Implant materials

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A peep into history

- In AD 600 HONDURAS Inca indian carved bamboo stakes and implanted into jaw.
- In AD 600 Mayan population implanted fragments of mandible to replicate 3 lower incisors.
- Albucasis de Condue (936-1013) attempted to use ox tooth to replace missing teeth and this treatment was the first documented placements of implants.



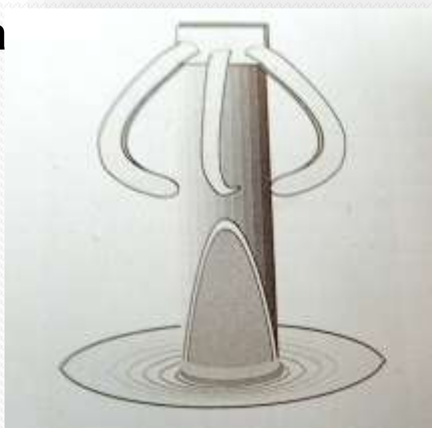
- Pierre Fauchard and John Hunter (18th century) transplanted the teeth of one human to another.

- In 1809 Maggiolo fabricated gold roots that were fixed to pivot teeth by means of spring.

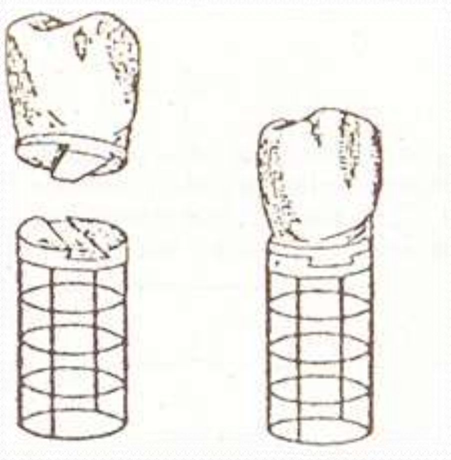
- In 1887 Harris implanted a platinum post coated with lead.

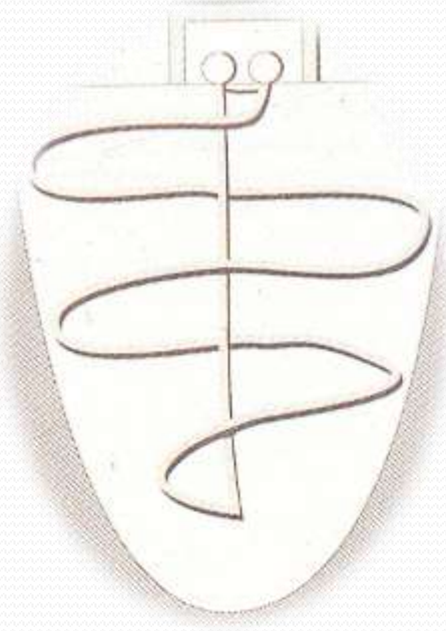
- In 1895 Bonwell used gold or irridium tubes implanted into bone to restore a single tooth.

- In 1905 Scholl demonstrated porcelain corrugated root implan



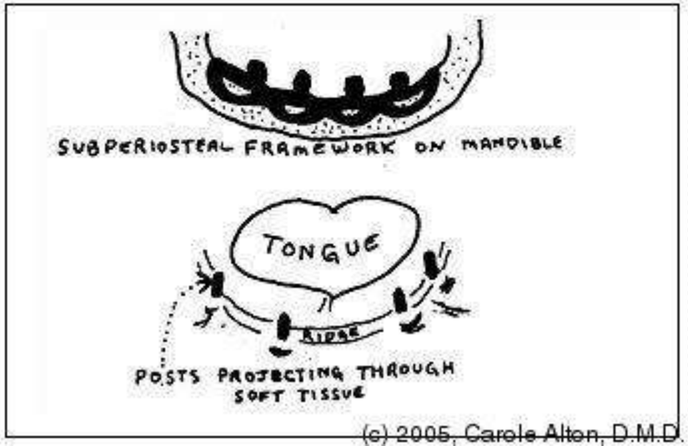
- In 1913 Greenfield introduced a hollow basket implant made from a meshwork of 24 gauge iridium platinum wires soldered with 24 carat gold.
- In 1937, Strock, Venable and Beach described a method of placing a VITALLIUM SCREW to provide anchorage for replacement of missing tooth.
- In 1947 Formiggini developed a single helix wire spiral implant made from stainless steel.

