OSSEOINTEGRATION

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- Material consideration
- Implant surface configuration
- Surface coatings
- Factors influencing bone-implant interface
- Failure of osseointegration
- Summary
- Conclusion

INTRODUCTION

- The discovery of osseointegration and it's application in clinical dentistry is one of the most significant development in dentistry. It has broadened our options for treatment of partially and fully edentulous arches. The science behind osseointegration has evolved over the past three decades both in laboratory and clinical environment as a result of extensive multidisciplinary cooperation.

- After placing of implants in the jaw bone it is retained by a process of osseointegration , which is a direct bone to implant union .
- This union is carried out in series of events which comprises bone healing , tissue seal and others.

- Different types of material are present to be used as implants such as metal and its alloys , ceramics and carbon , polymers and composites. Each material has its own way of integrating with the biomolecules .
- Success of this union depends on various factors which include operative , systemic condition, etc .

- Today the possibility of osseointegration has been proven beyond any doubt. Since it truly gives the option of replacing the lost tooth ,it’s popularity is obvious. Research is still going on for better materials and techniques.

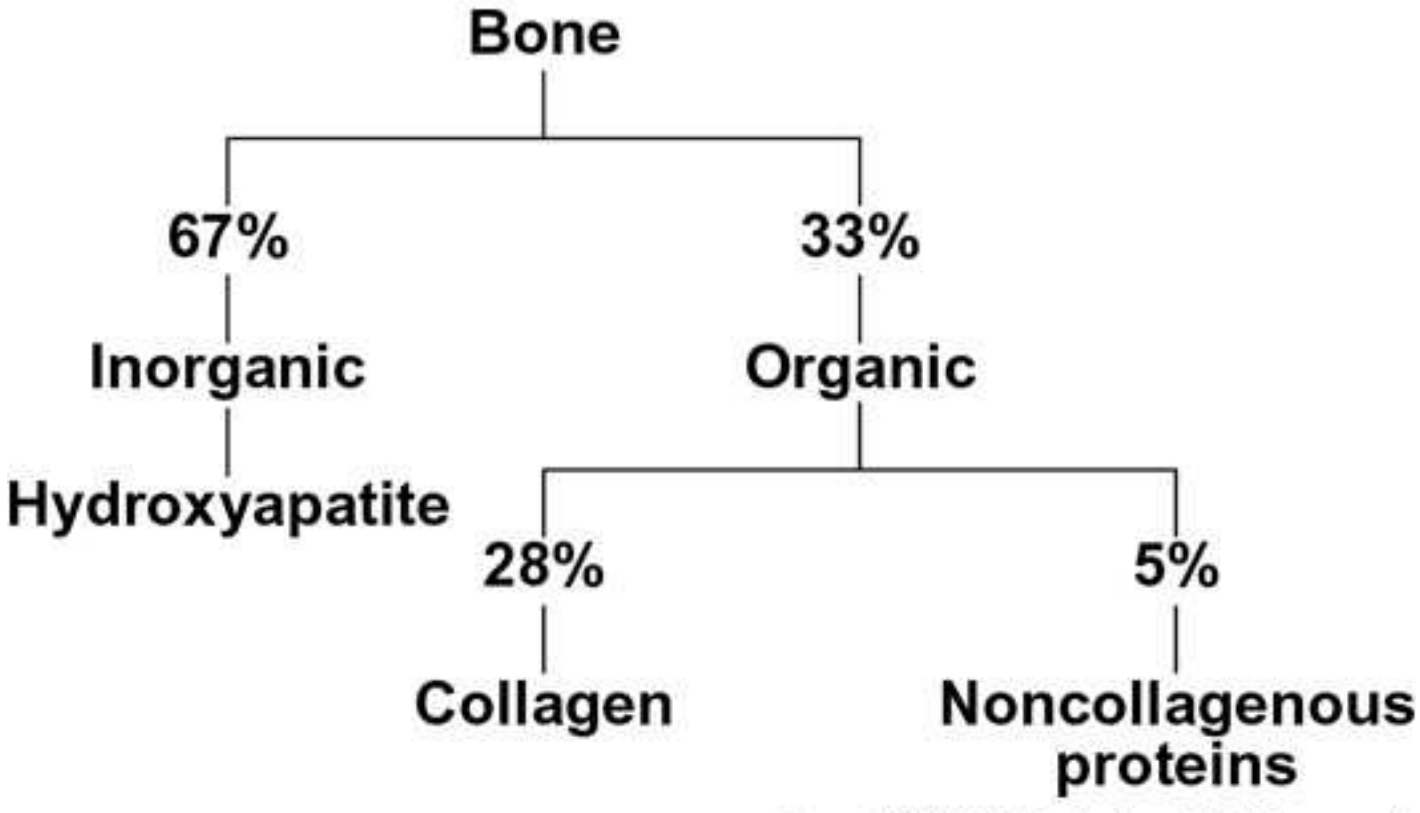
Definition

- **Acc to GPT - osseous integration** (1993) **1:** the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening 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

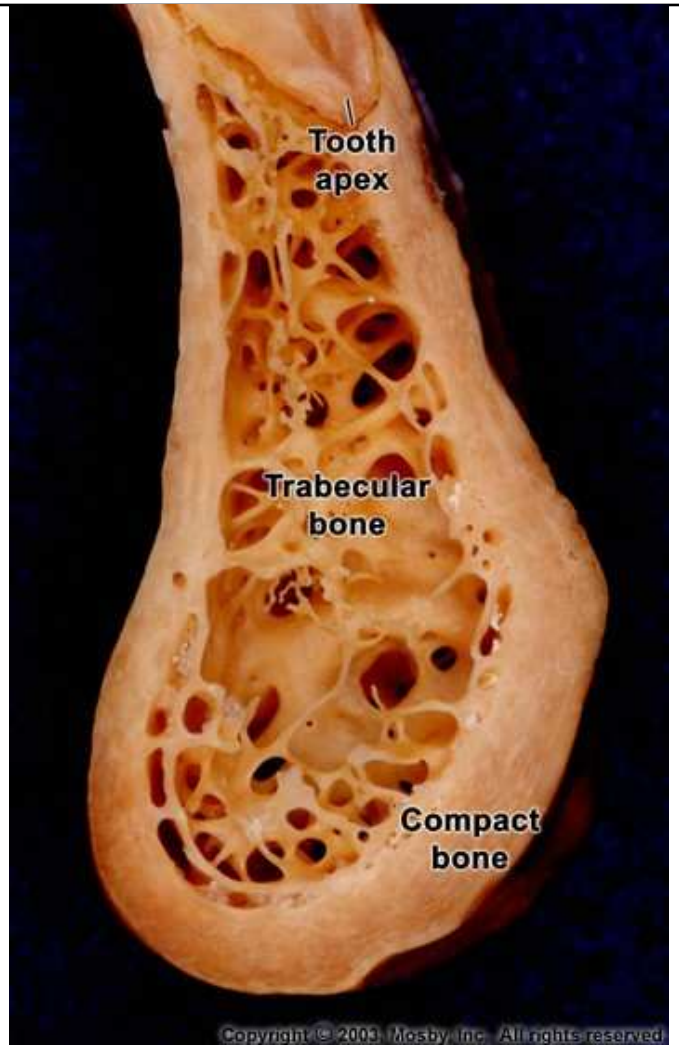
- **Fibrous integration :** a misnomer used to describe the presence of a layer of intervening fibrous connective tissue between a dental implant and the adjacent bone, while no real attachment or integration has occurred between bone and a biocompatible material

- **AAID** : tissue to implant contact with healthy dense collagenous tissue made of well organized collagen fibres, present between bone and implant

BONE PHYSIOLOGY



- Bone can be classified as
- Compact bone
- Spongy bone


Tooth
apex
Trabecular
bone
Compact
bone
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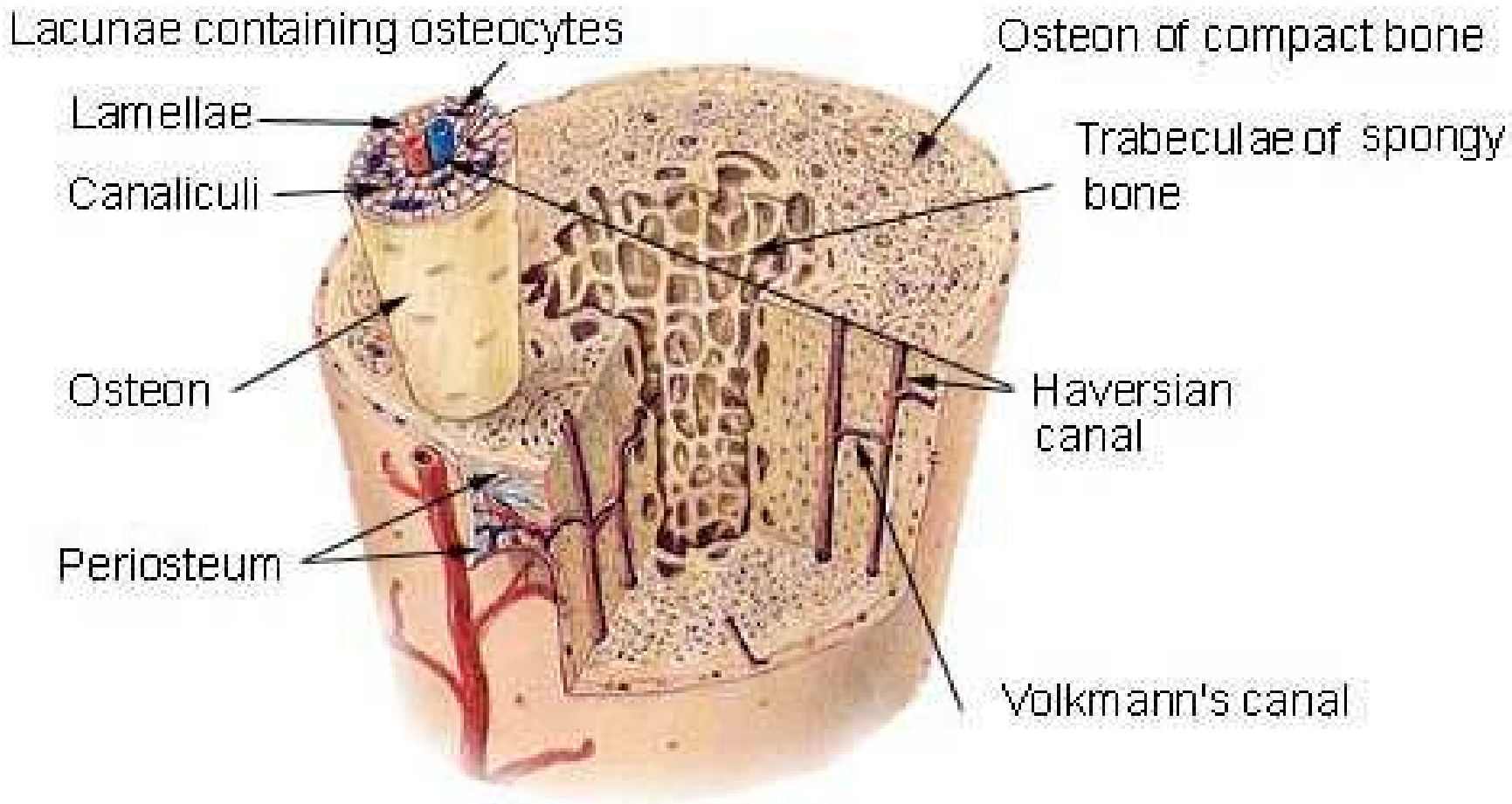
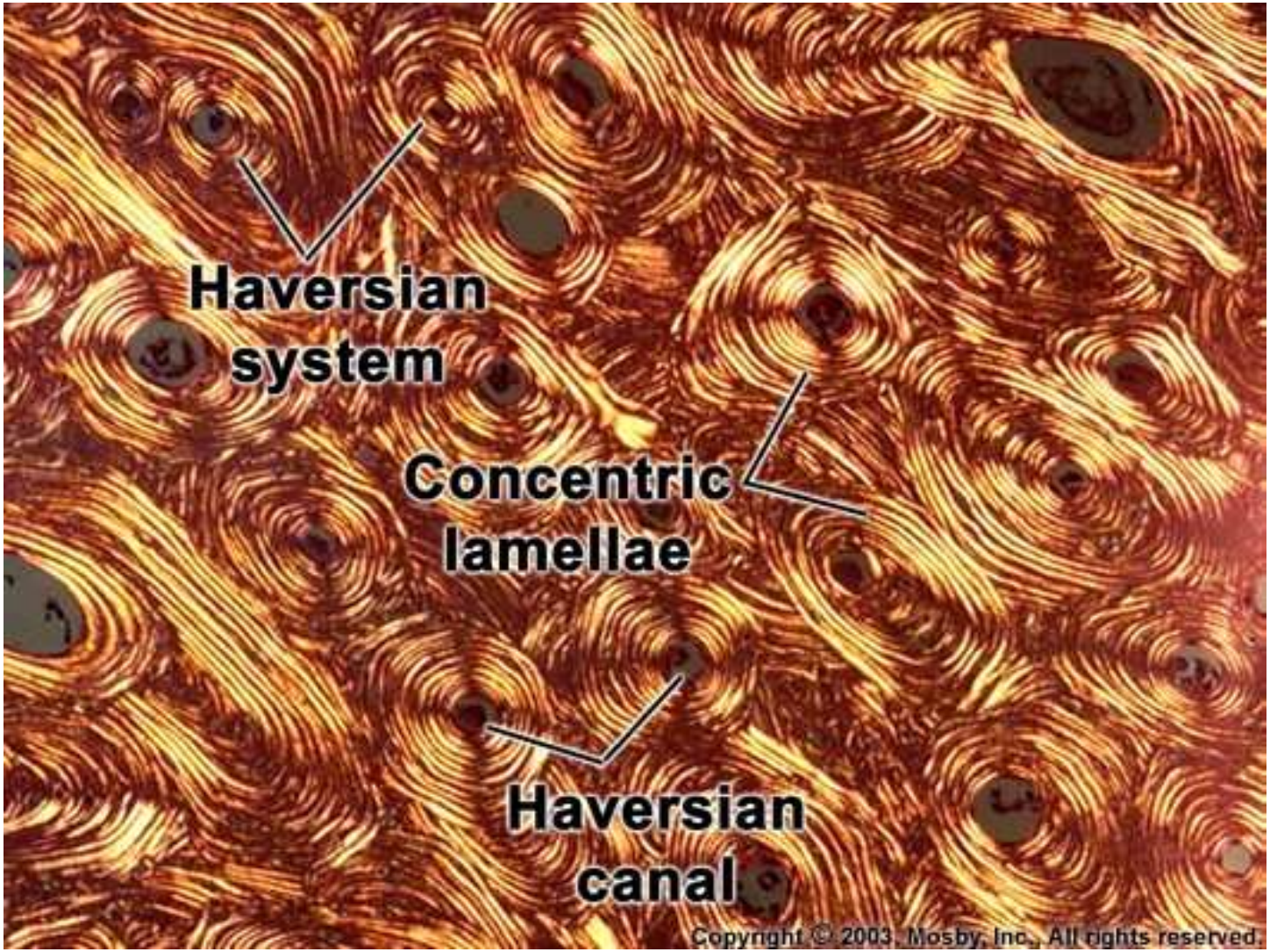
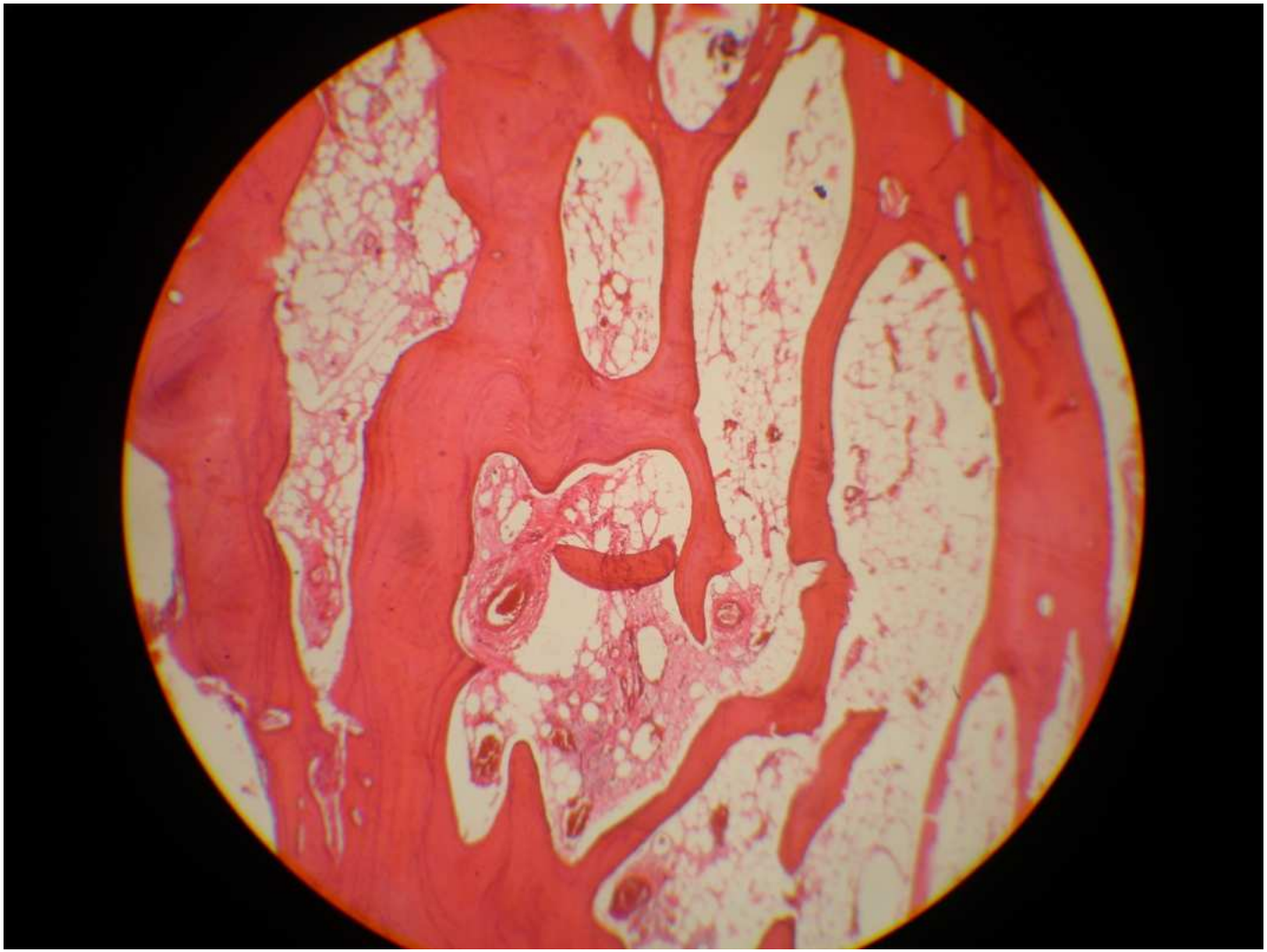
Compact Bone & Spongy (Cancellous Bone)



