherent brittleness has resulted in limitations. Ceramics have been used in bulk forms and more recently as coatings on metals and alloys.[13.14]

**Bioinertceramics**

**Aluminum, Titanium and Zirconium Oxides**

High ceramics from aluminum, titanium, and zirconium oxides have been used for root form, endosteal plate form, and pin-type dental implants.[15]

ADVANTAGE: It has a clear, white cream or light gray color that is beneficial for application, such as anterior root form devices. Minimal thermal and electric conductivity, biodegradation and reaction to bone, soft tissue and oral environment. It exhibits direct interface with bones similar to an Osseointegrated condition with titanium.[4]
DISADVANTAGE: Exposure to steam sterilization results in a measurable decrease in strength for some ceramics. Scratches or notches may introduce fracture initiation sites. Hard and rough surfaces may readily abrade other materials thereby causing a residue in contact with the periapical tissues. Dry heat sterilization within a clean and dry atmosphere is recommended for most ceramics.[4]

**Zirconia**

Zirconia holds a unique place amongst oxide ceramics due to its excellent mechanical properties. Yttria stabilized tetragonal zirconia polycrystalline (Y-TZP) materials exhibit ssuperior corrosion and wear resistance, as well as a high flexural strength (800 to 1000 MPa) compared to other dental ceramics. An *in vitro* study reported the fracture strength of one-piece unloaded zirconia implants to be 512.9 N *versus* 410.7 N after artificial loading. The effect of cyclic loading and preparation on the fracture strength of one-piece zirconia implants was also investigated. Kohal *et al.* found a decrease in fracture strength resistance following the cyclic loading and implant preparations, though with the values yet within the acceptable clinical levels to withstand average occlusal forces. On the contrary, Silva *et al.* found no influence of crown preparation on the reliability of one-piece zirconia implants at loads under 600 N. On analyzing the mechanical properties and reliability of two-piece zirconia implants, Kohal*et al.* reported low fracture strength values for both loaded and unloaded implants(average: 280 N) and accordingly could not recommend this implant prototype for clinical use. At ambient pressure, unalloyed zirconia can assume three crystallographic forms, depending on the temperature. At room temperature and upon heating upto 1170°C,the structure is monoclinic.[6] Despite the plethora of the zirconia-containing ceramic systems available on the market today, to date, only three have been used in dentistry.[6] These are Yttrium- stabilized tetragonal zirconia polycrystals (3Y-TZP). Alumina-toughened zirconia (ATZ), Zirconia- toughened alumina (ZTA).

**Current status and developing trends**

There are ablative and additive procedures developed to alter the surface characteristics of dental implant, which helps to improvise dental implants.

**Ablative procedures**

The removal of surface material by mechanical methods involved shaping/removing, grinding, machining, or grit blasting via physical force. A chemical treatment, either by using acids or using alkali solution of titanium alloys in particular, is normally performed not just to alter the surface roughness but also to modify the composition and to induce the wettability or the surface energy of the surface.[16]

- Grit blasting (Sand Blasting)
- Acid etching
- Anodizing
- Shot/laser peening[17]

**Acid Etching**

Acid etching appears to greatly enhance the potential for osseointegration especially in the earliest stages of peri-implant bone healing. It produces a clean highly detailed surface texture and lacks entrapped surface material and impurities. Also precise acid selection and the sequence of processing played the main role in preparation of the rough titanium surface. The surfaces are poorer if they were etched with hydrochloric acid than with sulfuric one.

Advantage

- It increases the protein absorption. It provides osteoblastic cell adhesion and shows better rate of bone tissue healing in peri-implant region.

Disadvantage

- Reduction in mechanical properties. [4]

**Grit Blasting**

Titanium surfaces can be grit blasted with hard ceramic metallic particles in order to roughen them. The particles are projected through a nozzle at high velocity by means of compressed air, depending on the size of the particles; different surfaces of roughness can be produced on titanium implants. The blasting material should be chemically stable, biocompatible and should not hamper the osseointegration of the titanium implants. Various particles, such as alumina, titanium oxide and calcium phosphate are often used.[18]

Advantage

- Provides mechanical anchorage and fixation to bone are favored and it has a high survival rate[4]

Disadvantage

- Residue of blasting material interfere with osseointegration[4]