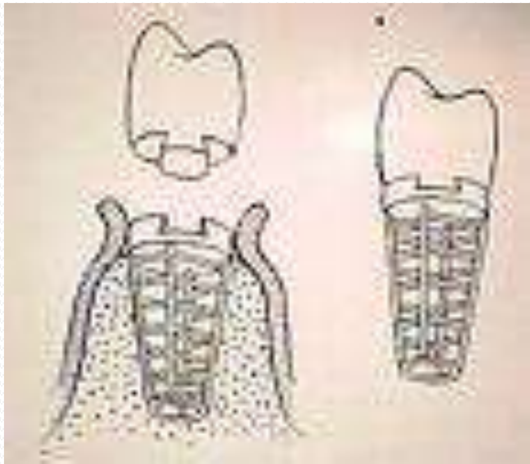




- In 1948 Goldberg and Gershkoff reported insertion of first viable subperiosteal implant.

- In 1963 Linkow designed and introduced the hollow basket design with vents and screw threads.





- In 1952, Professor Brånemark developed a threaded implant design made of pure titanium.
- Dr. Brånemark discovered that titanium apparently bonded irreversibly to living bone tissue.
- More than thirty years later, the non-removable teeth attached to these roots are still functioning perfectly.

Implants

- **Definition** – A dental implant is a material or device placed in and or on oral tissues to support an oral prostheses.

CLASSIFICATION OF IMPLANTS

I . DEPENDING ON THE PLACEMENT WITHIN THE TISSUES

- Endosteal implant
- Subperiosteal implant
- Transosteal implant
- Epithelial implant

II. DEPENDING ON IMPLANT MATERIAL :

- A. Metals and alloys(Ti , Co-Cr-Mo alloys)
- B. Non metallic(polymers, ceramics)

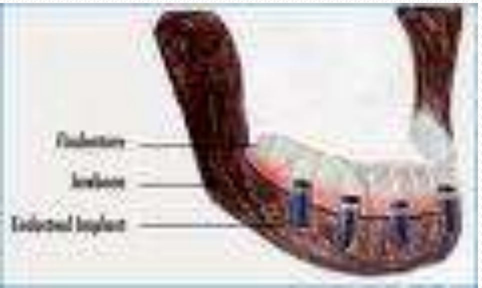
III. STAGES OF IMPLANT PLACEMENT:

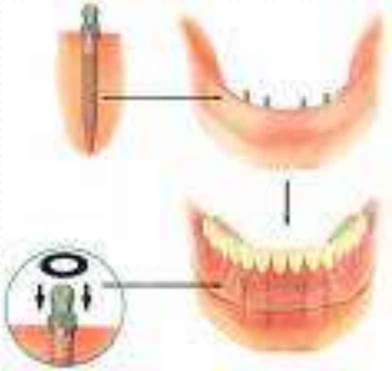
- Single stage
- Two stage

IV. BASED ON IMPLANT LOADING:

- Immediate loading
- Progressive loading
- Delayed loading

- **Endosteal implant**- which is placed into the alveolar bone/basal bone of maxilla or mandible.
- Can be used in all areas of the mouth
- Most commonly used.
- Eg blade implant – used in narrow spaces –posterior edentulous area.
- Because of bone loss application is minimal.





- Another example is ramus frame implant-which is a horse shoe stainless steel device inserted into mandible from one retromolar pad to other passing through symphysis area.
- Failure associated with greater morbidity.
- Most popular endosteal implant is the root form designed to mimic the shape of the tooth roots.
- Most successful endosteal implant
- Procedure technique sensitive in surgical and prosthetic stages