Compact bone



Spongy bone (trabecular bone)

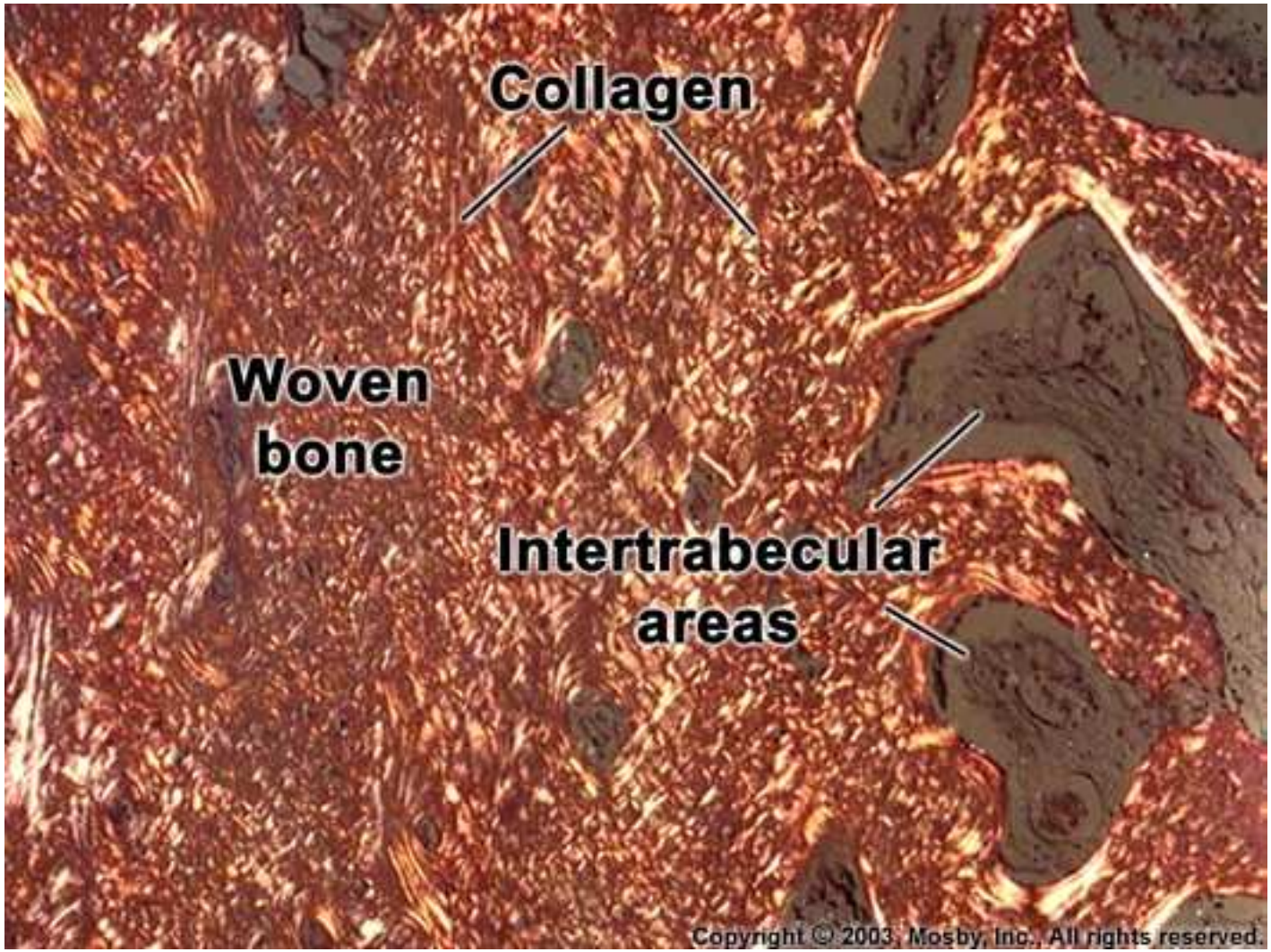


- Depending on age, developmental age, localization and function, bone consists of three tissue types that differ in collagen fibril arrangement and mineral content.
- ***Woven bone***
- ***Lamellar bone***
- ***Bundle bone***

Woven bone

- Formed by the osteoprogenitor cells in the vicinity of blood vessels during prenatal development ,growth and healing .
- Forms 30-50 µm /day
- High cellular osseous tissue
- Low mineral content
- More pliable than mature lamellar bone , it is more forgiving of the relative micromotion associated with interface healing
- Capable of stabilizing an unloaded implant , woven bone lacks the strength to resist functional loads .

Woven bone


Collagen
Woven bone
Intertrabecular areas
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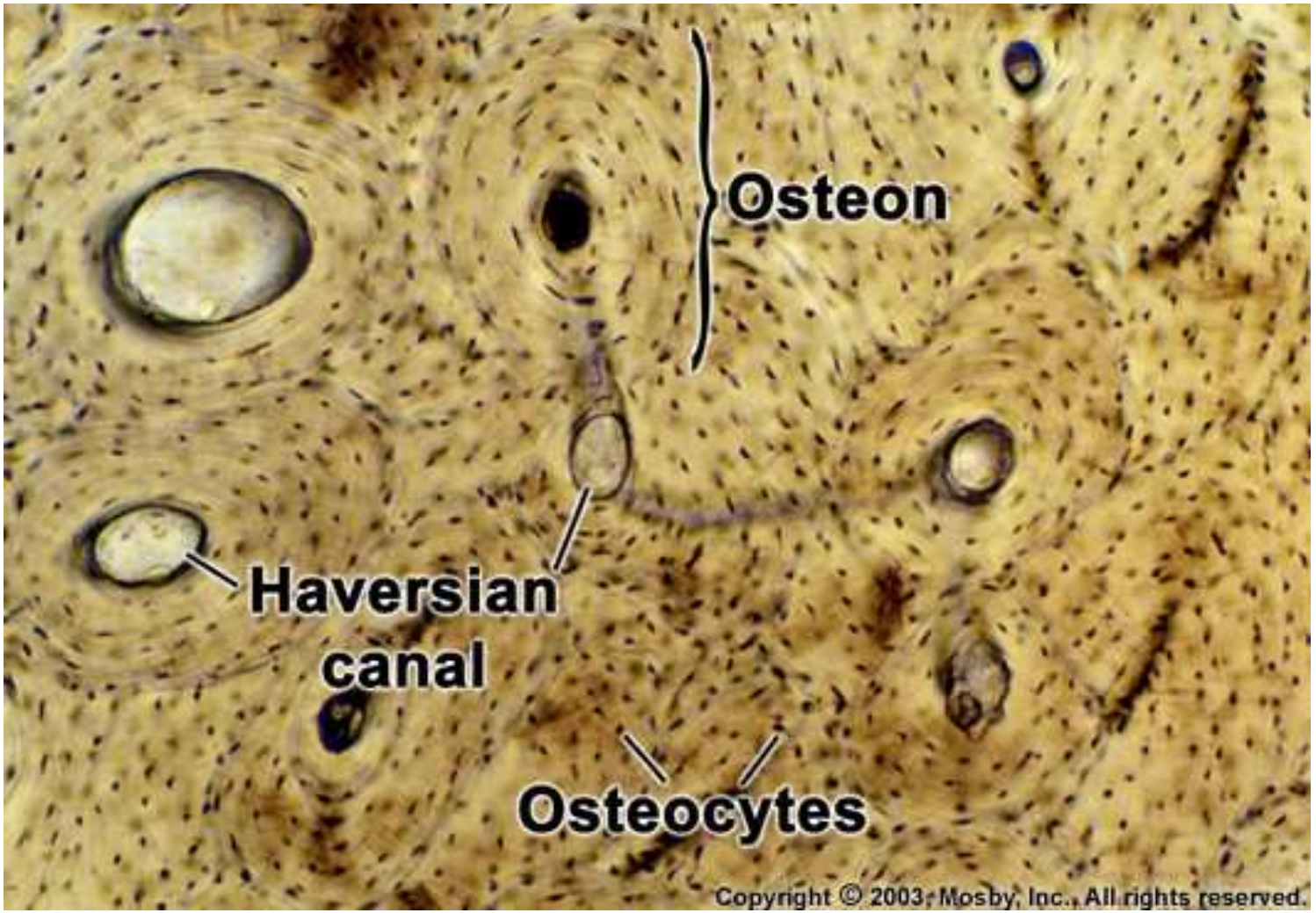
Lamellar bone tissue

- Principle load-bearing tissue
- Predominant component of mature cortical and trabecular bone
- Forms relatively slow (< 1.0μm/day)
- Have highly organized matrix, and are densely mineralized
- Orientation of the collagen fibrils differs from one layer to another .

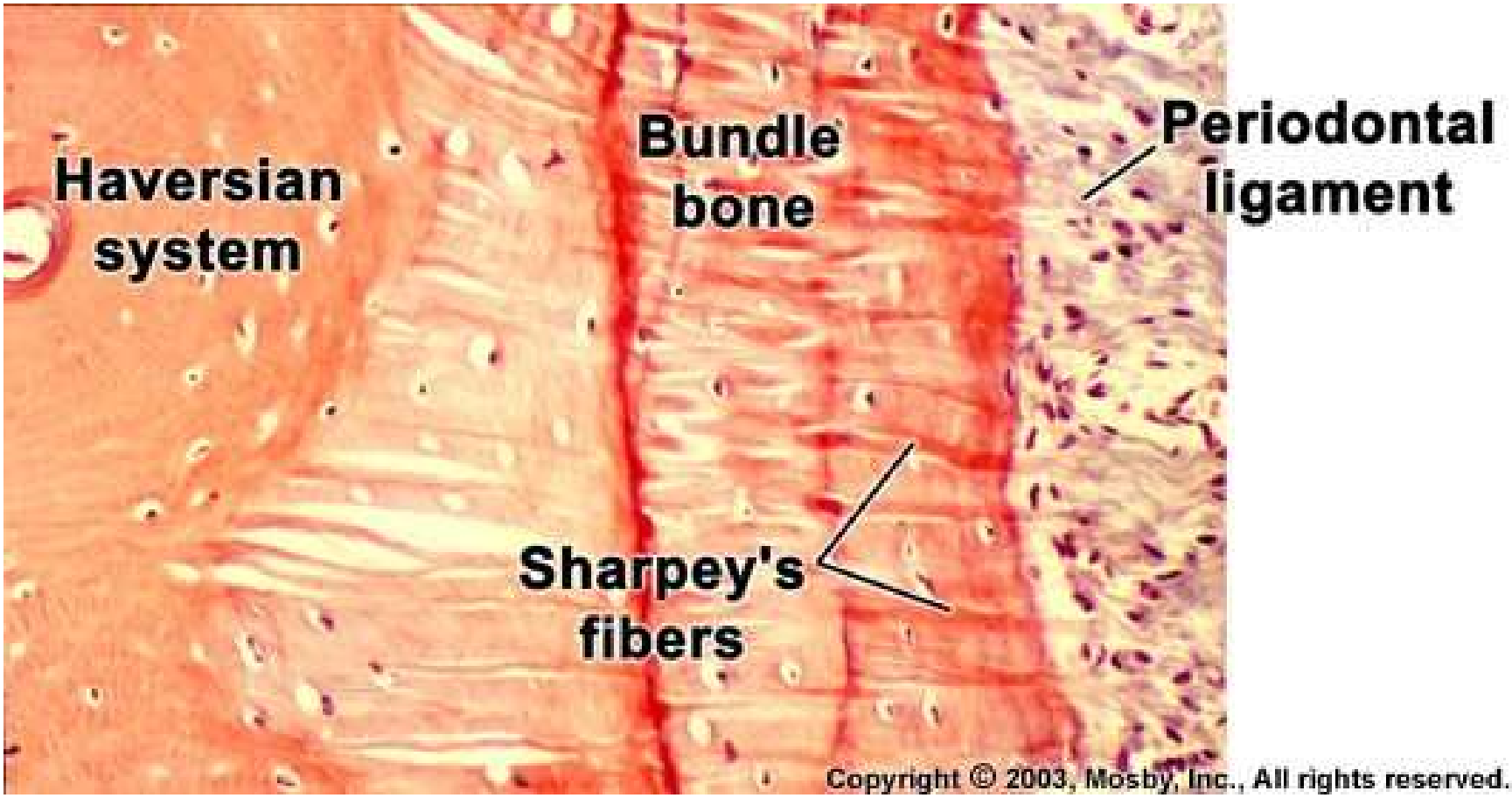
Lamellar bone



Bundle bone

- Found in the area of ligament and tendon attachment along the bone-forming surfaces.
- Striation are extension of sharpey’s fibers composed of collagen bundles from adjacent connective tissue that insert directly into the bone
- It is formed adjacent to the periodontal ligament of physiologically drifting teeth.

