Sri Aurobindo College of Dentistry

Indore, Madhya Pradesh

INDIA

MODULE PLAN

TOPIC :DENTAL IMPLANTS

SUBJECT:PROSTHODONTICS

TARGET GROUP: UNDERGRADUATE DENTISTRY

MODE: POWERPOINT – WEBINAR

PLATFORM: INSTITUTIONAL LMS

PRESENTER:DR.SUMEET JAIN

Dental Implant Biomaterials

ADA Specification No. **78**
ISO Specification No. **6877:2006**

DEFINITION-

[1]**implant** \ĭm-plănt´\ *vt* (1890): to graft or insert a material such as an alloplastic substance, an encapsulated drug, or tissue into the body of a recipient

[2]**implant** \ĭm-plănt´\ *n* (1809): any object or material, such as an alloplastic substance or other tissue, which is partially or completely inserted or grafted into the body for therapeutic, diagnostic, prosthetic, or experimental purposes; *syn*, DENTAL IMPLANT

- GPT 9

HISTORY

The desire to provide a substitute for a single tooth or an entire arch began in ancient civilizations where gold and ivory were commonly used.

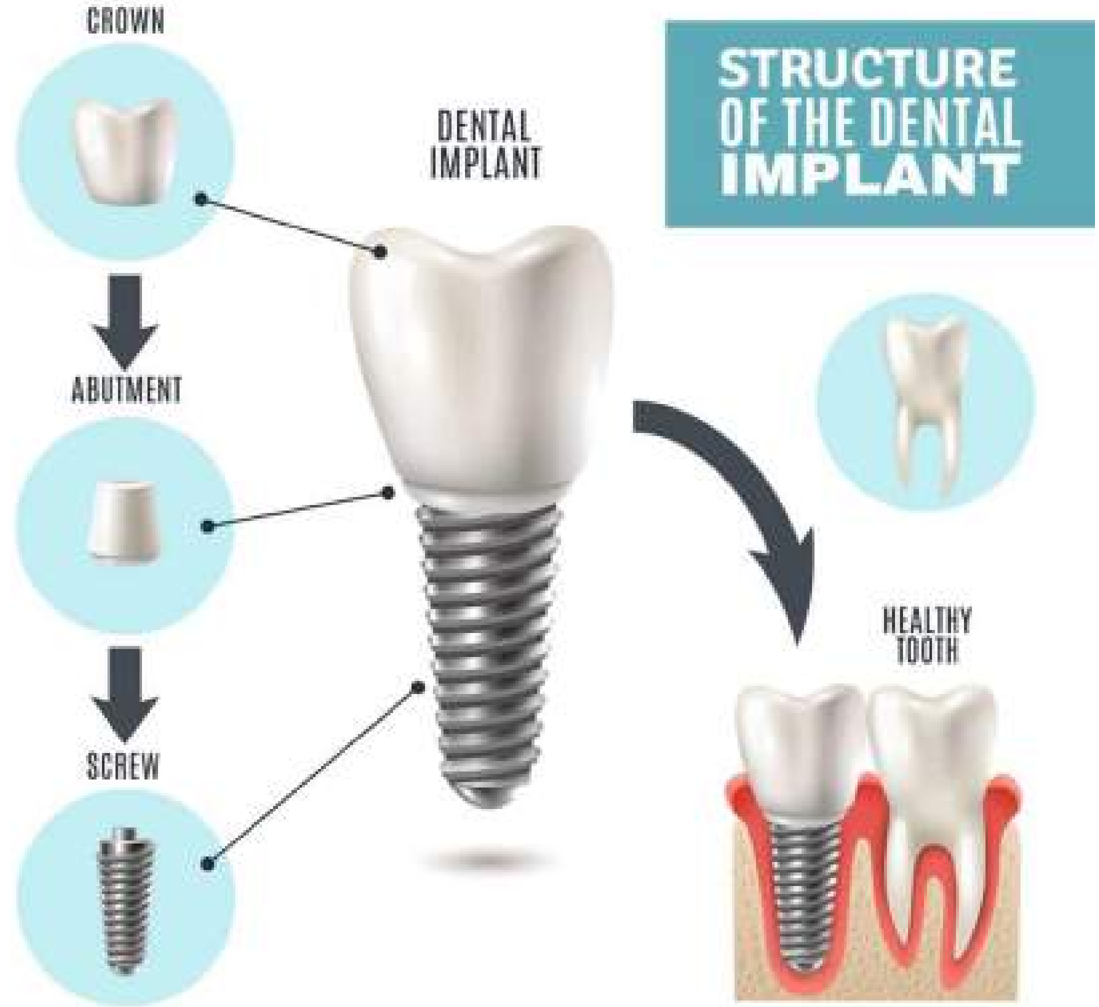
Yet modern dental implantology is approx. 30 years old.