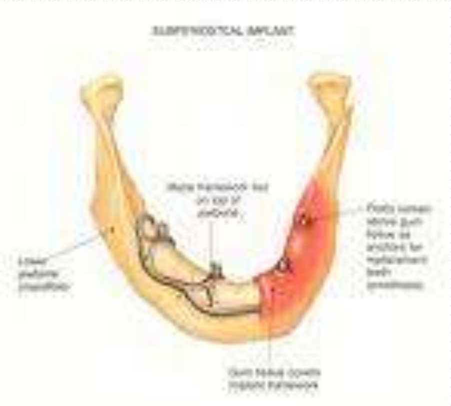


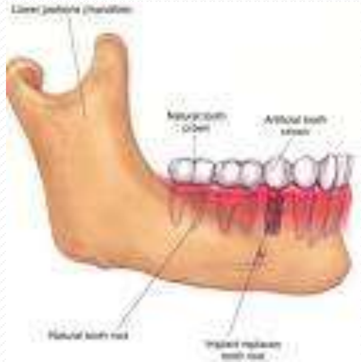
- **Subperiosteal implant-** which rests upon the bony ridge but does not penetrate it.

- Used to restore partially dentate or completely edentulous jaws

- Used when there is inadequate bone for endosseous implants.

- Limited use because of bone loss.

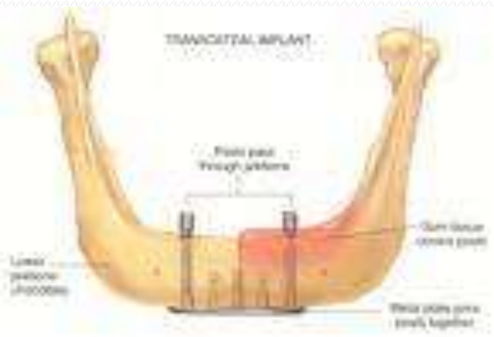




- **Transosteal implant-** combines the subperiosteal and endosteal components.

- Penetrates both cortical plates and passes through full thickness of alveolar bone.

- Eg staple bone implant,mandibular staple implant,transmandibular implant



- **Epithelial implants-** which is inserted into the oral mucosa.
- Simple surgical technique which requires mucosa to be used as an attachment site for the metal inserts.
- Disadvantages – painful healing,requirements for continual wear
- No longer used.

Implant properties

- Implant materials can be classified according to –
- Physical,mechanical,chemical and biological properties.
- These properties often include elastic moduli,tensile strength and ductility to determine optimal clinical applications.
- An implant with comparable elastic modulus to bone should be selected to produce a more uniform stress distribution.
- Metals posess high strength and ductility.
- Ceramics and carbons are brittle materials.

Attachment mechanisms

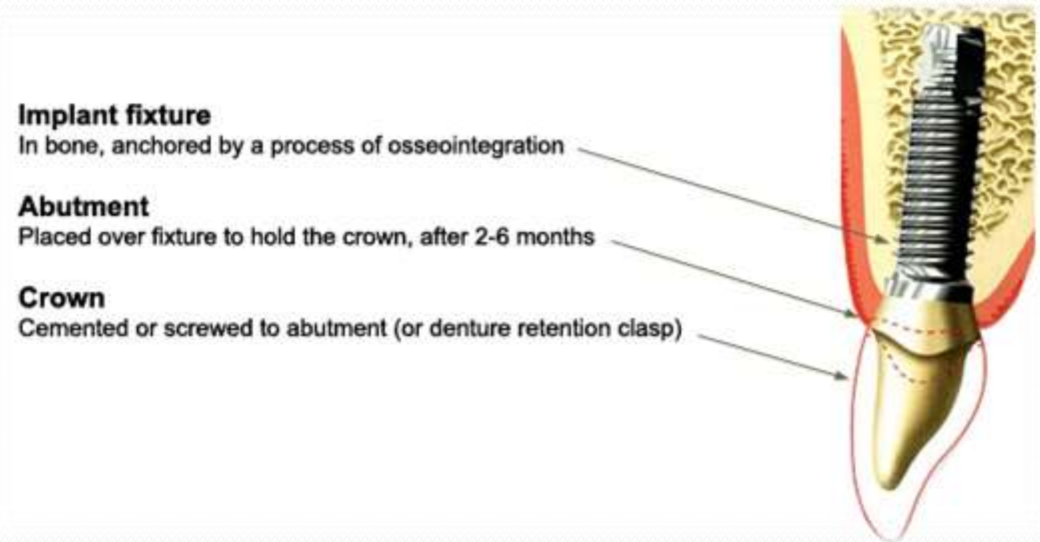
- Periodontal fibres -Most ideal form of attachment .
- Historically implant attachment through low differentiated fibrous tissue was widely accepted as a measure of successful implant implacement.
- Clinical studies indicate that this type of attachment eventually lead to an acute reaction,and progressive looseness will occur.
- Osseointegration described by Branemark is now the primary attachment mechanism of commercial dental implants.
- This mode is described as direct adaptation of bone to implants without any other interstitial tissue and is similar to tooth ankylosis where no PDL exists.
- Osseointegration can also be achieved through the use of bioactive materials that stimulate the formation of bone.