Bundle bone


Haversian system
Bundle bone
Periodontal ligament
Sharpey's fibers
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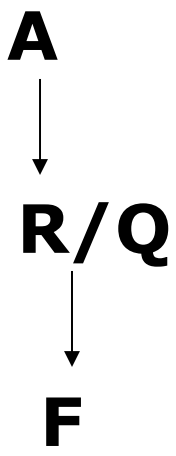
Modelling

- A surface specific activity that produces a net change in the size and/or shape of bone .
- An uncoupled process, meaning that cell activation(A) proceeds independently to formation(F) or resorption(R)
- Generalized change in overall dimension of a bone’s cortex or spongiosa
- Modelling is a fundamental mechanism of growth , atrophy and reorientation.

Bone Remodeling

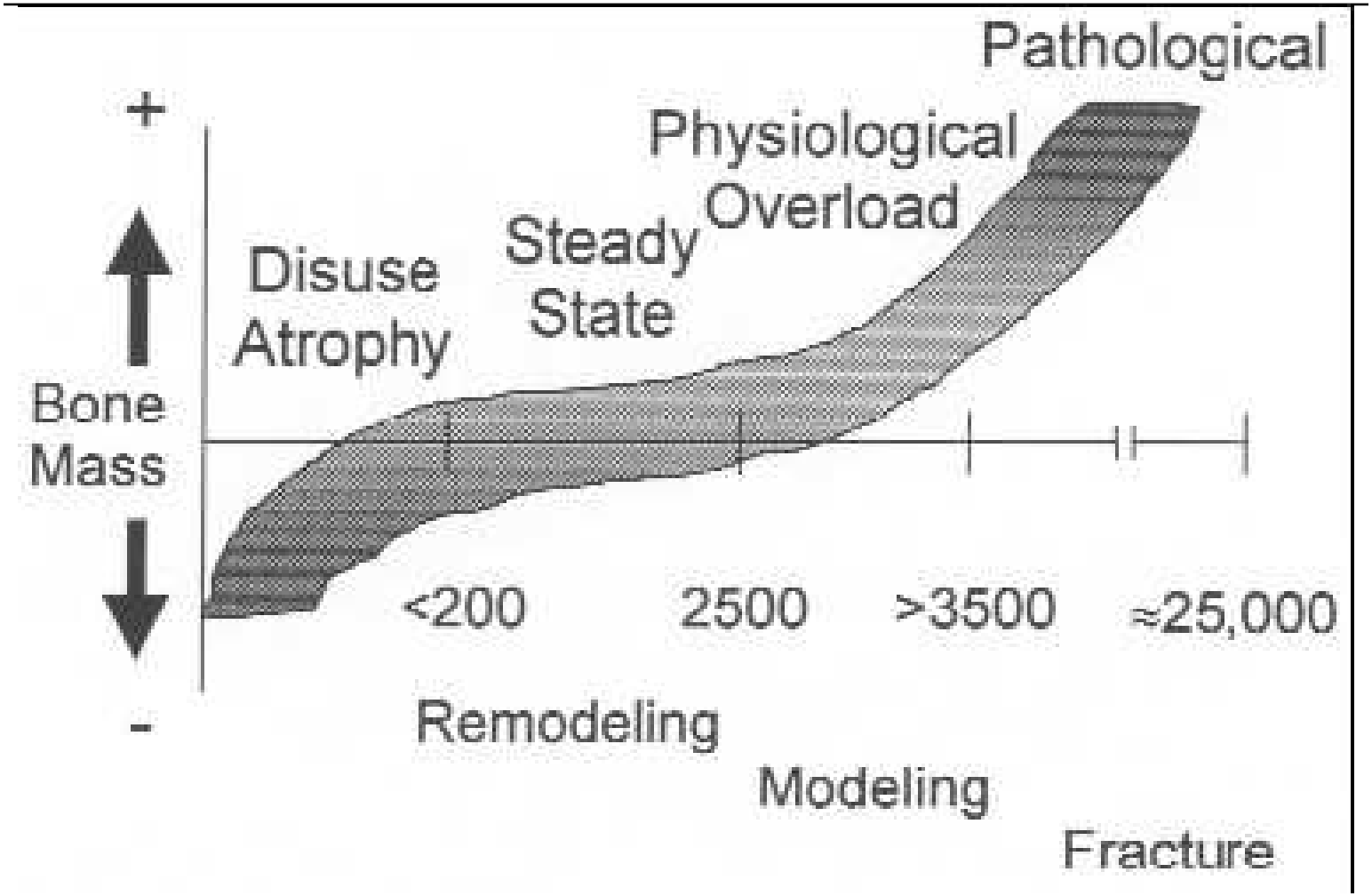
- It is the turnover or internal restructuring of previously existing bone .
- Coupled tissue level phenomenon



- Remodelling cycle = 17 weeks in humans
- Remodelling includes :

1. Localized changes in individual osteons or trabeculae
2. Turnover, hypertrophy,atrophy or reorientation .

Frost's mechanostat theory.



- Occlusal forces stimulates remodeling .
- It causes differentiate of bone cells to osteoclast; while the same stimulus causes osteoprogenitor cell to differentiated to osteoblast involved in bone formation
- Osteoblastic activity in adults and aged will be normally in quiescence

- Osteoblast will be activated by drilling procedure in this type of patients. The activated osteoblast produces protein for collagen formation which is a step of bone formation

The factors affecting remodeling are

- Proper local stimulation
- Thyroid hormone level
- Calcitonin
- Vit D level

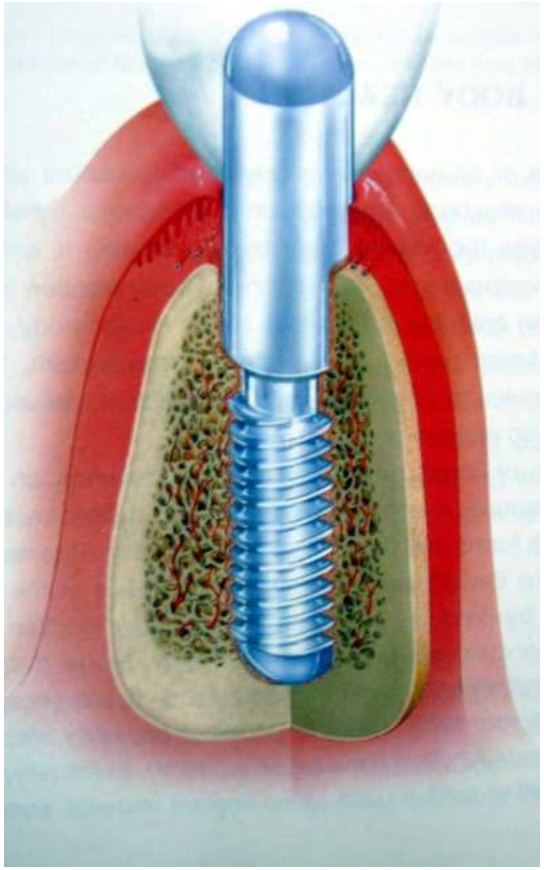
Bone to implant interface

There are two basic theories

- Fibro-osseous integration
- osseointegration

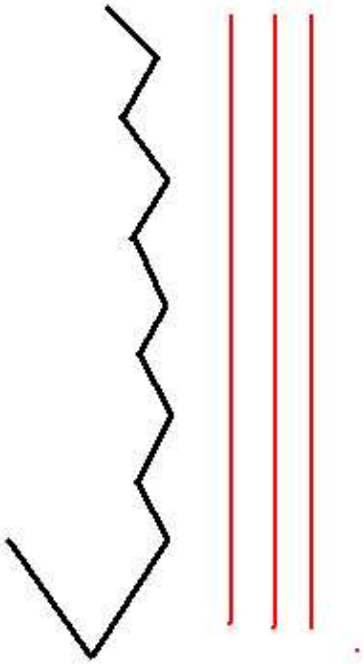
Fibro-osseous integration

- Fibrous integration refers to connective tissue made of well organized collagen fibers, present between the bone and implant.

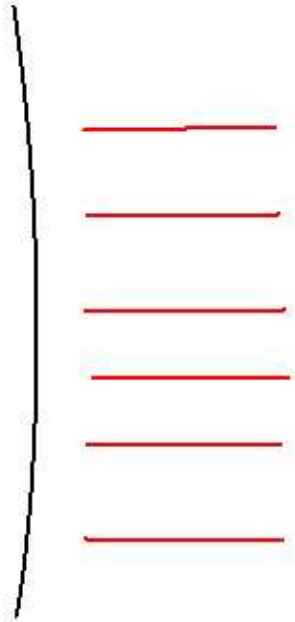


- In this theory collagen fibers work similar to sharpey’s fibers. They are proposed to affect bone remodeling at areas of tension in a manner similar to periodontal ligament.

- Weiss believes that these fibers invest the implant , originating from cancellous bone of one side weaving around the implant & inserting into bone of other side.
- However there are drawbacks to this theory.
- Firstly unlike sharpey’s fibers the collagen fiber around implant are arranged irregularly parallel to the implant body.



IMPLANT



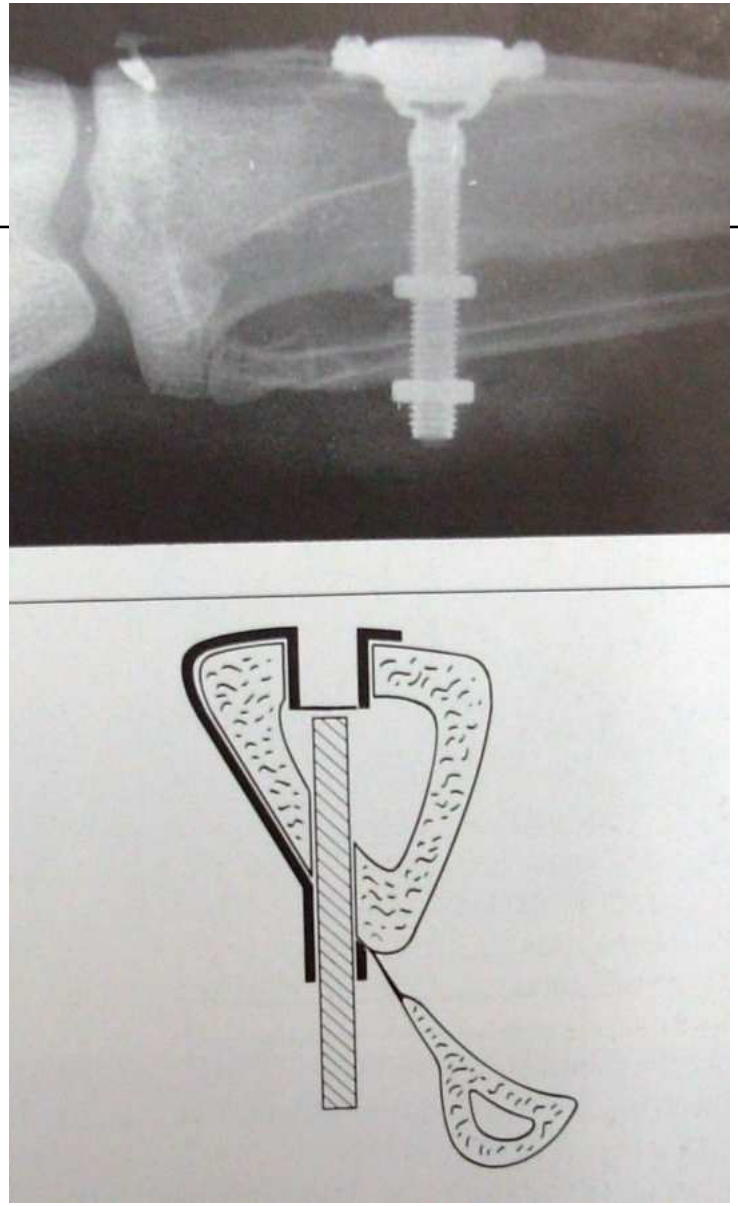
TOOTH

- When forces are applied they are not transmitted through the fibers as in natural dentition nor do they bring about bone remodeling as was thought earlier.

