Dental implant materials

Dental implant: 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

The composition and nature of the surface on an implant are important characteristics because of their effect on the biologic development of an interfacial relationship between the bone and the implant. To be successful, an implant must meet four conditions:

1) Be biocompatible so there is no undesirable reaction between the tissues and the implant (i.e. corrosion, dissolution and/or resorption.

2) Have an interface that stabilizes postoperatively in as short a time as possible.

3) Be capable of carrying and transferring the occlusal stresses that are placed upon it.

4) Remain stable for a long period of time.

Knowledge of the composition of implant materials, their surfaces, and their forms are important factors when developing an understanding of the biocompatibility of implants and how they develop a symbiotic relationship with living tissues.

Osseointegration: 1. The apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening fibrous connective tissue.

2. The process and resultant apparent direct connection of an exogenous material's surface and the host bone tissues, without intervening fibrous connective tissue present.

3. The interface between alloplastic materials and bone.

Biomaterials: 1. Any substance other than a drug that can be used for any period of time as part of a system that treats, augments, or replaces any tissue, organ, or function of the body.

2. A synthetic material used to make devices to replace part of a living system or to function in intimate contact with living tissue.

3. A variety of devices and materials are used in the treatment of disease or injury. Common place examples include suture needles, plates, teeth fillings, etc.

Bio-compatibility: Acceptance of an artificial implant by the surrounding tissues and by the body as a whole.

Selection of Biomedical Materials

The process of material selection should ideally be for a logical sequence involving:

1- Analysis of the problem.

2- Consideration of requirement.

3- Consideration of available material and their properties leading to choice of material.

- The most common classes of materials used as biomedical materials are polymers, metals, and ceramics. These three classes are used singly and in combination to form most of the implantation devices available today.

  - Implant material should have suitable mechanical strength, biocompatibility, and structural biostability in physiologic environments.
  - The development of biomaterials sciences has resulted in classification schemes for implantable materials according to chemical composition and biologic response.

Classification of implant materials:-

1. According to biocompatibility of the material in the bone **Strunt's classification**.

2. According to type of material. metallic or non-metallic **(Combe's classification).**

1. Strunt's classification according to biocompatibility:

Depending on their reaction with surrounding bone and on the ability of implant material to stimulate bone formation (behaviour of the material in bone).

a. Distant osteogenesis: (biotolerated material):

In this type, there will be a gap between implant & bone which is filled with connective tissue. There will be a connective tissue capsule (fibrous scar). Possible osteoid or chondroid contact can be seen. The type of the materials include,

Stainless steel, Co-Cr-alloy, gold alloy, poly methyl methacrylate.

b. Contact osteogenesis: (Bio inert material)

In this type, there is contact between implant & bone like: Titanium. Tantalum, Aluminium oxide & ceramic (non-reactive type).

Ceramics are 2 types:

-Reactive: induce bone formation

-Non reactive: does not induce bone formation

c. True bond osteogenesis: (Bioactive material)

In this type, there is a chemical bond between the implant and bone, materials like ceramics bioglass, calcium phosphate apatite.

d. Bond osteogenesis: (Bio inert & structure osteotropic material)

In this type there is physical & chemical bonding of implant to bone, materials: Titanium with rough surface (to increase the surface area) & very thin thickness of coating layer.

2. Combe's classification:-

1- Metallic material.

2- Non-metallic material.

Non-metallic material:

a. Bio inert (non-reactive): mean minimal interaction between implant material & the tissue like: Polymers, Viterous carbon, nonreactive types of Ceramic e.g. (Aluminium oxide and Zirconium oxide).

Polymers: There are a large number of polymeric materials that have been used as implants or part of implant systems. The polymeric systems include acrylics, polyamides, polyesters, polyethylene, polysiloxanes, polyurethane, polytetra-fluoro-ethylene (PTFE), poly ether ether ketone (PEEK) and a number of reprocessed biological materials.

All polymers are radiolucent, they are used as coating or membrane but nowadays they used the PEEK as solid implant after modification of their mechanical properties by addition of different types of fillers.

Vitreous carbon:- Stable & well tolerated material, classified as ceramic because of inertness & biocompatibility. It has undesirable physical properties, widely used in cardio-vascular disease.