Implant components

- Fixture – implant component that engages the bone.
  (threaded ,grooved ,perforated ,plasma sprayed , or coated.)

- Transmucosal abutment – provides connection between implant fixture and prosthesis.

- Prosthesis .



- Placement of implant done in various stages-
- First stage – surgery - implant placed into bone.
- Second stage – implant left alone for a period of 4 – 6 months to become osseointegrated.
- Third stage – second surgery-implant uncovered-healing cap placed for proper healing of soft tissues.
- Fourth stage – placement of abutments and eithere a fixed or removable denture.
- Some implant systems require only one surgical intervention,and implant is immediately placed in contact with the oral environment.
- Advocated for immediate loading.
- Relatively successful.

Clinical success of dental implants

- **In 1979 Schintman and Schulman proposed following requirements –**
- Mobility of an implant must be less than 1 mm .
- No evidence of translucency.
- Bone loss should be less than one third the height of the implants.
- There should be absence of infection,damage to structures,or violation of body cavities.
- Success rate must be 75% or more after 5 yrs of functional service.

- **In 1986 Albrektsson et al included the following conditions-**
- Individual ,unattached implant is immobile when tested clinically.
- Radiograph does not demonstrate any evidence of periapical transluscency.
- Vertical bone should be less than 0.2mm following implant's first year of service.
- Implant performance must be absent of signs and symptoms such as pain,infections,neuropathies,parasthesia,or violation of mandibular canal.
- Success rate of 85% or more at end of 5 yrs

Implant failures

- Cigarette smoking.
- Osteopenia ,Osteoporosis.
- Diabetes .
- Uncontrolled periodontal disease.
- Internal factors including bone height,bone density and attached mucosa.
- Severe mucosal lesions.
- Previous radiotherapy to the jaws.
- Bleeding disorders

Implant materials

- **2 basic classes of materials-**

1. Ceramics
2. Metals

Implant materials

- Dental implant materials
  - metals
    - CP Titanium and Ti-6Al-4v alloys
    - Cobalt alloys
  - ceramics
    - Inert ceramics
      - alumina
      - Carbon
      - Zirconia
    - Bioactive ceramics
      - Bioactive glasses and ceramics
      - Calcium phosphates

Metallic implants

- Metallic implants undergo several surface modification to become suitable for implantation.

- Modifications are passivation,anodization,ion implantation and texturing.

- Titanium most commonly used implant material.

- Titanium – Gold standard.

Titanium

- Atomic number – 22
- Atomic wt – 47.9
- Low specific gravity
- High heat resistance
- High strength
- Resistant to corrosion (titanium oxide)
- Pure titanium forms several oxides TiO, TiO_2, Ti_2O_3
- TiO_2 most stable

- Ti and Titanium alloys most commonly used namely Ti-6Al-4V and Ti-6Al-4V extra low interstitial (ELI).
- Ti-6Al-4V most commonly used.
- Modulus of elasticity of Ti-6Al-4V is closer to that of bone than any other implant material.
- This ensures a more uniform distribution of stress along the bone-implant interface.
- ELI contains low oxygen – improve the ductility of the ELI alloy.
- Newer titanium alloys developed include Ti-13Nb-13Zr and Ti-15Mo-2.8Nb.
- These alloys exhibit greater corrosion resistance.