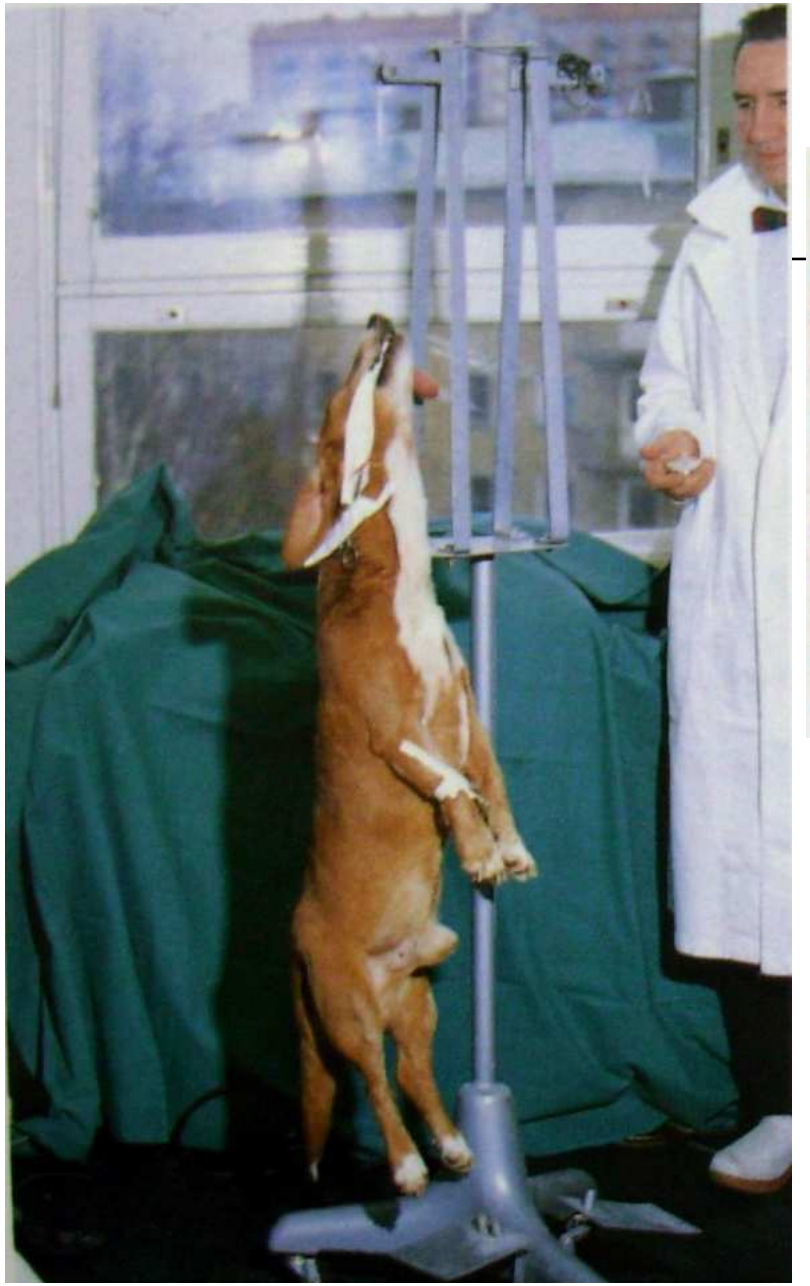
Osseointegration

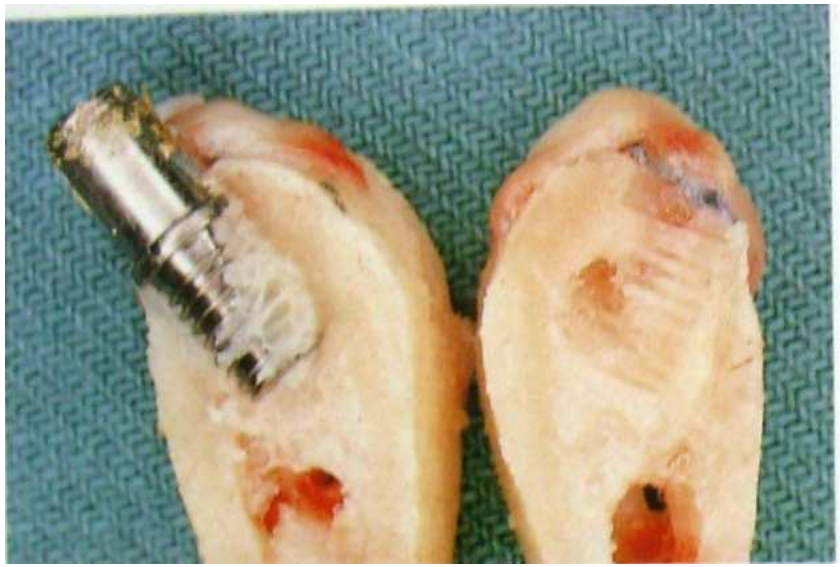
- the apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening connective tissue

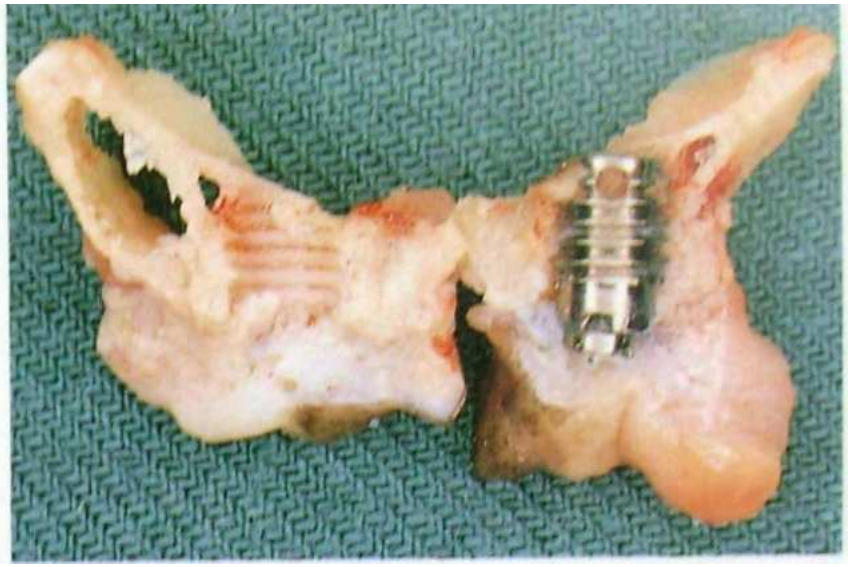
- The theory developed as a result of series of experiments carried out by branemark and his collegues. These Studies began on bone marrow of rabbit fibula in order to study the nature of marrow in a living bone.



- Another series was carried out to assess bone response to various types of injuries.
- Then in 1960s microscopic study of bone marrow using implanted titanium chambers began.
- It was found that at the end of experiment the chambers had completely integrated into the bone and had to be cut out.







Mechanism of osseointegration

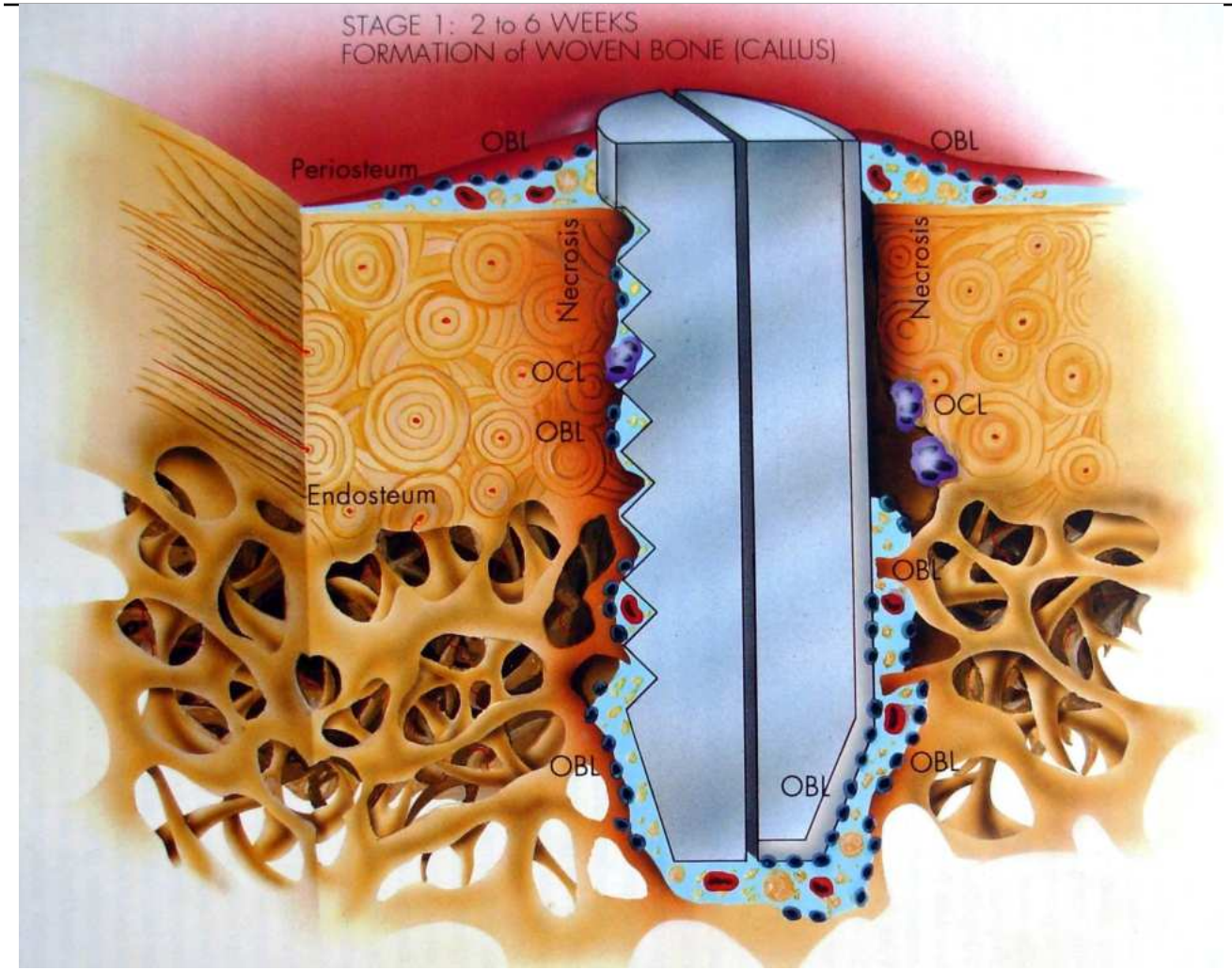
- The healing process in implants is similar to healing in a normal bone. It can occur as primary or secondary healing

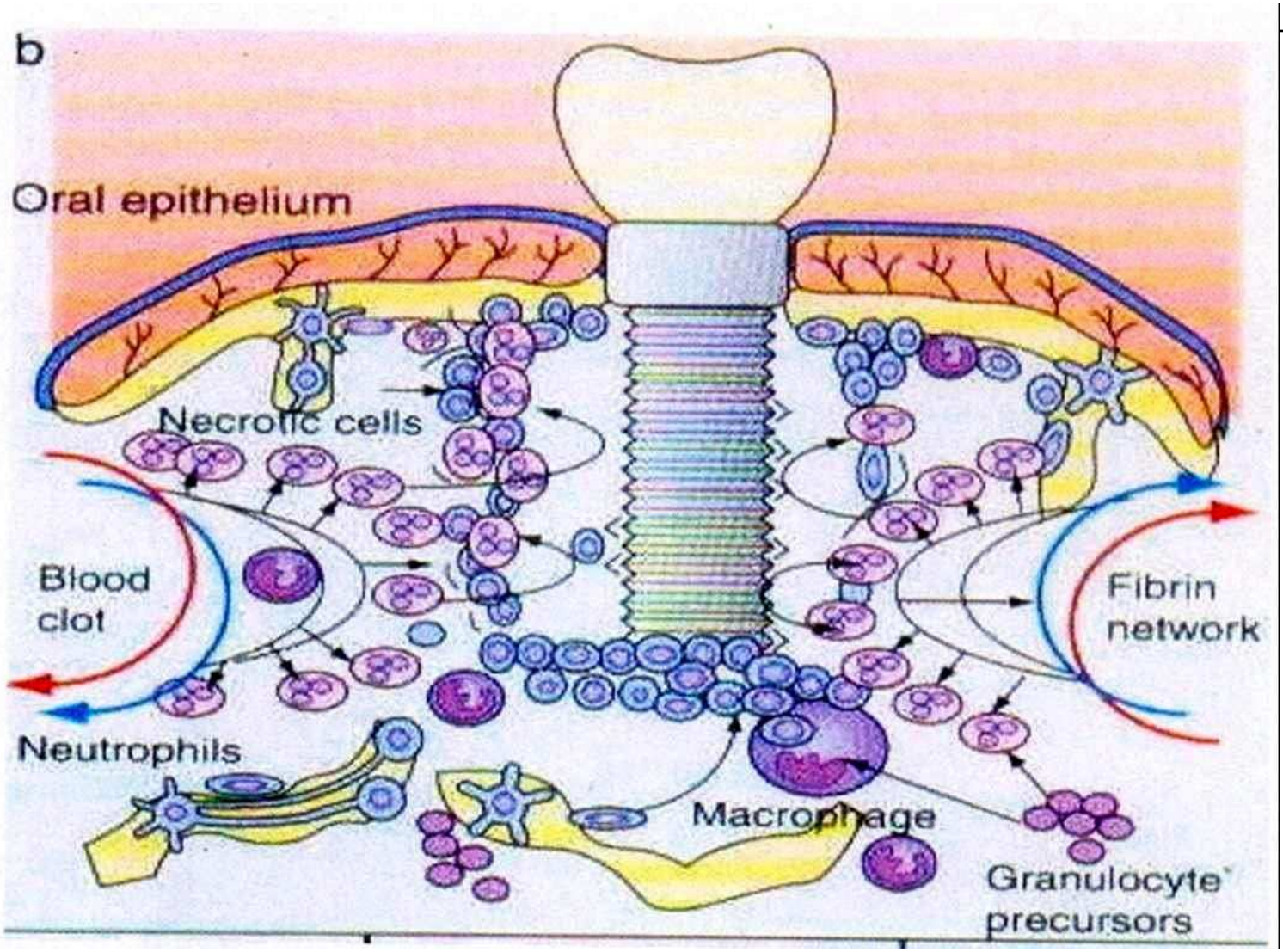
- Primary bone healing occurs at the fracture site with a clean break. The sites are positioned by pressed fixation or closely approximated.
- In this type of healing there is a well-organized bone formation with minimal granulation tissue formation. When implants are considered this type of healing is ideal.