Disadvantages of carbon:

1. It has not performed well in clinical practice & high percentage of clinical failure & withdrawal of this device.
2. Radiolucent in x-ray.
3. Color of the material is black.
4. Brittle & lack of ductility.

The **pyrolytic carbons** appear to have better potential due to their enhanced physical properties & may be further reinforced with carbon fiber producing a material which is well tolerated when implanted.

Non-reactive ceramics:

- One type of non-reactive ceramics that has shown evidence of success in clinical studies is made from **Aluminum oxide** (Al_2O_3),either as poly crystalline or single crystal.
- Although this ceramics is well tolerated by bone , it is not bioactive, because it does not promote the formation of bone
- It does possess high strength , stiffness and hardness
- These implants are designed with either screw or blade shape
- It appears to work optimally when they are used as abutment for prosthesis in partially edentulous patient.

Zirconia-based ceramics

* It is well tolerated in the tissue
* Possess mechanical stability during the experimental method of one year
* Attractive color
* Ease of preparation of abutment
* Radiographic opacity
* Surface structure is important to create enough unique fracture toughness.

* Because of their good combination of mechanical property and excellent biocompatibility, Zirconium's ceramics are recognized as one of the best biocompatibility for joint prosthesis.

- Proper quality control during manufacturing & polishing when used as endosseous dental implant.

b. **Bio active** (Hydroxy apatite, Bioglass):- those material used to enhanced the bond strength of implant to bone & accelerate the rate at which attachments occurs mainly used as coating applied to develop bounded interface with bone to promote bone formation.

The bioactive materials promote bonding to bone by:

1- Providing bonding sites for collagen fibers.

2- Providing an environment which favors osteoblast over fibroblast.

3- Releasing ions which promote hydroxyapatite formation.

- Have a bone-implant interface characterized by direct chemical bonding.
- Free calcium and phosphate compounds at the surface.
- Materials which have designed into them a controlled surface reactivity.

Surface reactivity effect on ionic changes and this effect osteoblast formation rather than osteoclast formation, but this depends on the field.

* Used as coating not as implant because of brittleness and dissolution of the material.

Hydroxy apatite

HA ceramics has been shown to be biocompatible. non-toxic & capable of forming a biochemical bond with bone due to its chemical similarity to bone mineral. The use of HA as coating for titanium substructures addressed to mechanical deficiencies of the material while realizing the benefits of its bioactivity.

Bioglass:-

- Dense ceramic material made from CaO,Na2O,PO5,Si2O, this material bonds chemically to bone. The bond has been shown to be strong that when tested failure fracture occurs with bone or bioglass material leaving interface intact.
- Thus the brittle nature of bioglass become the limiting factor in its use as stress bearing dental implant.

Metallic materials:

The conventional metals and alloys used for medical devices belong to three main metallic systems: stainless steel, cobalt chrommium alloys and titanium alloys.

These systems exhibit an excellent combination of high strength, relative workability and good resistance to corrosion. The improvements made mainly consist in variations in the chemical composition, heat treatments and processing technologies in order to improve aspects such as fatigue behaviour, wear, corrosion, ion release and stress transmission to the surrounding tissues.

- Metal like Stainless steel &Co-Cr alloy because of their acceptable physical properties and relatively good corrosion resistance.
- They are tolerated by bone to a certain extent but cannot integrate with it.
- So currently titanium or titanium alloy implants are widely used for their superior properties of biocompatibility
- Other metals that are used as implants materials are gold, tantalum.

Titanium

- They have proven their worth as a material of choice for the prosthetic superstructure since the late 80 years. Titanium has certain specific properties which makes it absolutely ideal for these applications.

■ It is a silvery-gray metal of groups IV b of the periodic table. It is light weight metal with density of 4.51 g/cm_3, it has low elastic modulus of 110 GPa and a relatively high melting point of 1668°c.

■ Pure titanium is ductile, elastic modulus is 1/2 of steel & 5 times greater than compact bone.

- ♦ Titanium is a reactive metal. This means that in air, water or any other electrolyte an oxide is spontaneously formed on the surface of the metal. This oxide is one of the most resistant minerals known, building a dense film which protects the metal from chemical attack, including that of aggressive body fluids.