The American Society for Testing and Materials(ASTM) committee F-4 on materials for surgical implants recognizes four grades of commercially pure Titanium and two Titanium alloys:

- Cp titanium grade I (0.18% Oxygen)
- Cp titanium grade II (0.25% Oxygen)
- Cp titanium grade III (0.35% Oxygen)
- Cp titanium grade IV (0.40% Oxygen)

ADVANTAGES:

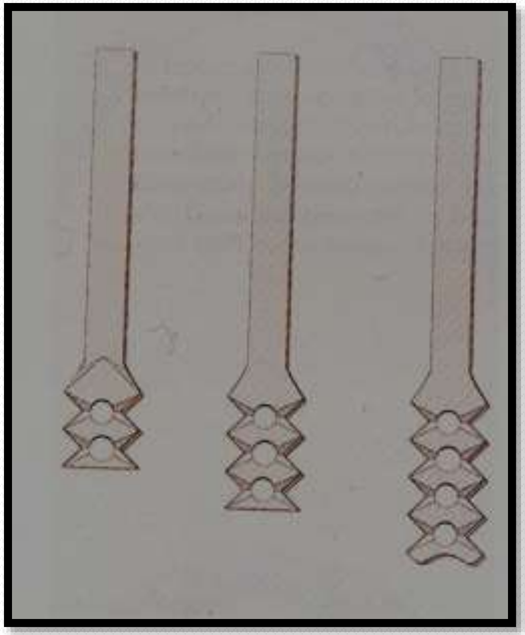
•High degree of biocompatibility
•High strength
•High corrosion resistance.

•DISADVANTAGES:

•High cost
•Difficult and dangerous to cast

COBALT-CHROMIUM MOLYBDENUM ALLOYS:

- Elemental composition of this alloy consists of-
  - Cobalt- 63%
  - Chromium- 30%
  - Molybdenum- 5%
  - Carbon , manganese and nickel- traces.



- COBALT: provides continuous phase of the alloy
- CHROMIUM: provides corrosion resistance through the oxide surface(Cr_2O_3).
- MOLYBDENUM : stabilizer; also provides strength and bulk corrosion resistance.
- CARBON: serves as a hardner
- Secondary phases based on Co,Cr,Mo,Ni and C provides strength(4 times that of compact bone) and surface abrasion resistance.

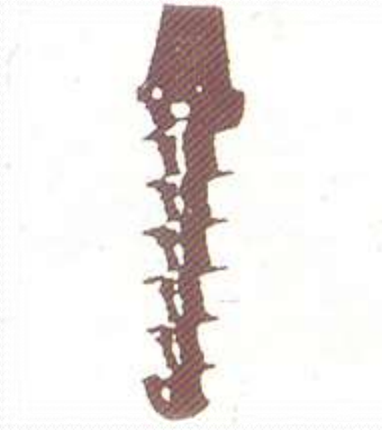
ADVANTAGES :

- Low cost and ease of fabrication
- When properly fabricated , good biocompatibility

DISADVANTAGES :

- Poor ductility

- VITALLIUM was introduced by Venable in 1930's and is part of Co-Cr –Mo alloy family.

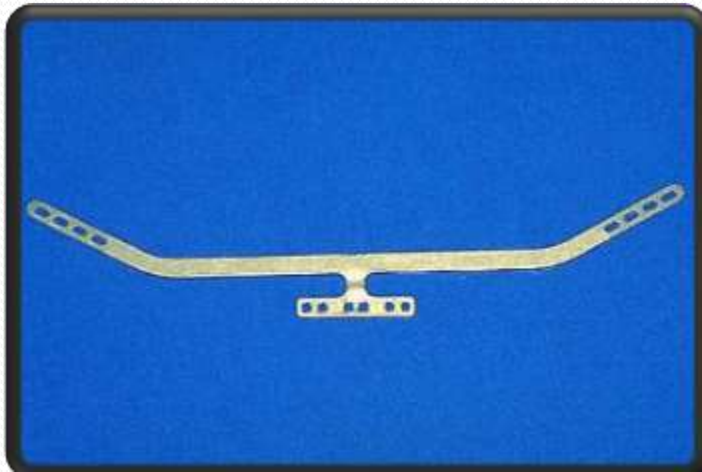


Stainless steel

- 18 % chromium for corrosion resistance.
- 8 % nickel to stabilize the austenitic structure.
- 80% iron
- 0.05-0.15% carbon
- **Properties:**
- It has high strength and ductility, hence is resistant to brittle fracture.
- High Tensile strength
- Ease of fabrication

Disadvantages :

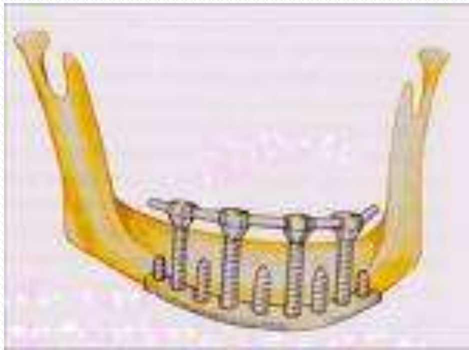
- It cannot be used in Ni sensitive patients
- Susceptible to pit and crevice corrosion
- Galvanic potential.