In 1952, Professor Branemark, a Swedish surgeon accidentally discovered that titanium can directly osseo-integrate with the bone when he implanted titanium capsules to study the healing patterns of bone. This paved the way for the wide usage of titanium within the tissues.

Materials like platinum, silver, cobalt alloys, steel, lead, acrylic resin, carbon, alumina and ceramics are also being used. Following their use in orthopaedics, these materials made their way into dental implantology.

PARTS OF IMPLANT

1. Abutment
2. Implant Body/Fixture:
3. Healing Screw
4. Healing Caps



ABUTMENT

It is that part of the implant which supports the crown and provides retention to it. It resembles a prepared tooth and is attached to the body of the implant.

IMPLANT BODY/FIXTURE

It is placed in the bone during implant surgery and provides anchor to the restoration. It is fixed onto the bone and the abutment is screwed onto it.

HEALING SCREW

It is placed over the implant body after the first stage of surgery to facilitate suturing of the tissues and prevent growth of tissues over the edge of the implant.

HEALING CAPS

They are placed over the implant body and protrude outside the tissues into the oral cavity.

They maintain the tissue contour around the implants and also help in permanent restoration of the implant.

ADVANTAGES

1. Implants can avoid cutting down of neighboring natural teeth, thus preserving natural healthy tissue.

2. They help preserve bone and reduce bone resorption.

3. They reduce the load on the remaining natural teeth as they offer individual support.

4. They cause improved efficiency in chewing and speaking compared to complete denture wearers.

DISADVANTAGES

1. Involves a surgical procedure
2. Waiting period of 3–4 months to enable healing before prosthesis
3. Increased cost compared to conventional treatment

INDICATIONS

1. Loss of one or more natural teeth, especially when most of the posterior teeth serving as occlusal stops are missing

2. Presence of a good quality and quantity of bone around the edentulous area. Inadequate bone can be corrected by bone grafts prior to implant placement

3. Patient unwilling to undergo a reduction of the natural teeth for a fixed prosthesis like a bridge

4. Providing support for overdentures

5. Implant-supported maxillofacial prosthesis In a nutshell, it is indicated when the implant support prosthesis appears to be superior to conventional treatment in terms of esthetics and function.

CONTRAINDICATIONS

1. Inferior quality of bone in edentulous area
2. Bruxism
3. Steroid therapy
4. Bleeding disorders
5. Immunodeficient conditions
6. Proximity to anatomical structures such as the inferior alveolar nerve or a large maxillary sinus (not an absolute contraindication; necessary precautions should be taken)

CLASSIFICATION OF IMPLANTS

1. BASED ON MATERIALS USED
2. BASED ON BIOLOGICAL RESPONSE
3. BASED ON HISTOLOGY
4. BASED ON IMPLANT DESIGN
5. BASED ON MACROSCOPIC DESIGN
6. BASED ON SURFACE TREATMENTS

BASED ON MATERIALS USED

1. **Metals and alloys:** It includes titanium and its alloys, stainless steel, cobalt chromium, and molybdenum

2. **Ceramics and carbon implants:** Made of carbon with stainless steel

3. **Polymers and composites:** Polymethylmethacrylate and polytetrafluoroethylene

BASED ON
BIOLOGICAL RESPONSE

BIOTOLERANT

These materials are not easily rejected when implanted into living tissue but are surrounded by a fibrous layer in the form of a capsule.

Examples

1. METALS like gold, Co-Cr alloy, stainless steel, zirconium, niobium
2. POLYMERS like polyethylene, polyamide, polymethylmethacrylate, polyurethane

BIOINERT

These materials allow close apposition of bone on their surface, leading to contact osteogenesis.

Examples

1. METALS like commercially pure titanium (Cp-Ti) and titanium alloy
2. CERAMICS like aluminum oxide and zirconium oxide

BIOACTIVE

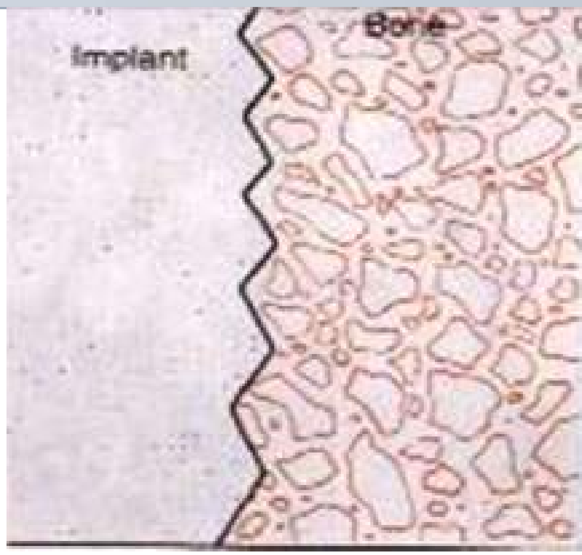
These materials allow the formation of bone onto their surface, but ion exchange with host tissue leads to the formation of a chemical bond along the interface.