- ♦ Titanium is (inert) in tissue. The oxide film in contact with the tissue as practically insoluble; no ions are released that could go on to reach with organic molecules.

- ♦ Titanium possesses good mechanical properties. Its tensile strength is very close to that of the stainless steel used for load-bearing surgical implant.

- ♦ The poisoning effect of titanium is low because the metal is passivated by the immediate formation of the surface oxide during manufacturing. The thickness of the oxide increases during sterilization in water vapor. It is this oxide layer that the biomolecules meets when the implant is placed into bone. Beside its excellent physical properties. Ti has a high corrosion resistance.

Commercially pure titanium CPT

- ➢ CPT is available in four grades, the purest is known as grade 1

American specification require that such material should contain maximum of 0.18% by weight of oxygen and 0.2%by weight of iron The strength of CPT increase with increase concentration of oxygen & iron.

Grad I:- Titanium is the softest. The most ductile, made as barrier for GBR procedure.

Grade 2:- Used for Implant and abutment parts.

Grade 4:- is the hardest type & least ductile.

Ti 6 Al 4V:- require particular tensile strength of this alloy.

- ♦ (Ti-6AI-4V) alloy was found to cause adverse tissue reaction in the interface in contrast to CPT, the metal has been found to cause the most natural tissue reaction of those metals tested.

Types of surface modification:

1- Machined surfaces:-

The microscopic surfaces of machined implants are related to machining operation used for forming the threated shapes & include fine machining lines, pits & grooves. Such features invariably occur during machining of metal such as Ti & Ti alloys. These line surface features may be significant for promoting osteoblast adherence, bone formation & attachment to the implant surface & therefore promoting osseointegration.

2- Shot-blasted features:-

Using of sand blasting medium for producing rough surface. Typically A1¬205, Sic, glass or TiO2, shot (particles) is used to erode a substrate to form very irregular surface with pits & depressions that vary in size & shape depending on the blasting condition.

3- Chemically etched surface

■ Chemical etching has been used to develop textured bone-interfacing implant surfaces for enhanced implant fixation. As a result of the controlled surface chemical attach that results from exposure to acid solutions small pits form more or less regular arrays over the implant surface. The result of such treatment is significant increase in implant surface area (2 time or more) that result in more effective mechanical interlock of bone & improved implant fixation.

4- Porous Sintered Surfaces

This is another approach for achieving fixation by bone in growth & micro mechanical interlock through sintering Ti-6AI-4V alloy powders to a mechanical Ti alloy substrate.

5- Plasma-sprayed surfaces

It is a process by which a material is deposition on to a substrate to form an irregular surface suitable for promoting secure implant fixation by bone growth onto surface irregularities. It is used widely because of the higher temperature reached & higher powder particle velocities. It exhibits higher densities & higher bond strengths.

Plasma is a neutral electrical flame containing equal amount of positive & negative charges. The ions & electrons are produced by passing a gas or mixture of gases through a high current arc.

Surface design: the design of implant surface can be:

- Porous
- Roughened (minimize shear movement)
- Granulated
- Textured (screw shaped surface is ideal for dental implant).
- Smooth (weak bonding because sliding of implant).

Ceramic coating:-

The types of ceramic coatings available include both the bioactive type such as calcium phosphates & the inert ceramics such as aluminum oxide & zirconium oxide. Methods of applying ceramic material as coating for dental implant are:-

1) Plasma spraying.
2) Vacuum deposition techniques.
3) Sol Gel & Dip coating method.
4) Electrolytic processing (Electrochemical).

Electrochemical coating has advantages:-

1) Thin coating layer.
2) Fine crystalline structure.
3) High solubility.
4) 100% coverage of porous implant structure.

Advantage of HA coating:-

1- Aids in direct bonding of bone to the implant surface.

2- Quick closure of the surgical site as a new bone grows from the implant surface to meet bone growing from the socket.

- **The final properties** of a ceramic coating are influenced by the method of processing.

*The **most popular** ceramic coating from a commercial stand point is plasma -sprayed HA.

Enhancement of bone –to-implant contact

Many methods used for this purposes:

1- Hydroxyapatite (plasma sprayed onto a roughened & prepared titanium implant (HA coating range from 50-70nm,also pressurized hydrothermal post plasma – spray increase the crystalline HA content from 77 to 96% this improve bone adhesion .