Other metals

- Cobalt-chromium-molybdenum alloys consisting of 63% cobalt,30% chromium,and 5% molybdenum.
- Molybdenum is a stabilizer , chromium provides passivating effect, carbon serves as hardner.
- Vitallium was used as implant material.
- It was shown to lack electrochemical activity and tissue reaction.

- Ticonium a Ni-Cr-Mo-Be alloy was also used as a dental implant material although it showed less biocompatibility.
- Inspite of titaniums excellent biocompatibility Co-Cr-Mo alloys and stainless steel are still sometimes used for larger implants.
- Used in subperiosteal and transosteal implants.
- Castability and low cost.

CERAMIC AND CERAMIC COATED IMPLANT MATERIALS:

- **Ceramics implants are of two types mainly:**

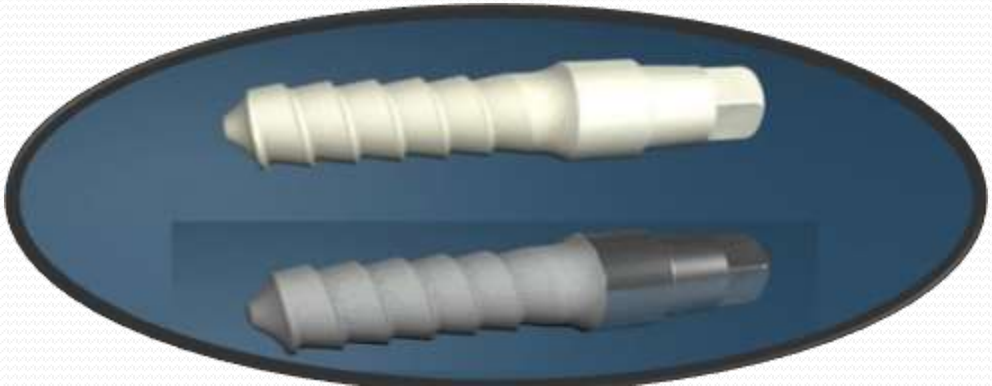
- BIO-INERT: aluminium oxide
- BIO-ACTIVE: hydroxyapatite.

- **GENERAL PROPERTIES OF CERAMICS:**

- High compressive strength upto 500MPa.
- Less resistance to shear and tensile stress
- High modulus of elasticity
- Brittle

- Ceramic implants can withstand only relatively low tensile stresses.
- Tolerate high levels of compressive stresses.
- Al_2O_3 used as a gold standard for ceramic implants because of its inertness and no evidence of immune reaction in vivo.
- ZrO_2 also demonstrated high degree of inertness.
- These ceramic materials are not bio-active.
- Have high strength,stiffness,and hardness and function well as subperiosteal or transosteal implants

- Use of calcium phosphates as coating materials for metallic implants promotes bone to implant integration.
- The more HA coating the more resistant it is to clinical dissolution.
- A minimum of 50% crystalline HA is considered an optimal concentration in coating of implants.
- Dissolution of the ceramic coating occurs at a higher rate with a more amorphous HA structure.
- Advantage of ceramic coating is that they stimulate the adaptation of bone.
- Studies suggest that there is greater bone – to – implant integration with the HA coated implants.



- Another form of bioactive ceramics are bioglasses.
- Known to form a carbonated hydroxyapatite layer.
- Formation of layer is initiated by migration of calcium,phosphate,silica,and sodium ions towards tissue .
- Silica gel layer is formed.
- Silicon depletion initiates migration of calcium and phosphate ions .
- Calcium-phosphorous layer is formed that stimulates osteoblasts to proliferate, stimulating the formation of bone.
- Bioglasses are very brittle,which makes them unsuitable for use as stress bearing implant materials.