Examples:

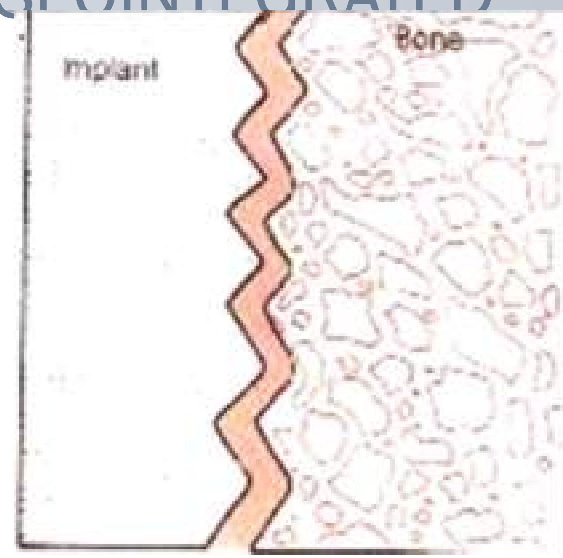
CERAMICS like HA, tricalciumphosphate, bioglass, fluorapatite, andcarbon-silicon

BASED ON **HISTOLOGY**

OSSEOINTEGRATED



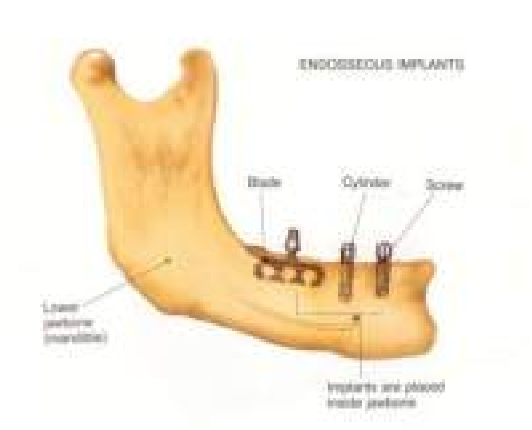
FIBRO-OSSEOINTEGRATED



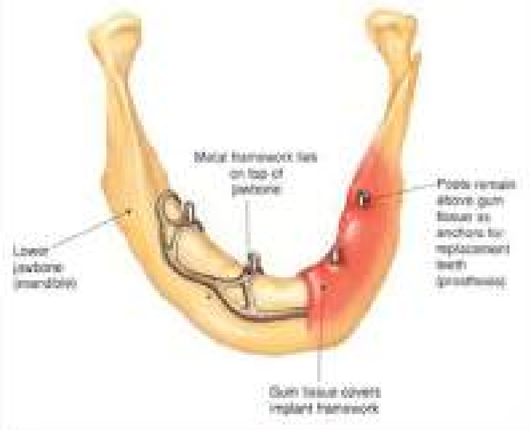
BASED ON **IMPLANT DESIGN**

1. ENDOSTEAL IMPLANTS
2. SUBPERIOSTEAL IMPLANTS
3. TRANSPERIOSTEAL IMPLANTS

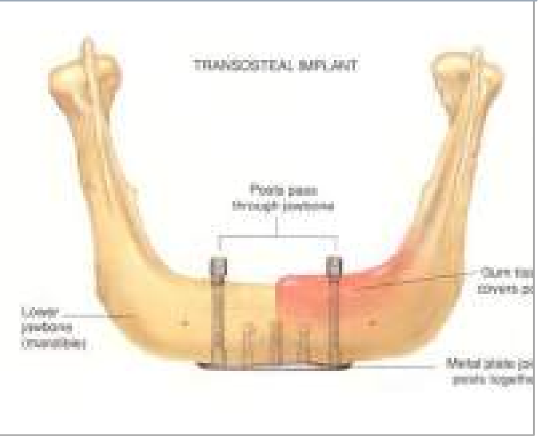
ENDOSTEAL IMPLANTS



SUBPERIOSTEAL IMPLANTS



TRANSPERIOSTEAL IMPLANTS



BASED ON
IMPLANT DESIGN

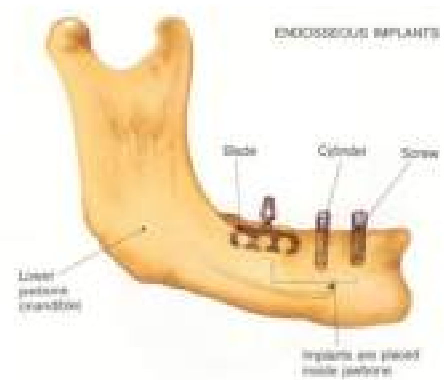
1. ENDOSTEAL IMPLANTS

Endosteal implants are placed into the alveolar and/or basal bone of the maxilla and mandible and transect only one cortical plate.