**Anodization**

Anodization produces modifications in the microstructure and the crystallinity of the titanium oxide layer.[19] Anodized surfaces result in a strong reinforcement of the bone response with higher values for biomechanical and histomorphometric tests in comparison to machined surfaces. Two mechanisms have been proposed to explain this osseointegration: Mechanical interlocking through bone growth in pores and biochemical bonding. Modifications to the chemical composition of the titanium oxide layer have been tested with the incorporation of magnesium, calcium, sulfur or phosphorus. It has been found that incorporating magnesium into the titanium oxide layer leads to a higher removal torque value compared to other ions.[20]

**Shot Peening/Laser Peening**

Shot peening is similar to sand blasting[21], where the surface is bombarded with small spherical particles, each particle on coming in contact with the surface causes small indentations or dimples to form. Laser peening involves the use of high intensity (5-15 GW/cm2) nanosecond pulses (10-30 ns) of a laser beam striking a protective layer of paint on the metallic surface. These implants demonstrate a regular honeycomb pattern with small pores.[22]

Advantage

- It is a contamination free peening method. It improves fatigue strength and retards stress corrosion cracking. It also provides appropriate roughness for good osseointergration[4]

Disadvantage

- It is expensive procedure and technique sensitive[4]

**Additive techniques**

It is often carried out on the outer coating surface to improve the aesthetic of the material and its performance.[16]

**Porous and featured coatings**

The implant surface may also be covered with a porous coating. These may be obtained with titanium or hydroxyapatite particulate-related fabrication processes.[4]

Plasma sprayed technique is used most commonly

- Types of Plasma Sprayed Coatings are
  - Plasma sprayed titanium
  - Plasma sprayed hydroxyapatite[4]
- Alternative surface coating techniques
  - Electrophoretic Deposition
  - Sol gel Deposition(Dip Coating)
  - Hot Isostatic Pressing
  - Pulse Laser Deposition
  - Anti-inflammatory Implant Coating. [4]

The materials used to perform ablative and additive procedures on surface of dental implants are

**Carbon & carbon silicon compounds**

These were introduced in 1960 for use in implantology.[4] Used mainly as surface coatings for implants materials[4]

ADVANTAGES: Can be used in the regions that serve as barrier to elemental transfer of heat and electrical current flow. Control of color and provide opportunities for the attachment of active biomoleculeor synthetic compounds.[4]
DISADVANTAGE: Mechanical strength is relatively poor. Minimal resistance to scratching or scraping procedures associated with oral hygiene.[4]

**Polymers**

Polymeric implants were first introduced in1930s. The use of synthetic polymers and composites continues to expand for biomaterial applications. Fiber-reinforced polymers offer advantages in that they can be designed to match tissue-properties, can be anisotropic with respect to mechanical characteristics, can be coated for attachment to tissues, and can be fabricated at relatively low cost. However they have not found extensive use in implant due to

✓ Low mechanical strength and lack of osseointegration. It is used currently to provide shock absorbing qualities in load bearing metallic implants.ADVANTAGE: They can be changed to a more porous or softer form. They can be manipulated easily. They do not generate microwaves or electrolytic current as do metals They show fibrous connective tissue attachment. They are more aesthetically pleasing.

DISADVANTAGE: Polymers have inferior mechanical properties as compared to other biomaterials. They have poor adhesion to living tissue.[4]

**Future are as of application**

Synthetic substances for tissue replacement have evolved from selected industrial grade materials such as metals, ceramics, polymers, and composites. This situation offers opportunities for improved control of basic properties. The simultaneous citation of the biomechanical sciences also provides optimization of design and material concepts for surgical implants. Knowledge of tissue properties and computer-assisted modeling and analyses also support the present developments. The introduction of anisotropy with respect to mechanical properties; chemical gradients from device surface-to-center with bonding along the tissue interfaces; and control of all aspects of manufacturing, packaging, delivering, placing, and restoring enhance the opportunities for optimal application and, it is hoped, device treatment longevities. Health care delivery would benefit from better availability and decreased per-unitcost.[4] Combinations to provide compositions with surfaces, the addition of active biomolecules of tissue inductive substances, and a stable transgingival attachment mechanism could improve device systems. An integrated chemical and physical barrier at the soft tissue transition region would, atleast theoretically, enhance clinical longevities. Devices that function through bone or soft tissue interface along the force transfer regions could be systems of choice, depending on the clinical situation.[4] Unquestionably, the trend for conservative treatment of oral diseases will continue. Thus it can be anticipated that dental implants will frequently be a first treatment option. There for increased usage of root form systems is to be expected. Clearly the true efficacy of the various system will be determined by controlled clinical studies with 10- to 20-year follow-up periods, which include statistically significant quantitative analyses.[4]