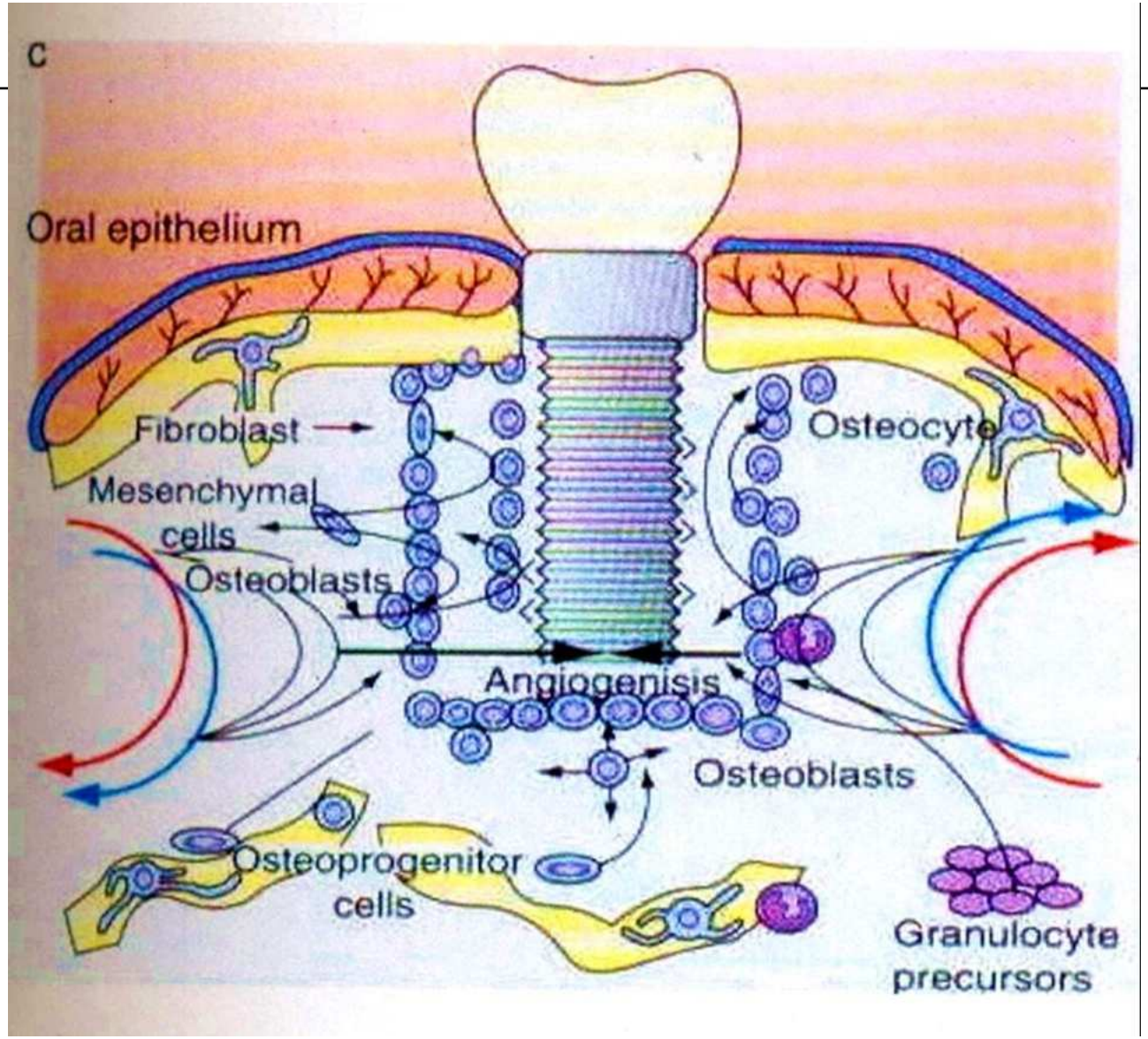
- Hence to duplicate this healing process, the surgery should be performed on healthy bone, free from infection or necrotic tissue

- Secondary healing occurs when a large defect or large fracture site precludes close approximation of the two sites.
- This type of healing is prolonged due to infection and granulation tissue formation.
- This type of healing may result in fibrous tissue formation, which is undesirable in case of implants

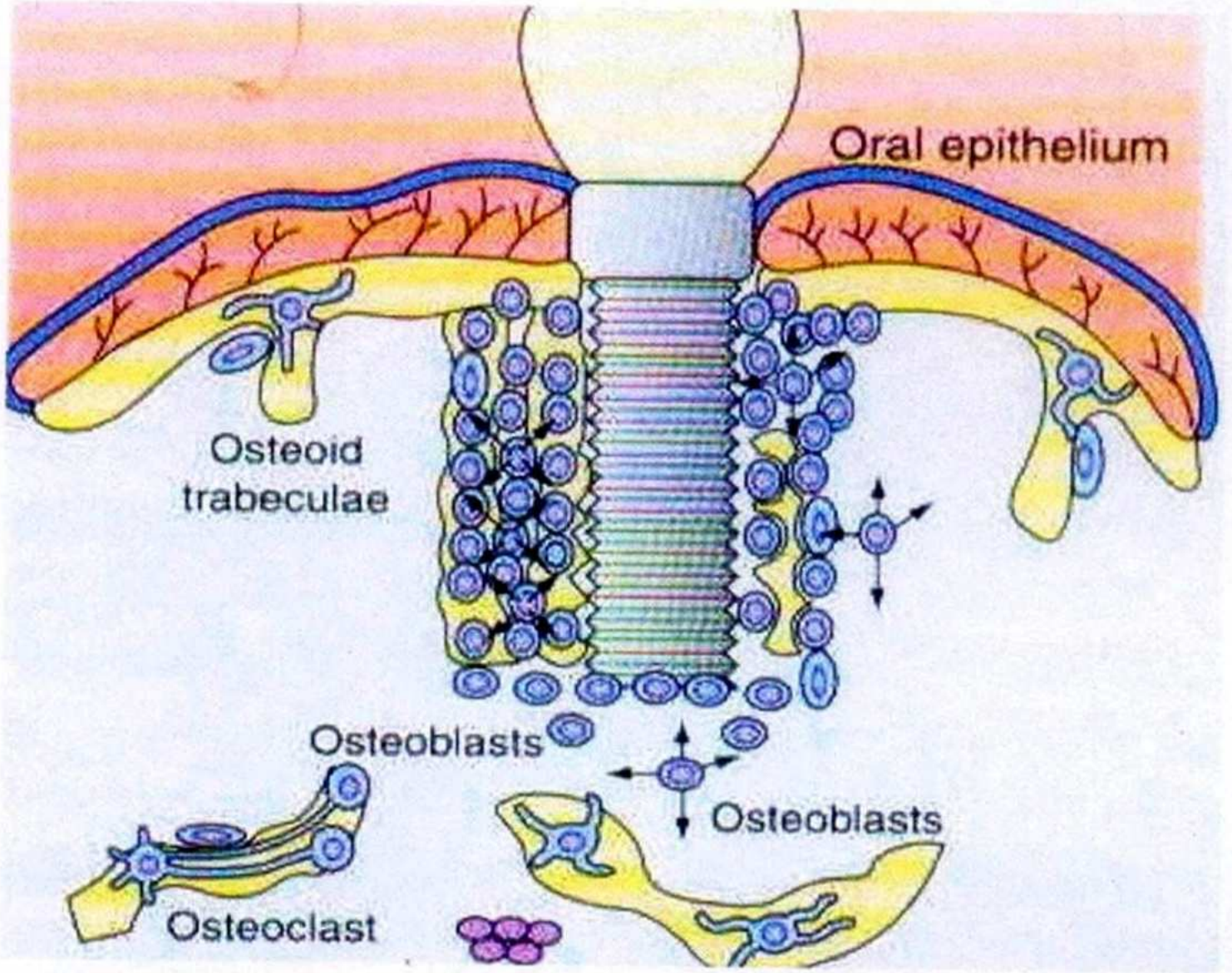
Healing

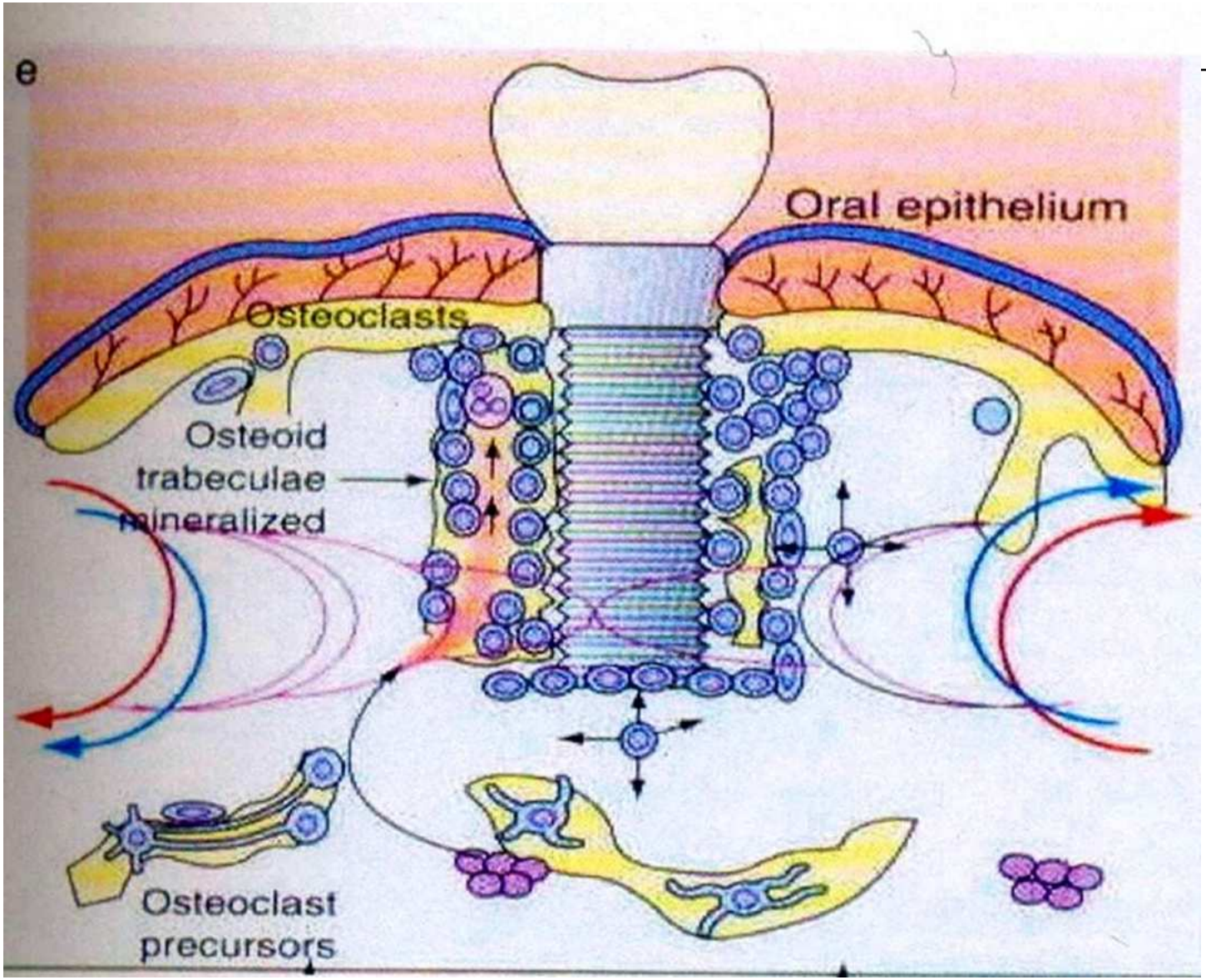

STAGE 1: 2 to 6 WEEKS
FORMATION of WOVEN BONE (CALLUS)
Periosteum
OBL
OBL
Necrosis
Necrosis
OCL
OCL
OBL
Endosteum
OBL
OBL
OBL
OBL

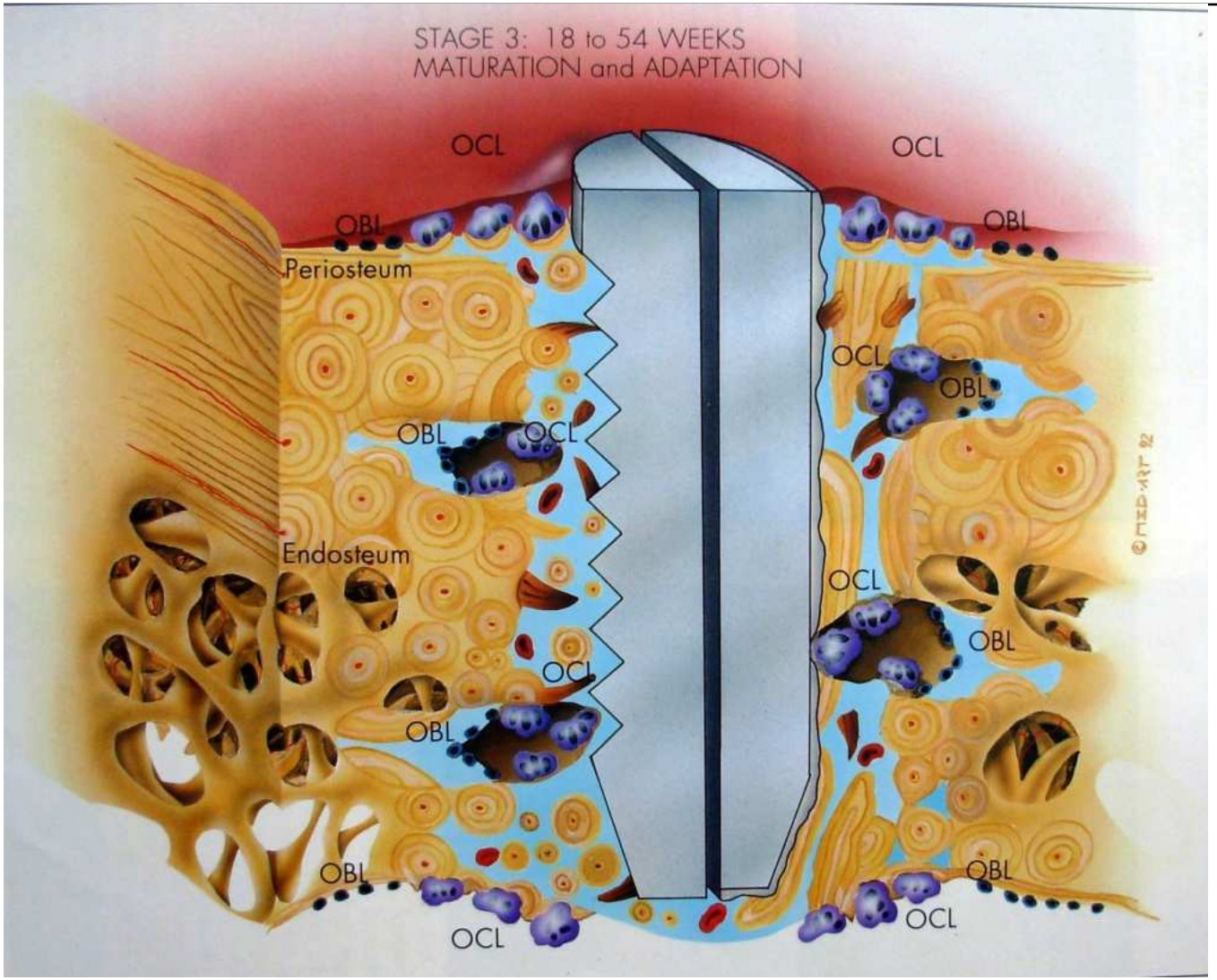

b
Oral epithelium
Necrotic cells
Blood clot
Fibrin network
Neutrophils
Macrophage
Granulocyte precursors