ADVANTAGES :

- Excellent biocompatibility
- Minimal thermal and electrical conductivity
- Color is similar to bone, enamel and dentine
- Chemical composition is similar to constituents of normal biological tissues.

DISADVANTAGES:

- Low mechanical, tensile and shear strength under fatigue loading.
- Variations in chemical and structural characteristics
- Low attachment strengths for some coatings with substrate interfaces.

Polymers

- Polymeric implants -First used in 1930's.
- Not used nowadays :-
- Because of low mechanical strength and susceptibility to frature during function.
- Sterilisation accomplished only by gamma radiation or exposure to ethylene oxide gas .
- Contamination of polymers.
- During 1940s methyl methacrylate was used for temporary acrylic implants to preserve dissected space to receive a Co-Cr implant later.

- **DISADVANTAGES:**

- Low mechanical strength hence susceptible to mechanical fracture

- Physical properties of polymers are greatly influenced by changes in temperature, environment and composition.

- Their sterilization can be accomplished only by gamma irradiation or exposure to ethylene oxide gas.

- Contamination of these polymers because of electrostatic charges that attract dust and other impurities from the environment.

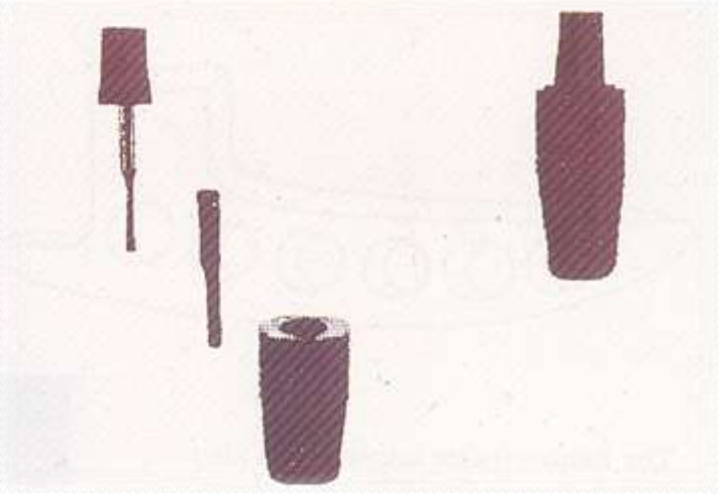
- IMZ IMPLANT:

  The use of polymers for osseointegrated implants is now confined to its components. The IMZ implants are either plasma sprayed or HA-coated and incorporate a polyoxymethylene(POM) intra mobile element(IME) which acts as a shock absorber.

- IME is placed between the prosthesis and the implant body to initiate mobility, stress relief and shock absorption capability to mimic that of the natural tooth.

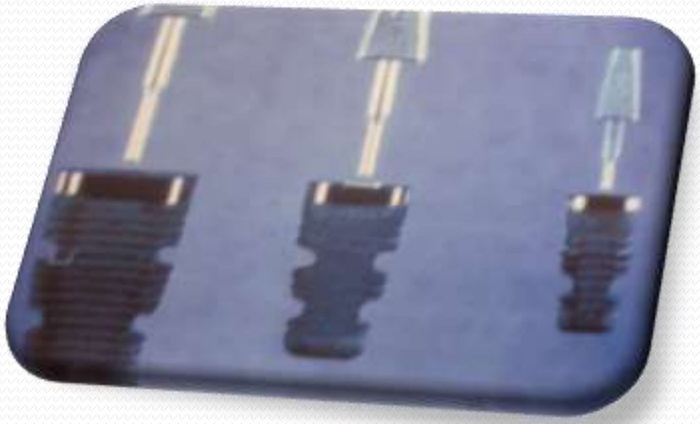
CARBON AND ITS COMPOUNDS:

- Carbon and its compounds(C and SiC) were introduced in the 1960's for use in implantology.
- VITREOUS CARBON, which elicits a very minimal response from the host tissues, is one of the most biocompatible material



ADVANTAGES:

- Carbon is inert under physiological conditions.
- Has a modulus of elasticity equivalent to that of dentin and bone.
- Thus it deforms at the same rate as these tissues enabling adequate stress distribution.