**References**


1. Glossary of Implant Dentistry. International Congress of Oral Implantologists Volume-3.
2. Glossary of prosthodontic term. Academics of prosthodontics. J Prosthet Dent 2017;117;9;e29.
3. Hulbert SF, Bennett JT. State of the art in dental implants. J Dent Res 1975; 54 Spec NoB:B153-57 [PMID: 1055740DOI: 10.1177/00220345750540021001]
4. Carl E Misch. Contemporary Implant Dentistry, 3rd ed. St. Louis; Mosby; 2008.
5. Monika S, Yashpal S, Pooja A, Vipin A, Krati J. Implant biomaterials: A comprehensive review. World J Clin Cases 2015 January 16; 3(1): 52-57
6. RehamB.ACriticalReviewofDentalImplantMaterialswithanEmphasisonTitaniu m*versus* Zirconia. *Materials* 2015, *8*, 932-58.
7. WilliamsDF: Biocompatibility of orthopaedic implants, vol1, BocaRaton, Fla, 1982, CRCPress.
8. Hillmann G, Donath K: Licht und elektronemikro skopische untersuchung zur biostabilitat dentaler titanimplantate, *Z Zahnarztl Implantol* 7:170-177, 1991.

9. Schliephake H, Reiss G, Urban R et al: Freisetzung von titan aus schraubenimplantaten,*Z Zahnarztl Implantol* 6:6-10, 1991.
10. Ferguson AB, Laing PG, Hodge ES: The ionization of metal implants in living tissues, *JBoneJoint Surg Am* 42A:77-90, 1960.
11. Plenk H,Zitter H: Material considerations. In Watzek G, editor: *Endosseous implants: scientific and clinical aspects,* Chicago, 1996, Quintessence.
12. Bosker H, Kijk L: Het trans mandibulaire implantaat, *Ned Tijdschr Tandheelkd* 90:1983 pg. 381-89.
13. Hench LL, Ethridge EC: *Biomaterials, an interfacial approach,* New York, 1982, Academic Press.
14. Vincenzini P, editor: *Ceramics in surgery,* Amsterdam, 1983, Elsevier.
15. Sandhaus S: Nouveaux aspects del' implantologie, *L' Implant CBS Suisse*, Lausanne, Switzerland,1969
16. P.S.Patil et al. Dental Implant Surface Modifications: A Review. Journal of Dental andMedical Sciences..V(15), Issue 10 October;2016;132-141.
17. Barrere F, van der Valk CM, Dalmeijer RA, van Blitterswijk, de Groot, Layrolle P. In vitro and in vivo degradation of biomimetic octacalcium phosphate and carbonate apatite coatings on titanium implants. J Biomed Mater Res 2003;64(2):378-87.
18. Le Guehennec L, Soueidan A, Layrolle P, Amouriq Y. Surface treatments of titanium dental implants for rapid osseointegration. Dent Mater 2007;23:844-54.
19. Sul YT, Johansson CB, Roser K, Albrektsson T. Qualitative and quantitative observation of bone tissue reactions to anodized implants. Biomaterials 2002;23:1809- 17.
20. Sul YT, Johansson C, Wennerberg A, Cho LR, Chang BS. Optimum surface properties of oxidized implants for reinforcement of osseointegration: Surface chemistry, oxide thickness, porosity, roughness and crystal structure. Int J Oral Maxillofac Implants 2005;20(3):349-59.
21. Pypen CM, Plenk H Jr, Ebel MF, Svagera R, Wernisch J. Characterization of microblasted and reactive ion etched surfaces on the commercially pure metals niobium, tantalum and titanium. J Mater Sci Mater Med 1997;8:781-84.
22. Gaggl A, Schultes G, Muller WD, Karcher H. Scanning electron microscopical analysis of laser treated titanium implant surfaces: A comparitive study. Biomaterials2000;21:1067-73.
23. Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2022). Post-pandemic health and its sustainability: Educational situation. *International Journal of Health Sciences*, *6*(1), i-v. https://doi.org/10.53730/ijhs.v6n1.5949
24. Rakhmonov, O. M., Shadmanov, A. K., & Juraev, F. M. (2021). Results of endoscopic treatment of benign prostatic hyperplasia in patients with metabolic syndrome. *International Journal of Health & Medical Sciences*, *5*(1), 21-25. https://doi.org/10.21744/ijhms.v5n1.1811