Examples are blade implants and ramus frame implants.

- All implants placed within the bone are endosteal implants.
- More than 90% of the implants placed nowadays are endosteal implants.

ENDOSTEAL IMPLANTS

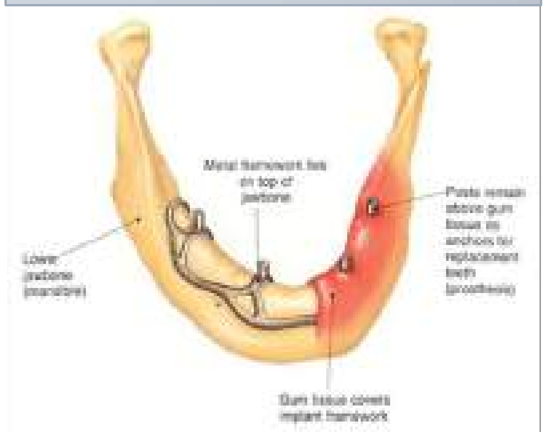


BASED ON
IMPLANT DESIGN

2. SUBPERIOSTEAL IMPLANTS

Subperiosteal implants introduced by Dahl (1940) and Berman (1951) consist of an implant substructure that is a custom cast frame placed directly over the bony cortex just below the periosteum.
The superstructure can be used to replace partially or completely edentulous jaws.

SUBPERIOSTEAL IMPLANTS



BASED ON **IMPLANT DESIGN**

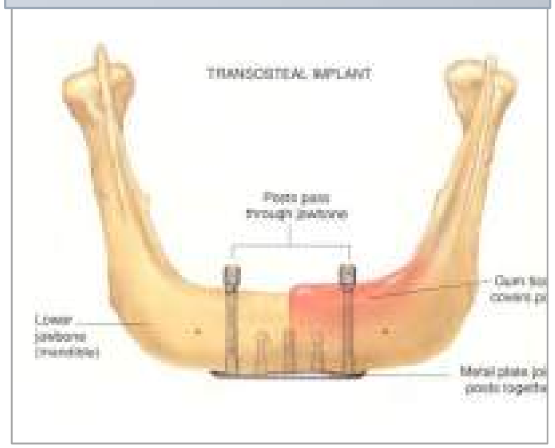
3. TRANSPERIOSTEAL IMPLANTS

Transosteal implants penetrate both cortical plates, thus combining subperiosteal and endosteal implants and passing through the full thickness of the alveolar bone.

Examples are

- Transmandibular Implant
- Staple Bone Implant
- Mandibular Staple Implant.

TRANSPERIOSTEAL IMPLANTS



BASED ON
MACROSCOPIC DESIGN

1. THREADED OR THREADLESS
2. CYLINDRICAL OR CONICAL
3. HOLLOW OR SOLID

THREADED OR THREADLESS

CYLINDRICAL OR CONICAL

HOLLOW OR SOLID

BASED ON SURFACE TREATMENTS

A. Titanium plasma sprayed (TPS)

B. Aluminum oxide coated

C. Hydroxyapatite coated

D. Machined

E. Blasted or etched with other biomaterials

F. Electropolished

IDEAL REQUIREMENTS OF **IMPLANT MATERIALS**

- ✓Must be chemically stable in tissue and oral fluids
- ✓Be non irritating
- ✓Non allergenic
- ✓Non cytotoxic
- ✓Non carcinogenic
- ✓The material should harmonies biomechanical with the physical properties of the tissues and possess bio-adhesiveness
- ✓Adequate strength and fatigue resistance to withstand complex masticatory and functional stresses
- ✓Material must be easy to fabricate, manipulate, and adopt.

MATERIALS USED IN DENTAL IMPLANTS

Materials used in dental implantology can be broadly studied under four groups namely,

1. METALS
2. CERAMICS BIO-ACTIVE (HYDROXYAPATITE, BIO-GLASS)
3. BIO-INERT (ALUMINIUM OXIDE).
4. POLYMERS AND COMPOSITES

METALS

1. TITANIUM AND ITS ALLOYS
2. IRON-CHROMIUM- NICKEL-BASED ALLOYS- STAINLESS STEEL
3. COBALT-CHROMIUM-MOLYBDENUM ALLOY

TITANIUM AND ITS ALLOYS

TYPES

1. COMMERCIALLY PURE TITANIUM (CP-TI)

2. TITANIUM-6 ALUMINUM-4 VANADIUM (TI-6AL-4VA)—GRADE 5 TITANIUM

TITANIUM AND ITS ALLOYS

COMMERCIALLY PURE TITANIUM (CP-TI)

Titanium is divided into four grades based onthe iron content; it ranges from 0.2% to 0.5% in Grade 1 (O2 [0.8%], Fe [0.2%]) through Grade 4 (O2 [0.4%], Fe [0.5%]).