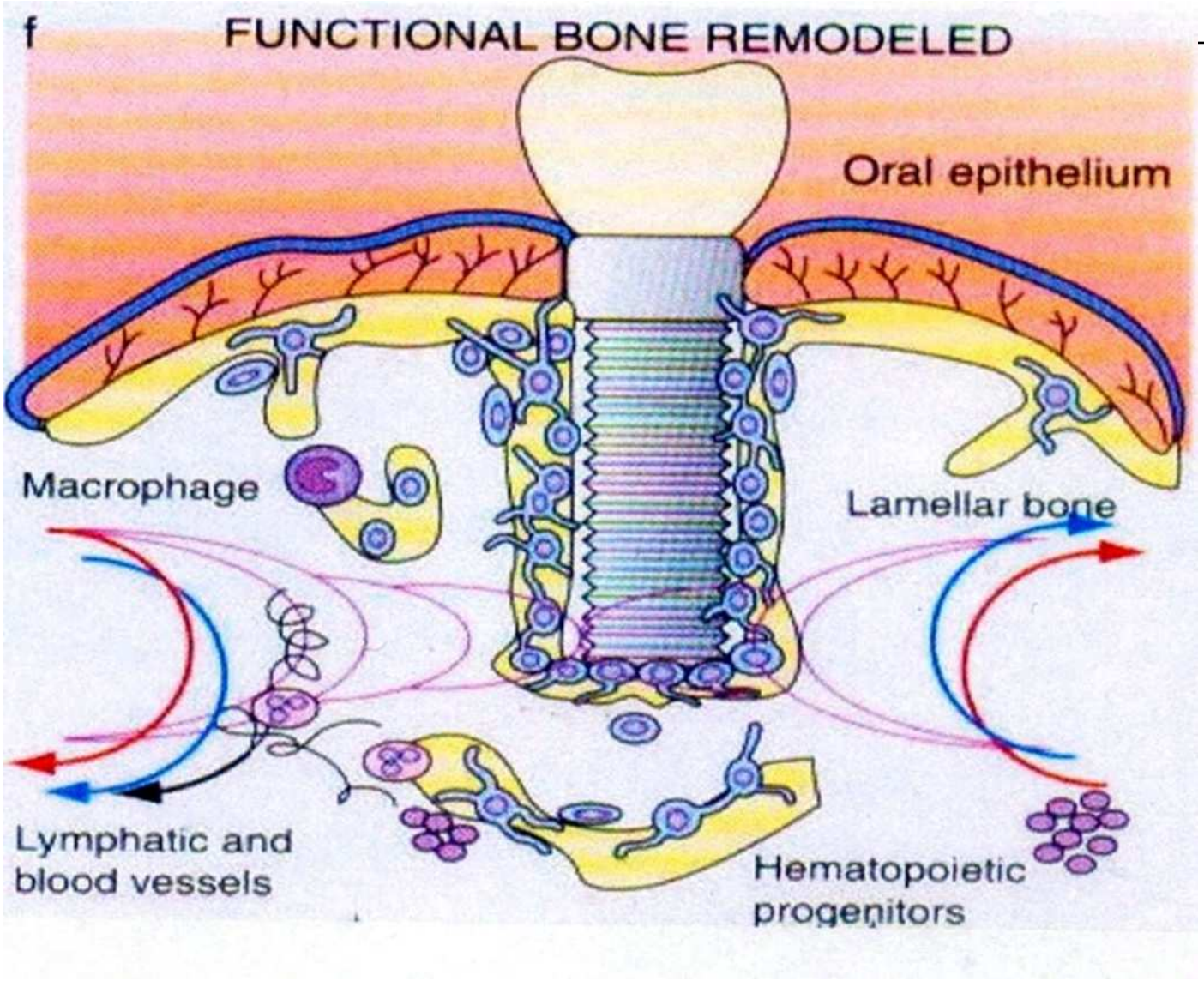

C
Oral epithelium
Fibroblast
Mesenchymal cells
Osteoblasts
Osteocyte
Angiogenisis
Osteoblasts
Osteoprogenitor cells
Granulocyte precursors


STAGE 2: 6 to 18 WEEKS
LAMELLAR COMPACTION and REMODELING
Periosteum
OCL
OBL
Endosteum
OCL
OBL
OCL
OBL


Oral epithelium
Osteoid
trabeculae
Osteoblasts
Osteoblasts
Osteoclast


e
Oral epithelium
Osteoclasts
Osteoid
trabeculae
mineralized
Osteoclast
precursors


STAGE 3: 18 to 54 WEEKS
MATURATION and ADAPTATION
OCL
OCL
OBL
OBL
Periosteum
OCL
OBL
OBL
OCL
Endosteum
OCL
OBL
OCL
OBL
OBL
OBL
OCL
OCL


f
FUNCTIONAL BONE REMODELED
Oral epithelium
Macrophage
Lamellar bone
Lymphatic and
blood vessels
Hematopoietic
progenitors

OSSEOINTEGRATION

Presented by
Dr Abhishek Apratim

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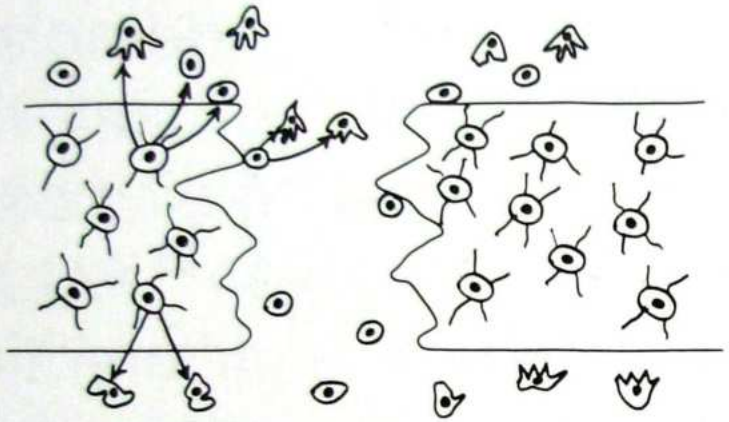
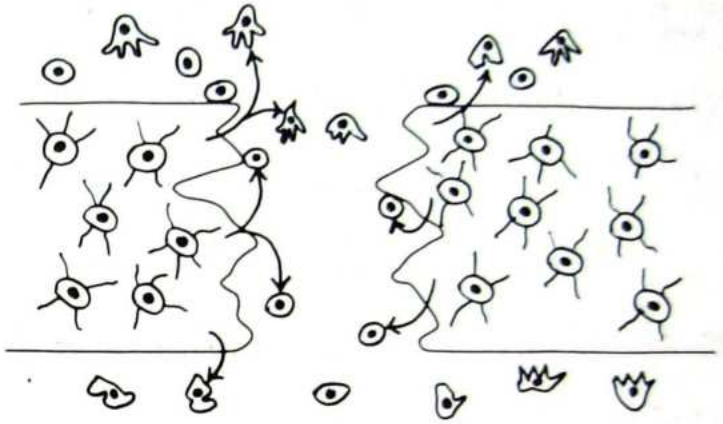
ADEQUATE STIMULUS FOR BONE REPAIR

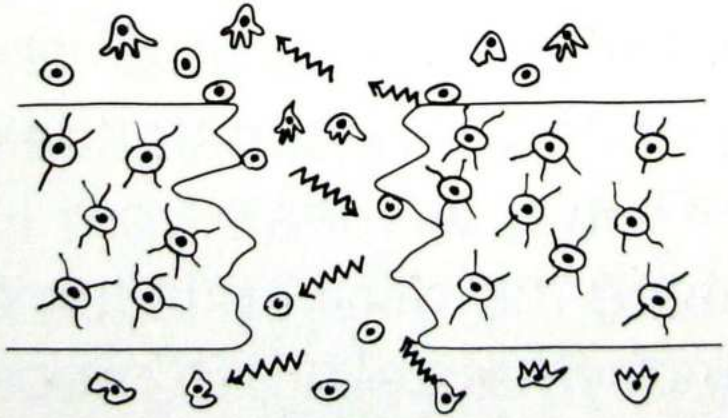
a) cell-to-cell contact



b) soluble matrix molecules



c) stress generated
electric potentials



- If remodeling not stimulated by loading or if the rate of bone formation decreases with age , a negative turnover in bone mass will take place just like in osteoporosis may result .

- Increased resorption or reduced formation of new bone at the host site can also be due to overloading or surface structures that are not suited for load transfer .
- Direct bone apposition is prevented by relative micromotion

- Branemark advocates complete immobilization of the system for 3 to 6 weeks
- 4 weeks in mandible and 6 weeks in maxilla
- Maximum load carrying capability is achieved in 4 to 5 months (lattice structure of woven bone is filled with well organized lamellae).

Tissue seal

Implant surgery

attached gingiva

regenerates around the implant

epithelial cuff /free gingival margin

regenerating epithelium forms the free gingival margin & a gingival sulcus

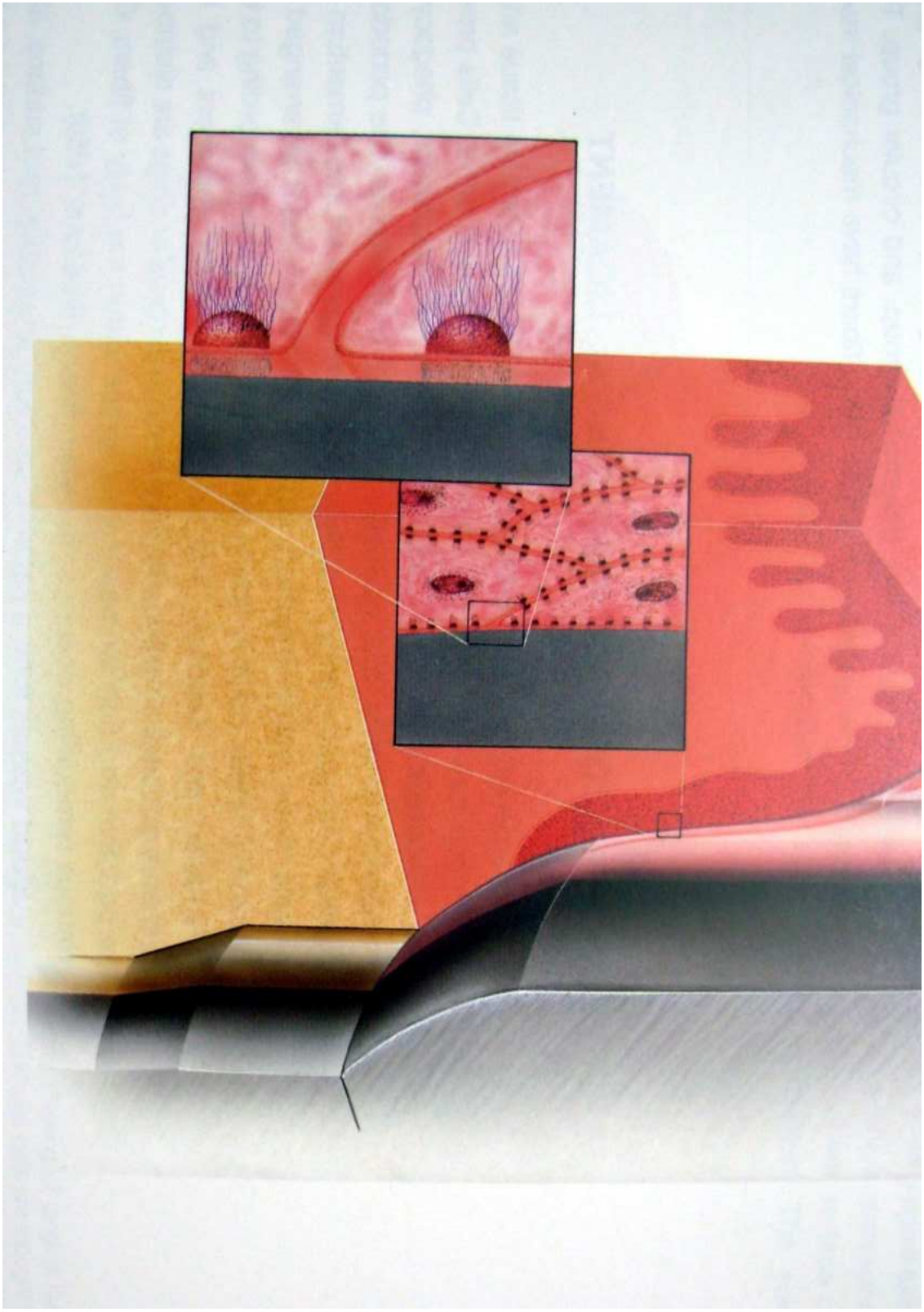
epithelium regenerate into the sulcus

Non keratinized sulcular (crevicular) epithelium & a zone of epithelial cells at the base of the sulcus that interface the implant surface.

Series of biologic attachment structures

Formation of a basal lamina collagenous structure (type IV)

attachment



Osseointegration vs biointegration

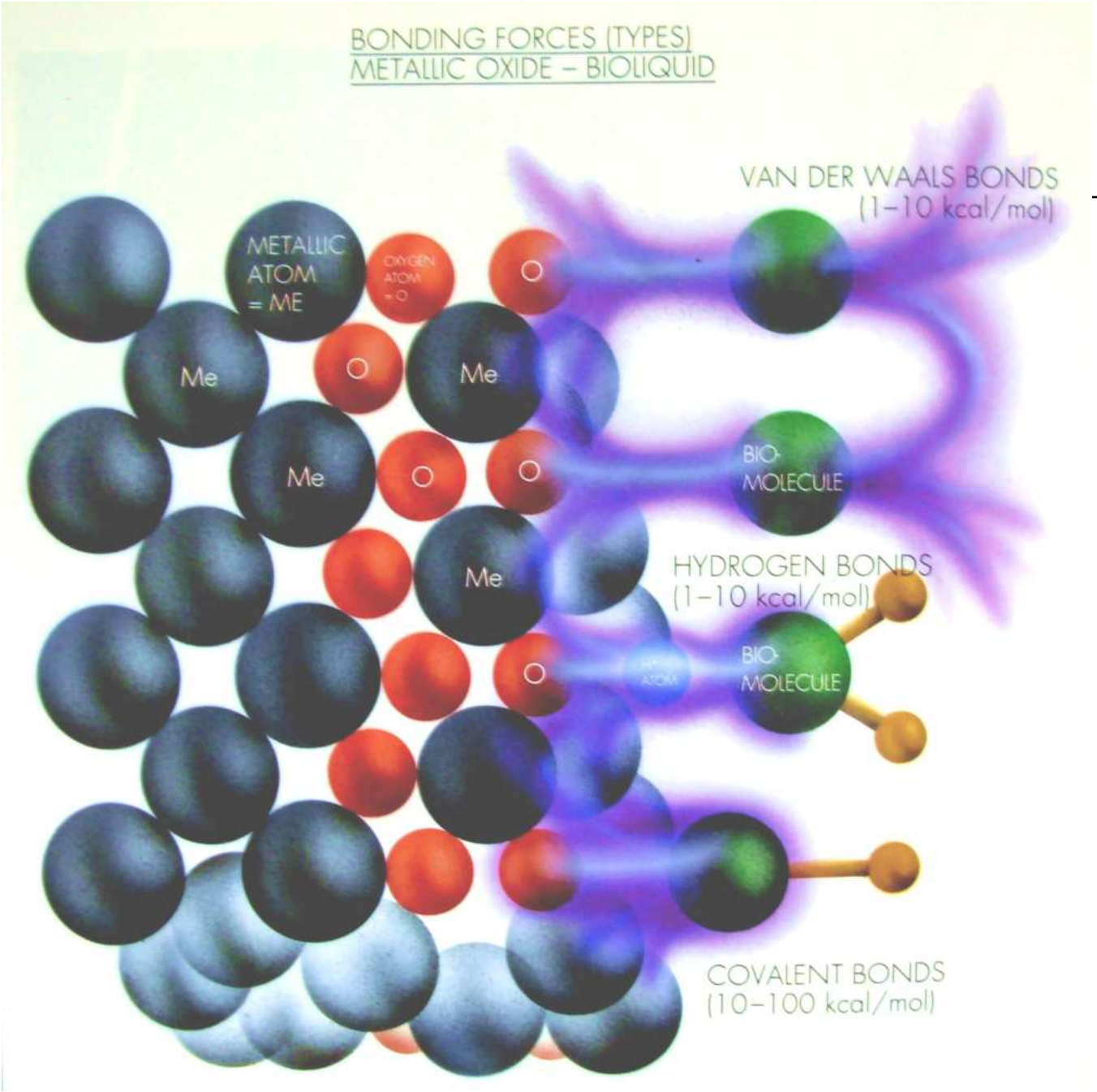
- there were two kinds of anchorage ;
- Mechanical
- Bioactive

- Mechanical retention :
- It basically refers to metallic substrate systems like Ti / Ti alloy . The retention is based on undercut forms like slots and vents.
- It involves direct contact between the dioxide layer on metal and bone with no chemical bonding.