DISADVANTAGES:

- Because of its brittleness, carbon is susceptible to fracture under tensile stress, which is usually generated as a component of flexural stress.
- It also has a relatively low compressive strength.
- Thus a large surface area and geometry are required to resist fracture.

Selecting an implant material

- Important consideration is the strength of implant material and type of bone in which implant is placed.
- For high load zone eg in posterior areas high strength material such as CP grade IV titanium or titanium alloys are used.
- Anterior implants designated for use in narrow spaces have smaller diameters in range of 3.25mm.
- Single implants placed in posterior areas have large diameters up to 5.0 mm

According to type of bone :-

- Type I- consists of homogenous compact bone.
- Type II- consists of thick layer of compact bone surrounding a core of dense trabecular bone.
- Type III- is a thin layer of cortical bone surrounding a core of dense trabecular bone.
- Type IV- is composed of thin layer of cortical bone with a core of low-density trabecular bone

- Much debate about when to use metal implants or ceramic coated implants.
- HA coated implants stimulate bone growth.
- Some studies show that HA is a very unstable implant material.
- Gottlander and Albrektsson examined bone to implant contact area both at 6 weeks and 12 months for HA and CPTi coated implants.
- They concluded that bone – implant contact at 6 weeks was 65% for HA and 59% for Ti.
- However at 12 months Ti exhibited 75% contact area versus 53% for HA.

- Some studies showed survival rate of HA-coated implants is initially higher than that that for titanium plasma sprayed implants,but decreased after 4 yrs.
- Due to the adherence of microorganisms to HA surface.
- A study revealed colonisation of coccoid and rod shaped bacteria on HA implants.
- Roughened surface of HA implants also contribute to plaque growth once coating is exposed.
- Numerous osteocytes were found along periphery of HA implants making it a better option for poor bone quality areas such as maxilla.
- Branemark type titanium implants were evaluvated in type IV bone and a survival rate of 63% was found for mandibular implants and 56% for maxillary implants.

- Another study compared the survival rate of titanium screw type implants and HA coated cylinders in type IV bone.
- At 36 months Ti implants had a survival rate of 78.3% compared with 98% for HA implants.
- In a follow up study titanium screws exhibited 91%-3 yr survival rate and 89% for a 7 yr period in type IV maxillary bone.
- All these studies indicate HA coated implants have greater survival rate in type IV bone.

- Another factor is the bone height.
- A 5 yr study revealed 70 % failure for titanium screws with only a height of 8 mm.
- The same height of HA coated implants resulted in only 4% failure

- There was no significant difference in failure when length of screws was increased to 12 mm.
- Another indication of HA coated implants is their placement in fresh extraction sites provided there are no existing pathological conditions.
- The review suggests that survival rates are similar for both coated and uncoated implants and that the HA coating did not compromise the long term survival of these implants.

Indications for HA implants include-

- Need for greater bone – implant interface contact area
- Ability to place the implant in type IV bone.
- Fresh extraction sites.
- Newly grafted sites.

BIOMECHANICAL CONSIDERATIONS:

- The attachment of bone to implants serves as the basis for the biomechanics analyses performed for dental implants.
- ATTACHMENT MECHANISMS:
- Fibro osseous integration (Weiss 1986)
- Bio osseous integration (Putter 1985)
- Osseointegration (Branemark 1969)

Fibrosseous theory

- Stated that collagen fibers invest the implants, originating at a trabaculae of cancellous bone on one side, weaving around the implant, and reinserting into a trabaculae on the opposite side.

Bio-osseus integration-

Some materials such as the bioglass ceramics promote an integration between bone and material with no intervening space.when this integration occurs material is said to biointegrate with the bone.

Biointegration appears to require a degradation of bioactiveceramic to promote bone formation.

Some examples are Bioglass,Ceravital,Biogran,Glass ceramic A-W and β-wollastonite.

Osseointegration-

Is defined as the close approximation of bone to an implant material.To achieve osseointegration bone must be viable and space between bone and implant must be less than 10 mm,and contain no fibrous tissue.

Summary

- Implant systems currently available are diverse.
- Implant materials range from commercially pure titanium to HA coated devices.
- When the mechanisms that ensure implant bioacceptance and structural stabilization are fully understood, implant failures will become a rare occurrence provided they are used properly and placed in sites for which they are indicated.

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