MICROSTRUCTURE

1. Hexagonal close-packed (alpha phase)
2. Cubic body-centered (beta phase)

TITANIUM AND ITS ALLOYS

COMMERCIALLY PURE TITANIUM (CP-TI)

PROPERTIES

Titanium exhibits the property of PASSIVATION (rendering substance inactive or inert by chemical action) upon contact w air or tissue fluids, which minimizes biocorrosion.

It is nearly always covered by an external oxide, TITANIUM OXI (TiO_2) layer which is biologically inert, thus aiding osseointegration.

TITANIUM AND ITS ALLOYS

COMMERCIALLY PURE TITANIUM (CP-TI)

1. It has a thickness of 2–10 nm.
2. Modulus of elasticity is five times greater (104 GPa) than comp
3. Titanium is lightweight and has a density of 4.51 g/cm.
4. It has a melting point of 1668°C.

TITANIUM AND ITS ALLOYS

COMPOSITION
90% TITANIUM
6% ALUMINUM
4% VANADIUM

TITANIUM-6 ALUMINUM-4 VANADIUM (TI-6AL-4VA)—GRADE 5

Modulus of elasticity of this alloy is five to six times (113 GPa) that of compact bone.

The alloy displays passivity upon contact with air or tissue fluids and is 60% stronger than pure titanium.

However, due to corrosion and wear, titanium concentrations have been found in both peri-implant tissues and parenchymal organs.

IRON-CHROMIUM-NICKEL BASED ALLOYS: STAINLESS STEEL

COMPOSITION
70% IRON (MAIN CONSTITUENT)
18% CHROMIUM (CORROSION RESISTANCE)
8% NICKEL (STABILIZES THE AUSTENITIC STRUCTURE)

TYPES

The alloy is used in wrought and heat-treated condition which results in high strength and ductility. Passivation is required to maximize biocorrosion resistance.

IRON-CHROMIUM-NICKEL BASED ALLOYS: STAINLESS STEEL

ADVANTAGE

1. Corrosion resistance
2. Increased ductility

DISADVANTAGE

1. Vulnerable to crevice and pitting corrosion
2. Contraindicated in patients allergic to nickel

TITANIUM AND ITS ALLOYS

COMPOSITION
63% COBALT (FOUR TIMES AS STRONG AS COMPACT BONE)
50% CHROMIUM (CORROSION RESISTANCE)
5% MOLYBDENUM
TRACES OF CARBON, MANGANESE, AND NICKEL

CERAMIC

Ceramics are inorganic, nonmetallic, and nonpolymeric materials that are either

- **BIOACTIVE**
- **BIOINERT (OSTEOCONDUCTIVE).**

Ceramic implants are manufactured **by compaction and sintering** at elevated temperatures.

BIOINERT CERAMICS

Bioinert ceramics are used in various types of implants such as root form, endosteal, plate form, and pin type dental implants.

ADVANTAGES

1. Do not exhibit thermal and electrical conductivity
2. Undergo minimal biodegradation
3. Reactions with bone are favorable

BIOACTIVE CERAMICS

PHYSICAL PROPERTIES

- Specific to the surface or form of product, porosity, and crystallinity.

CHEMICAL PROPERTIES

- Related to the calcium:phosphate (Ca/P) ratio, elemental impurities, and pH of the surroundings.
- These ceramics are applied to titanium and cobalt alloy substrates by plasma spraying.
- The rationale behind plasma spraying is to provide a roughened, biologically acceptable surface for bone growth and ensure anchorage in the jaw.
- The particles are small-sized crystalline HA ceramics.
- They have an average thickness between 50 mm and 70 mm and are mixtures of amorphous and crystalline phases.

BIOACTIVE CERAMICS

ADVANTAGES

1. Minimal thermal and electrical conductivity
2. Minimal biodegradation
3. Minimal reactions with bone

DISADVANTAGES

1. Fractures can be initiated by scratches or notches present on the implant surface.
2. A decrease in strength occurs when steam sterilized.
3. Residues of the chemical solutions used are found.

BIOGLASS

MECHANISM OF ACTION

Change in pH near the bio-glass surface causes sodium, calcium, and phosphorus ions to get dissolved. Hydrogen ions in the local tissue replace the lost sodium ions in the bio-glass.

At the surface, a silica-rich gel forms because of the selective dissolution of elements.

Ca and P ions migrate to the silica gel surface, from within both bio-glass and tissue fluids, when silicon is lost

Osteoblasts proliferate, producing collagen fibrils, as sufficient concentration of phosphorus is present at the surface

Collagen fibrils develop and get incorporated in the Ca and P gel. This Ca-P gel crystallizes trapping the collagen fibrils.