- Bioactive retention : It is achieved with bioactive material like HA which bond directly to bone.
- Bone is deposited on HA as a result of a physiochemical reaction.
- Research has shown that bone formation and maturation occurs at a faster rate and at earlier periods on HA coated implants than on uncoated implant

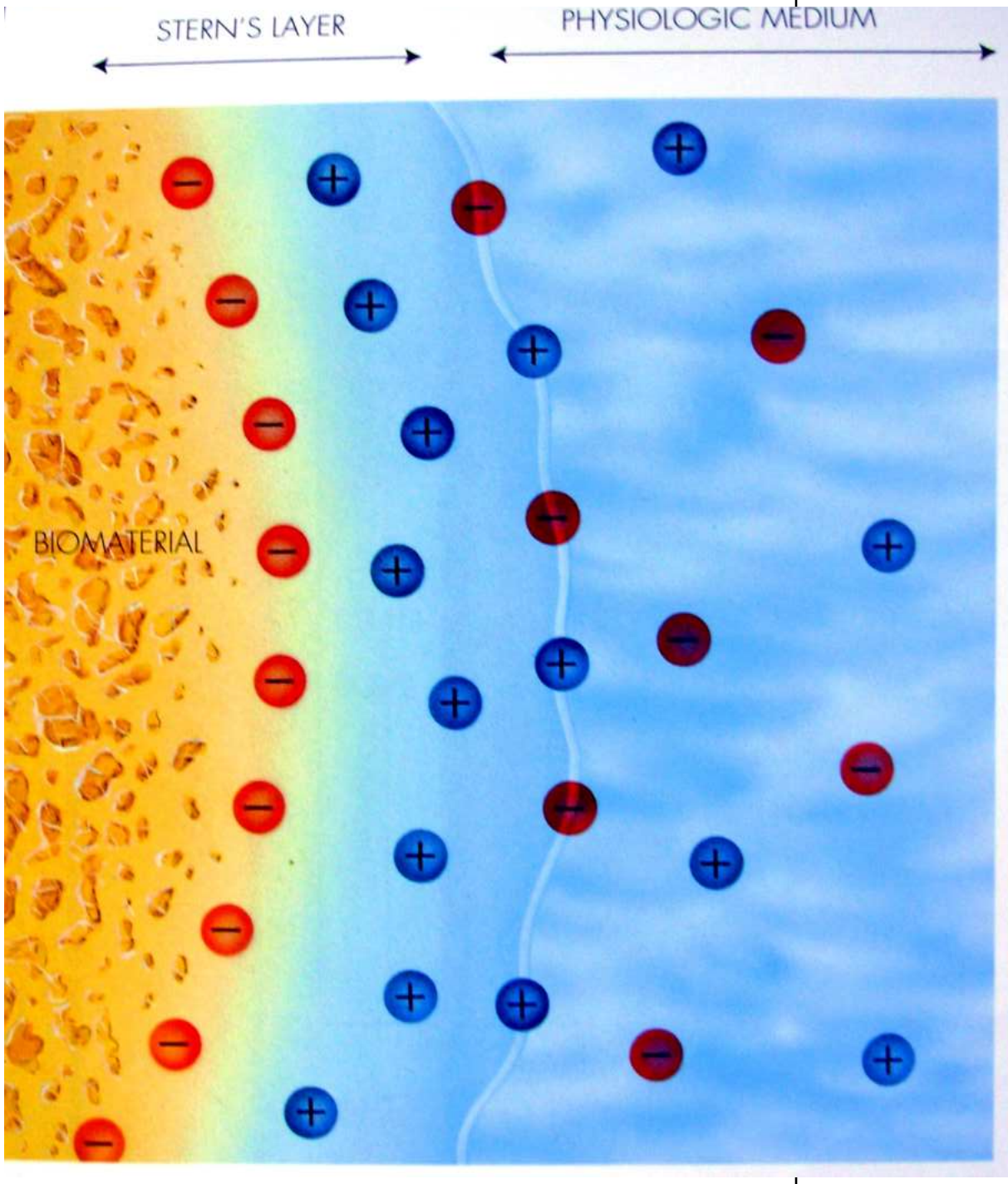
Bioadhesion

- According to kasemo and laussmaa the following types of bonding are distinguished between implant and bone molecule.
- Vander waals bonding
- Chemical bonding
- Hydrogen bonding


BONDING FORCES (TYPES)
METALLIC OXIDE – BIOLIQUID
VAN DER WAALS BONDS
(1–10 kcal/mol)
METALLIC
ATOM
= ME
OXYGEN
ATOM
= O
Me
Me
Me
Me
O
O
O
O
O
BIO-
MOLECULE
HYDROGEN BONDS
(1–10 kcal/mol)
BIO-
MOLECULE
COVALENT BONDS
(10–100 kcal/mol)

- Even though these forces tends to compete each other and predominate in different regions of the surface;
- the covalent bond can have a bond strength of 10 times that of hydrogen bond and must be considered as a crucial factor for bioadhesion.

- Surface energetic bonds , which can have a strength of 30 kcals/mol , can be considered irreversible
- Van der waals and hydrogen bonds thus have only a very low bond strength and may sometimes last only a few milliseconds at body temperature.


STERN'S LAYER
PHYSIOLOGIC MEDIUM
BIOMATERIAL

Zeta potential

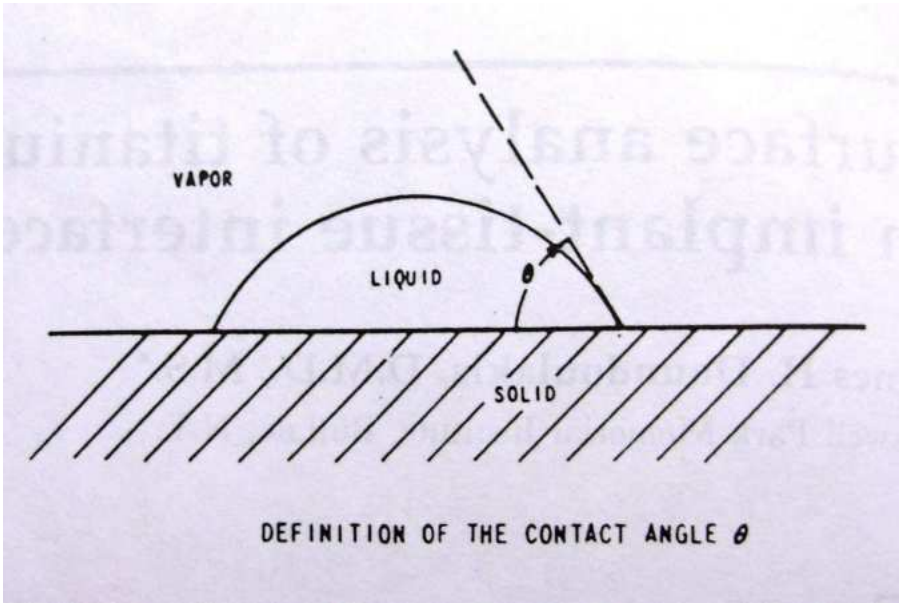
- Is a measure of the electrical potential difference between the monomolecular layer " stern's layer" that bonds to the biomaterial and surrounding physiologic medium.
- Electrical potential is determined by the ions dissolved from the biomaterial.

- Although the zeta potential reflects the electrical potential difference between a mono molecular adsorption layer on the implant surface and the surrounding medium. It will not necessarily cause a charge related adsorption of biolayer molecule.

- However zeta potential and surface tension together seem to have a crucial impact on bioadhesion and may cause adhesion of osteophilic proteins (osteonectin) or osteogenic cells to the implant surface either directly or via a yet undefined connective tissue layer.

Surface tension and bioadhesion

- Critical surface tension of both implant material and wetting fluid in the case of end osseous implants has a considerable influence on bio adhesive events.
- The wettability of a surface depends on both the critical surface tension of the material surface and the contact angle of the wetting fluid.



- Surface tensions below 30 dynes/cm are considered as material with low bioadhesive potential.

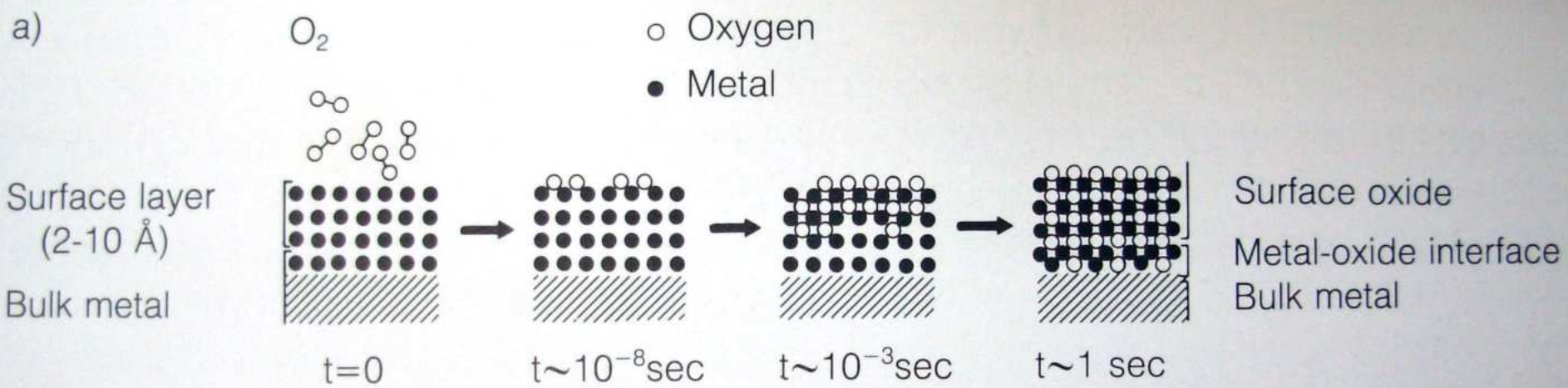
- Conventionally prepared passive oxidation implant material have surface tension ranges between 30-40 dynes/cm. The material that have subjected to modern cleaning methods
- eg. Radiofrequency glow dischargement can have surface tension up to 1000dynes/cm. It is otherwise known as plasma cleaning

MATERIALS

Titanium and it’s alloys

- Ti and its alloys especially (Ti-6Al-4V) have become the material of choice

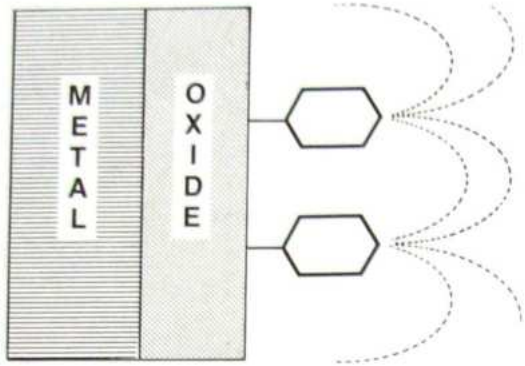
a)



b)

Oxide thicknesses

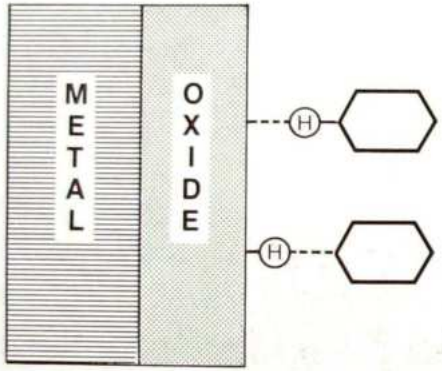
Au, Pt, Pd	0-5 Å
Fe, Ni, Al, Ti	15-50 Å



a.

van der Waals bonding
1–10 kcal/mol

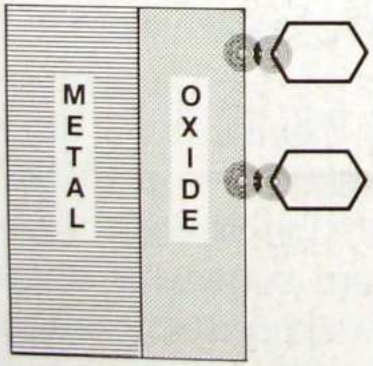
Key parameters:
- molecular polarizability
- dielectric constant of oxide



b.

Hydrogen bonding
1–10 kcal/mol

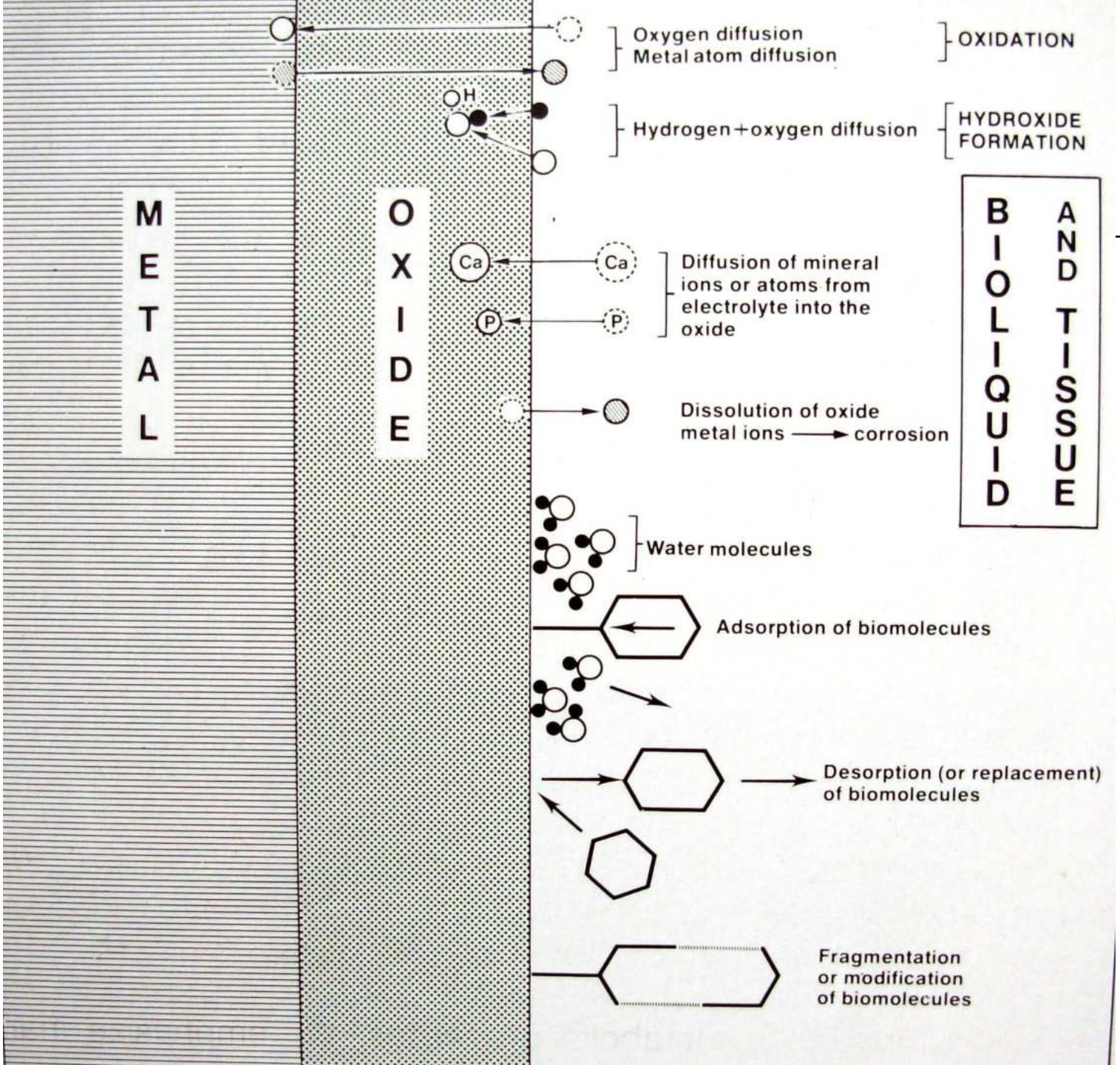
Key parameter:
- Presence of hydrogen at implant surface and/or in biomolecule