2- Titanium plasma – sprayed surface implant. The process is characterized by high – velocity molten drops of metal being sprayed onto the implant body to a thickness of 10-40nm this will get greater area for bone attachments & more term results in fully & partially edentulous patient.

3- Implant surface-Pitch, the number of threads per unit length, is an important factor in implant osseointegration. Increased pitch and increased depth between individual threads allows for improved contact area between bone and implant.

Moderately rough surfaces with 1.5µm also, improved contact area between bone and implant surface.

GBR (Guided Bone Regeneration)

- Bone augmentation procedures are frequently used in oral & maxillofacial reconstructive surgery when in sufficient bone volume for implant placement.

Several methods including **bone grafting & membrane techniques** have been described.

Materials used as GBR:

1. Millopore filter.
2. Poly lactic acid (PLA) it's used in iliac bone crest reconstruction.
3. Poly Galactine defect.
4. Collagene membrane.
5. Biobrane.
6. Dura matter.
7. Human periosteium.
8. E-PTFE (expanded poly tetra fluoro ethylene) most biocompatible material used in dental implant.

The principle of (GBR) has been successfully applied to the regeneration of bone in conjunction with the placement of endosseous dental implants where insufficient bone support exists before or after placement of implants.

e-PTFE membranes could regenerate bone in surgically created jaw defect, use a special membrane & under it special bone (pure tri-calcium phosphate) Ca;Po_4, which

is bioresorbable material, it will induce bone formation & then it will resolve like scaffold, when we put the membrane the bone will be guided in one direction for 1 month.

Indications

1. Dehiscence defects.
2. Residual osseous defect.
3. Fenestration defect.
4. Extraction defect

Non-resorbable membrane for oral surgery

TEFGEN-FD:

* Totally inserted biomaterial.

* Optimal use in oral surgery.

* Easy handling.

Application in:-

1. Protect extraction site.
2. Cover periodontal defect.
3. Provide space for bone augmentation.
4. Augment implant site.
5. Cover peri implant defect.

Advantages:

1- Non porous the pores are 0.2 micron.

2- No primary closure necessary.

3- Membrane can remain exposing to oral cavity.

4- Healing without infection.

5- Handled easy.

Uncomplicated removal, no need for 2^{nd} surgery described.

Mechanism of bone grafting (Osteogenesis, Osteoconduction, Osteoinduction)
Osteogenesis: is the development of bone; formation of bone, an osteogenic graft is derived form or composed of tissue involved the growth or repair bone Osteogenic cells differentiate and the different phases of bone regeneration, encourage bone formation in soft tissue, or active quicker bone growth

Osteoinduction: the capability of chemicals or procedures to induce bone formation through the differentiation and recruitment of osteoblasts; phenotypic conversion of mesenchymal cells into osteoblasts.

Osteoinduction is the act or process of stimulating osteogenesis. It can be used to enhance bone regeneration, and bone may even grow or extend into an area where it is not normally found.

Osteoconduction: the process whereby bone grows on a surface or on a scaffolding that is conductive to bone deposition; this is a passive process;

Osteoconduction provides a physical matrix or scaffolding suitable for deposition of new bone a conductive to bone growth allow bone apposition form existing bone, but they do not produce bone formation when placed in soft tissue.

Osteoconductive graft: a graft material that serves as a scaffold for new bone growth; this is a passive process.

Type of graft material:

1. Autogenous Bone: originating or derived from sources within the same individual; self-produced; self-generated; autologous

autogenous graft: a graft taken from the patient's own body.

Autogeneous Bone an organic autologous material utilizes osteogenesis, osteoinduction, osteoconduction the best grafting material from intraoral, extraoral.

Disadv. Need for second operative site possibility of not being to obtain a sufficient amount of bone

2. Allografts: allograft a graft of tissue between genetically dissimilar members of the same species.

3. Alloplast:

1. an inert foreign body used for implantation within tissue.

2. a material originating from a nonliving source that surgically replaces missing tissue or augments that which remains.

Alloplastic graft: a graft consisting of an inert material.

Alloplastic material: any non-biologic material suitable for implantation as an alloplast.