BIOGLASS

This strong bonding layer has been shown to be 100–200 mm thick, roughly 100 times thicker than layers formed on HA.

ADVANTAGES

1. Chemistry similar to normal biological tissue
2. Excellent biocompatibility
3. Minimal thermal and electrical conductivity
4. Modulus of elasticity similar to bone

DISADVANTAGES

1. Low mechanical, tensile, and shear strengths under loading
2. Low attachment between coating and substrate
3. Variable solubility

POLYMER

Polymers are mainly used for manufacturing the superstructure.

They act as shock absorbers to load-bearing implants.

It was thought that their flexibility would mimic the micromovement of the periodontal ligament.

ADVANTAGES

1. Excellent biocompatibility
2. Properties can be altered to suit clinical implication
3. Have ability to control properties through composite structures

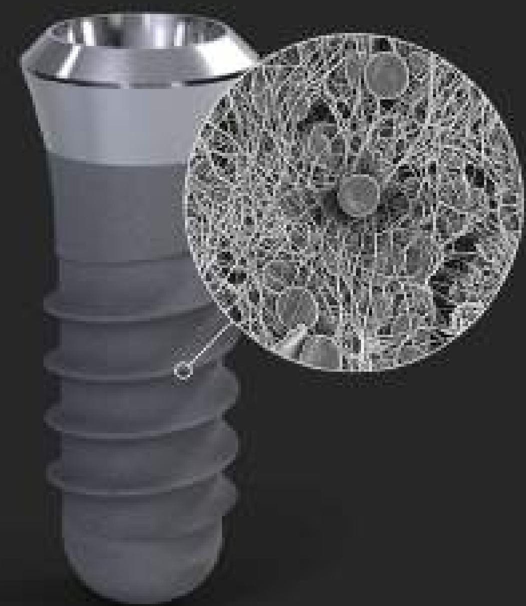
DISADVANTAGES

1. Inferior mechanical properties
2. Lack of adhesion to living tissues
3. Adverse immunological reactions
4. Cannot be sterilized by steam or ethylene oxide

Table 23-1 Mechanical Properties and Density of Metallic and Ceramic Implant Materials

Material	Grade or Condition	Yield Strength (MPa)	Elongation (%)	Modulus of Elasticity (GPa)	Tensile Strength (MPa)	Density (g/cm^3)
CP Titanium	1	170	24	102	240	4.5
	2	275	20	102	345	4.5
	3	380	18	102	450	4.5
	4	483	15	104	550	4.5
Ti-6Al-4V		860	10	113	930	4.4
Ti-6Al-4V ELI		795	10	113	860	4.4
Co-Cr-Mo	Cast	450	8	240	700	8.0
Stainless steel	Annealed	190	40	200	490	8.0
	Cold-worked	690	12	200	860	8.0
Aluminum oxide	Polycrystalline	400*(550) (flexure)	0.1	380	220	3.96
Zirconium oxide	Y_2O_3 (stabilized)	1200 (flexure)	0.1	200	350	6.0
Cortical bone		N/A	1	18	140	0.7
Dentin		N/A	0	18.3	52	2.2
Enamel		N/A	0	84	10	3.0

*ASTM Standard: Minimum Values



SURFACE CHARACTERISTICS OF IMPLANTS

The dental implant surfaces should stimulate bone growth around them upon placement.

The surface topography of an implant is variably modified with surface treatment and coatings in order to promote predictive osseointegration.

Harrison et al. (1911) demonstrated that movement, form, and arrangement of the cells of various tissues were influenced by the diffèrent surface patterns.

UNITS OF IMPORTANCE

- Sa: The Sa value represents the mean height of peaks and pits of the surface
- Sdr: Sdr is the developed surface area as compared to a perfect flat area

BIOCOMPATIBILITY OF IMPLANTS

- The concept of biomaterial biocompatibility does not refer to total inertness, but rather the ability of a material to perform with an appropriate response in a specific application.
- Biocompatibility is affected by the intrinsic nature of the material, as well as its design and construction.
- The American Dental Association outlines some acceptance provisions for dental implants, including

BIOCOMPATIBILITY OF IMPLANTS

ADA ACCEPTANCE PROVISIONS FOR DENTAL IMPLANTS

1. Evaluation of physical properties that ensure sufficient strength.
2. Demonstration of ease of fabrication and sterilization potential without material degradation.
3. Biocompatibility evaluation, including cytotoxicity testing
4. Freedom from defects
5. A minimum of two clinical trials, each with a minimum of 50 human subjects conducted for 3 years to earn provisional acceptance or 5 years to earn acceptance.

Surface characteristics of implants are classified based on the following:

1. ROUGHNESS
    a) a. Smooth: < 0.5 mm
    b) b. Rough: 0.5–3 mm
        I. Minimally rough: 0.5–1 mm
        II. Intermediately rough: 1–2 mm
        III. Rough: 2–3 mm
2. TEXTURE
    a) CONCAVE: By additive treatments like HA coating and titanium plasma spraying
    b) CONVEX: By subtractive treatments likeetching and blasting

ROUGHNESS

The roughness increases the surface area of implant adjacent to the bone and also improves cell attachment and biochemical interaction with the bone (Cooper, 2000).

There are various methods to increase surface roughness, namely,

1. Machining
2. Acid etching
3. Sandblasting
4. Sandblasting and acid etching (SLA)
5. Anodized surfaces
6. Titanium spraying
7. Porous sintering
8. Hydroxyapatite plasma spraying
9. Laser modification

ROUGHNESS

MACHINING

- Machining of the dental implant surface was the first surface modification carried out.
- It also showed very good follow-up results.
- Machined titanium has a smooth surface with Sa values less than 1 mm (0.53–0.96 mm).
- Implants with grooves on the threads are more stable than those without.
- The surface oxide consists of a 2–10 mm thick, mostly amorphous, layer of TiO2.

ROUGHNESS

ACID ETCHING

- In acid etching, the implant surface is pitted by removal from grains of the implant surface.
- Using Strong acids like
  - Hydrochloric Acid (HCl)
  - Sulfuric Acid (H2SO4)
  - Nitric Acid (HNO3)
- The roughness produced due to acid etching depends on
  - The Acid
  - Immersion Time Of The Implant In The Acid
  - The Bulk Of Material
  - Surface Microstructure.
- Acid etching results in a minimally rough surface with Sa values in the range of 0.3–1 mm.
- The resulting surface produced by acid etching is an amorphous titanium oxide layer about 10 mm thick.

ROUGHNESS

ACID ETCHING

- Acid etching results in a minimally rough surface with Sa values in the range of 0.3–1 mm.
- The resulting surface produced by acid etching is an Amorphous Titanium Oxide Layer about 10 mm thick.
- Etching roughens the machined surface with the Goal Of Improving Osseointegration.

ADVANTAGES

Increased attraction of osteoblasts to the implant surface occurs due to a microscopic increase in the surface area. This results in an increased mechanical interlocking of bone and implant.

ROUGHNESS

SANDBLASTING

- This is done by blasting the surface with small particles of aluminum trioxide and titanium dioxide.
- This allows adhesion, proliferation, and differentiation of osteoblasts.
- The roughness is due to a crater formation as the blasted particles hit the surface of the implant.
- Sa values are 0.5–2 mm

ROUGHNESS

SANDBLASTING AND ACID ETCHING (SLA)

- Most of the commercially available dental implants are usually first sandblasted and then etched with acids.
- As a result, improved surface roughness as well as removal of the embedded blasting particles occurs.
- Sa values for blasted and acid-etched implants are 1–2 mm.

Improved hydrophilicity of the implant surface (SLActive) results due to minimal carbon contamination, which is removed by nitrogen rinsing.

Advantages of SLActive implants

Healing, osseointegration, and stability of implants are achieved in 6 weeks with SLActive as against the usual 12 weeks.

ROUGHNESS

ANODIZATION

Anodization or anodic oxidation of a titanium implant surface results in a partial crystalline and phosphate-enriched micro-structured surface.

This results in improved bone ingrowth due to mechanical interlocking.

ADVANTAGES

1. Higher clinical success rate.
2. Bone–implant contact ratio is high.
3. Removal torque values are higher.

ROUGHNESS

TITANIUM SPRAYING

The titanium plasma-sprayed (TPS) screw implant (Institute Straumann AG, Waldenburg, Switzerland) is a self-tapping titanium screw with a titanium plasma-flame–sprayed surface.

There is a six-fold increase in the surface area of the implant–bone interface, thereby improving retention.

ROUGHNESS

.POROUS SINTERING

Porous sintering of the implant surface refers to incorporation of porosity on the implant by sintering of the metal powder.

The pores give an **increased retention** due **to increased in growth of surrounding bone into the pores.**

Recently, laser-sintered metals have been developed to improve long-term performance..

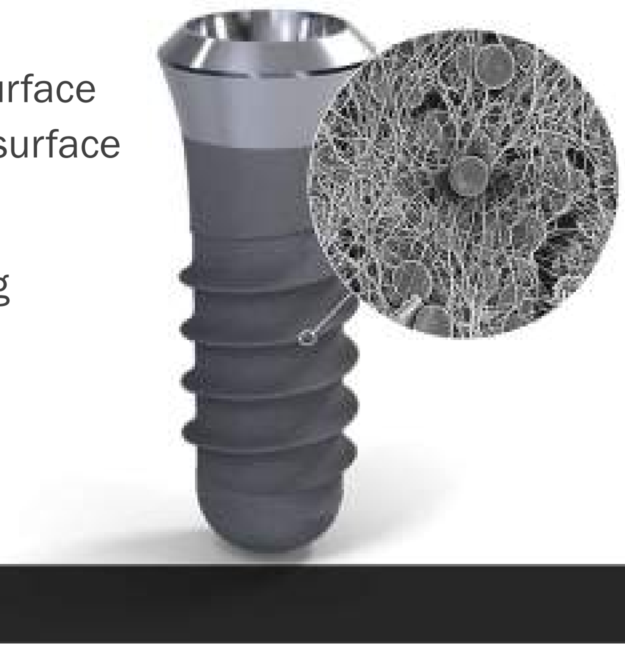
ROUGHNESS

.HYDROXYAPATITE PLASMA SPRAYING

It is the most frequently used method for deposition of calcium phosphate coatings like HA on the implants. *This is done to improve the bioactivity.*

The thickness of the coatings produced ranges from 100 to 300 mm. Surface area of the implant increases up to approximately six times the original surface area.

The arithmetic average roughness (Ra) for HA coated by plasma spraying process is 5.0 ± 1 mm.



ROUGHNESS

.HYDROXYAPATITE PLASMA SPRAYING

ADVANTAGE

There is a higher percentage of bone–implant contact in HA-coated implants than in conventional titanium implants.

DISADVANTAGES

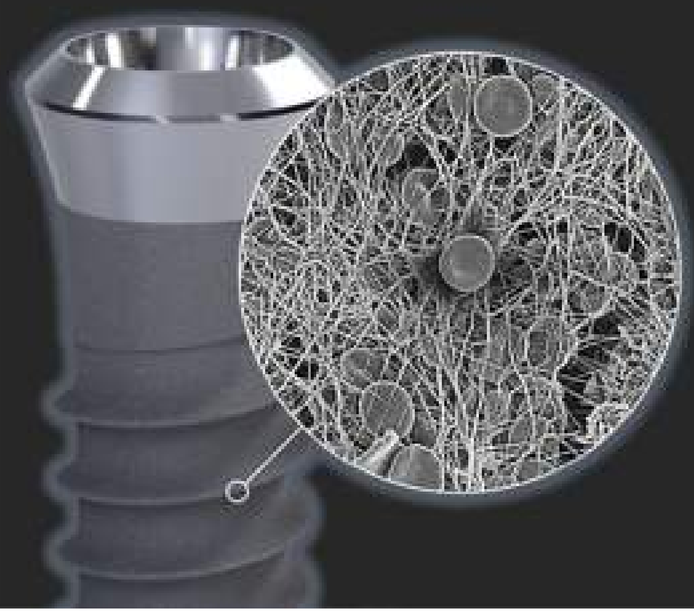
1. Possibility of microbial infection leading to implant failure.

2. Crystallinity and composition of the coating are not uniform.

3. Thickness of the HA layer is not uniform.

4. Long-term adherence of the HA coating to the implant material is poor.

OTHER METHODS OF CALCIUM PHOSPHATE DEPOSITION



1. SPUTTER DEPOSITION
2. BIOMIMETIC PRECIPITATION
3. BIOACTIVE GLASS COATINGS

OTHER METHODS OF CALCIUM PHOSPHATE DEPOSITION

SPUTTER DEPOSITION

It involves deposition of bio-ceramic thin films (based on Ca-P systems).

ADVANTAGES

- Improves adhesion between the substrate and the coating.
- Higher removal torque when compared to uncoated titanium implants.

DISADVANTAGE

- Time consuming.

OTHER METHODS OF CALCIUM PHOSPHATE DEPOSITION

BIOMIMETIC PRECIPITATION

- Calcium phosphate is biomimetically precipitated onto the surfaces of implant materials to **promote early ingrowth of bone into the porous surfaces.**
- Rough and porous calcium-deficient HA in the **Ca/P ratio of 1.51** is grown on the implant surface.
- A **20–25 *mm*** thick layer of HA coating is produced.

ADVANTAGES

1. Facilitates early bone ingrowth into porous surfaces.
2. Failure due to debris coating, macrophage infiltration, and fibrous tissue encapsulation does not occur as with the plasma-sprayed HA coatings.

ULTRASTRUCTURAL CHARACTERIZATION OF BONE–IMPLANT

Ultrastructural characterization of bone–implant interface is especially important with the emerging nanostructured implant surfaces:

1. **SMOOTH IMPLANT SURFACE:** Between the smooth implant surface and the surrounding bone, there is a zone of collagen fi brils that is poorly mineralized. T is appears as an electron lucent layer of 20–50 nm.
2. **ROUGHENED IMPLANT SURFACE:** Implant surfacesroughened by acid etching also show an electron dense layer between the implant and the surrounding bone.

When analyzed, bioactive implant surface shows formation of an apatite layer between the collagenous bone and surface of the implant.