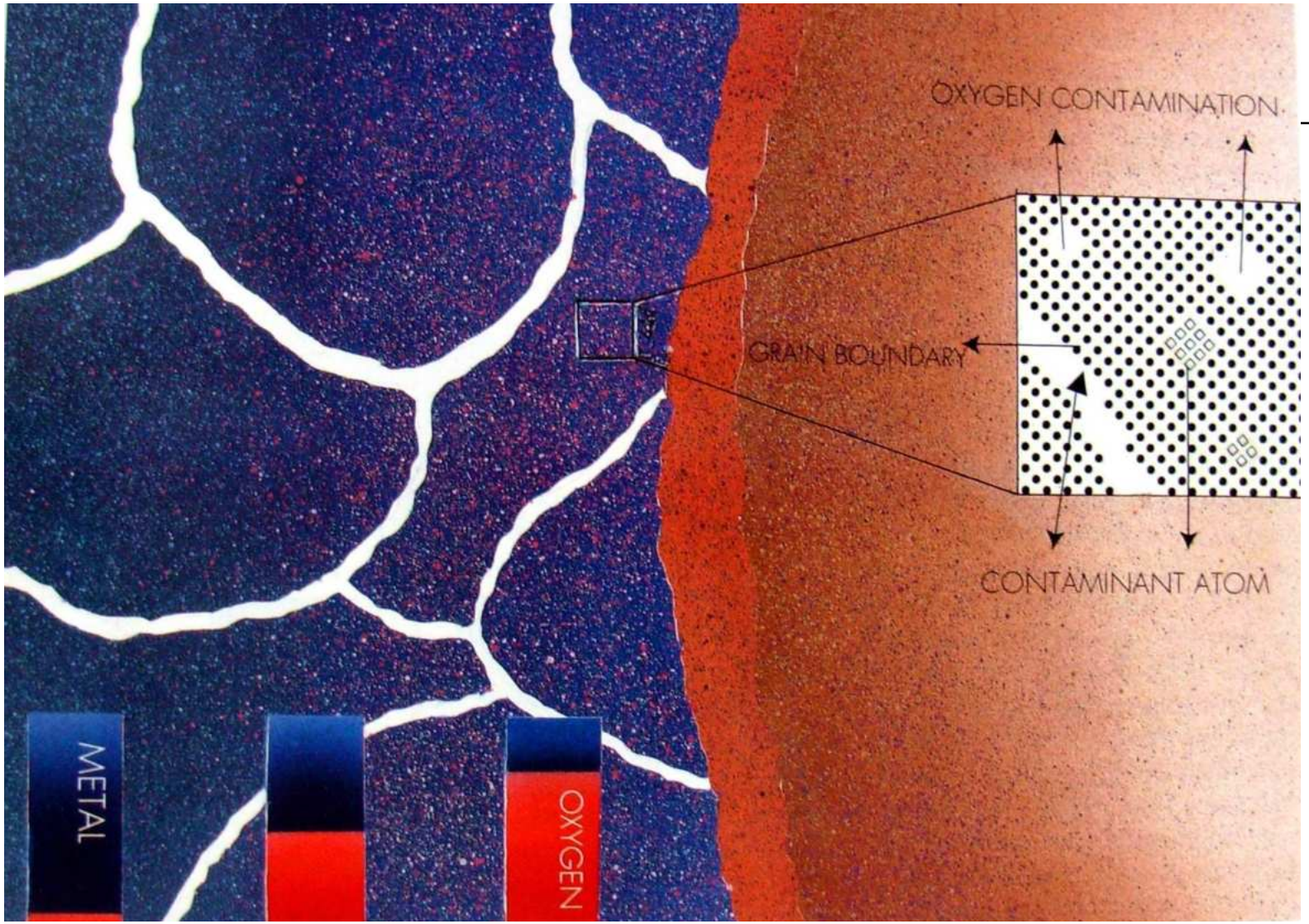


c.

Local chemical bonds (covalent, ionic....)
10–100 kcal/mol

Key parameters:
- local microstructure
- local chemical composition of oxide
- defects, grain boundaries, impurities etc.


METAL
OXIDE
BIOLIQUID AND TISSUE
Oxygen diffusion
Metal atom diffusion
OXIDATION
H
Hydrogen+oxygen diffusion
HYDROXIDE FORMATION
Ca
P
Diffusion of mineral ions or atoms from electrolyte into the oxide
Dissolution of oxide metal ions → corrosion
Water molecules
Adsorption of biomolecules
Desorption (or replacement) of biomolecules
Fragmentation or modification of biomolecules


OXYGEN CONTAMINATION
GRAIN BOUNDARY
CONTAMINANT ATOM
METAL
OXYGEN

Ceramics

- Introduced in early 1890
- They are biologically inert material which elicit no foreign body reaction. They are brittle hence create problem with excessive bite force.
- Bioactive ceramics which are commonly used are
- 1. Hydroxy apatite (Ca10 (PO4) 6 (OH)2)
- 2. Tricalcium phosphate Ca3 (PO4)2
- 3. Bioglasses

- Ceramic can make up the entire implant or they can be applied in the form of coating.
- The reaction of bone to CPC –coated implant differss from that to titanium oxide surface in that simultaneous bone formation starting from both the bone host site and from the CPC-coating.
- They implantopetal and implantofugal bone formation .

- Osteogenic potential of these coatings confirmed by the fact that large areas of newly formed bone can be observed directly on CPC coating even if there is no direct contact between the coating and the peri-implant bone .
- By experiments it has been found that the bone contact formed by the CPC coated implant is more that the titanium implant.

- From the bone side the ,
  osteoprogenitor cells

  ↓

  Implant surface

  ↓

Small heaps of mineral is formed

Bioglass (SiO_2-CaO-Na_2O-P_2O_5-MgO)

- Another bioactive material ceramic
- Forms carbonated hydroxyapatite layer in vivo as a result their of calcium and phosphate content.
- Formation of this layer is initiated by the migration of calcium, phosphate ,silica and sodium ions toward tissue as a result of external pH changes.

Silica rich gel layer is formed

↓ **Silicon depletion**

Migration of calcium and phosphate (bioglass and tissue)

↓

Calcium and phosphorus layer

↓ **Stimulates**

Proliferation of osteoblast

- Osteoblast

- Collagen fibers (gets incoporated into the calcium-phosphate layer)

- Calcium-phosphate crystal

Oxides of Al and Zr

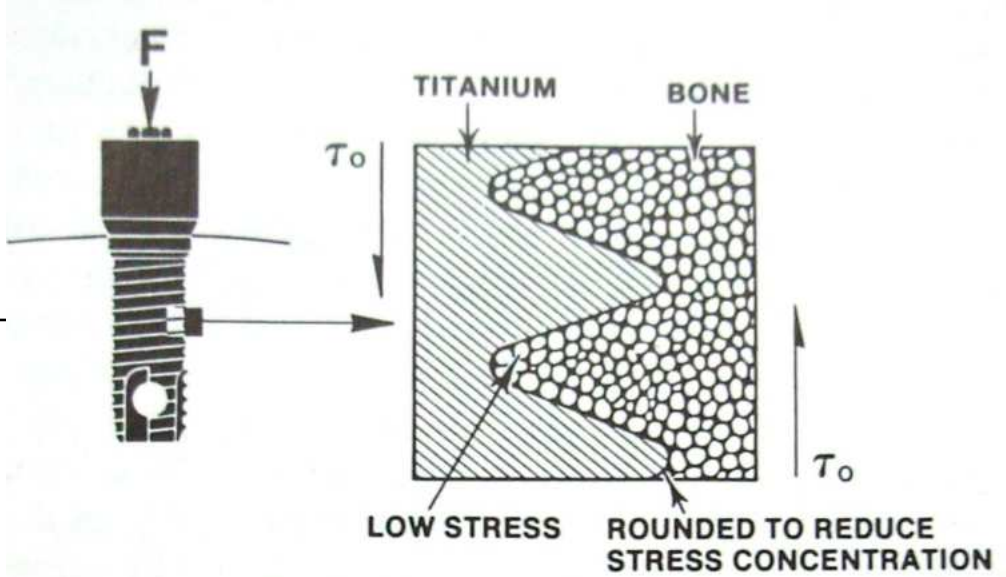
- Alumina (Al_2O_3) are inert with no evidence of ion release or immune reaction in vivo
- They have high surface wettability compared with those of metallic surface implant .
- Zirconia (ZrO_2) high inertness but low wettability
- Theses material are not bioactive as they do not promote bone formation .

Polymers

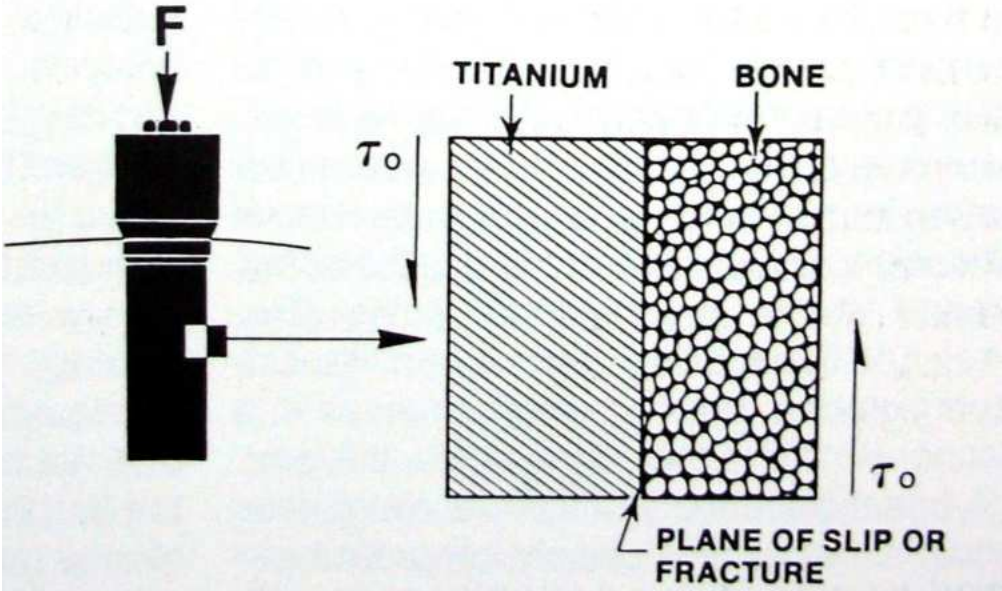
- Lack of adhesion to living bone
- They are much softer and flexible with lower modulus of elasticity than other class of biomaterial .
- Their use is restricted for making shock absorbing components incorporated in o the superstructures supported by implants.

IMPLANT DESIGN

- Designs which creates larger surface area like threaded implant which can also balance the force distribution plays a very important role in initial fixation
- perforations, vents, ledges, grooves, flutes etc. can also be used to increase the surface area.



(a) THREADED IMPLANT



(b) SMOOTH IMPLANT

SURFACE TOPOGRAPHY

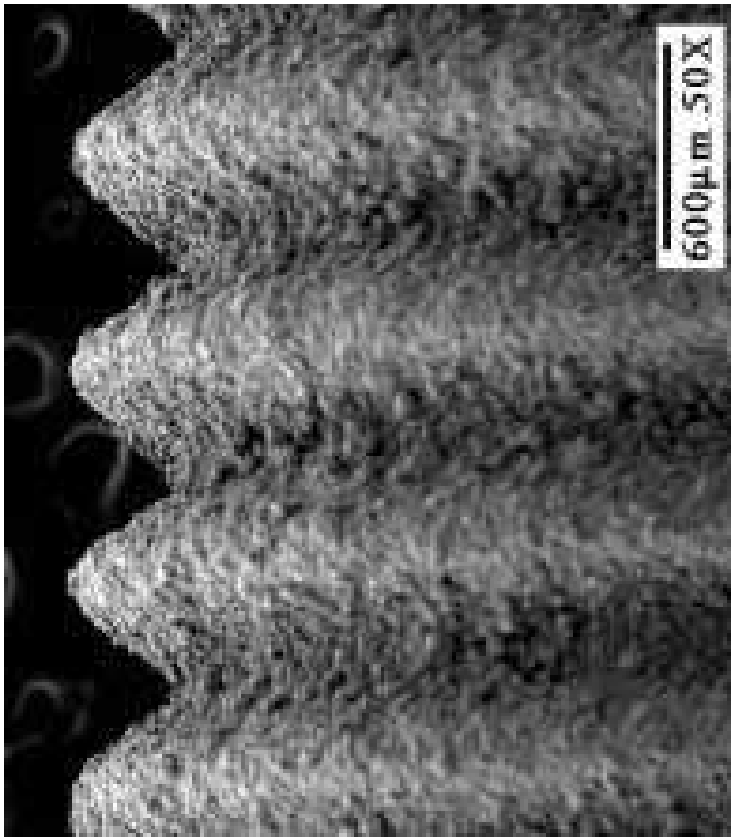
Roughness

- Surface roughness on nanometer scale will influence the local electromagnetic field close to the implant surface and may give rise to van der waal's interaction
- Also introduces bonding sites of different bonding energies than on anatomic flat surfaces

- Mechanical properties of the interface is also influenced

Plasma spray

- Involves heating of the particle by plasma flame at a temperature of approx $15,000^0$ c to $20,000^0$c.
- The particle is propelled onto the implant in Argon inert environment to a thickness of 50 to 100µm .



Ion-sputter coating

- Involves directing a ion beam at a solid phase of the particle block , vaporizing it to create a plasma , and then recondensing this plasma on the implant .

- With experiments it was found that the bone to implant contact was in the order of
- Plasma spray >ion-sputter>uncoated implants

Blasting with particle

- Implant surface is bombarded with Al_2O_3 or TiO_2 particle to make it rough

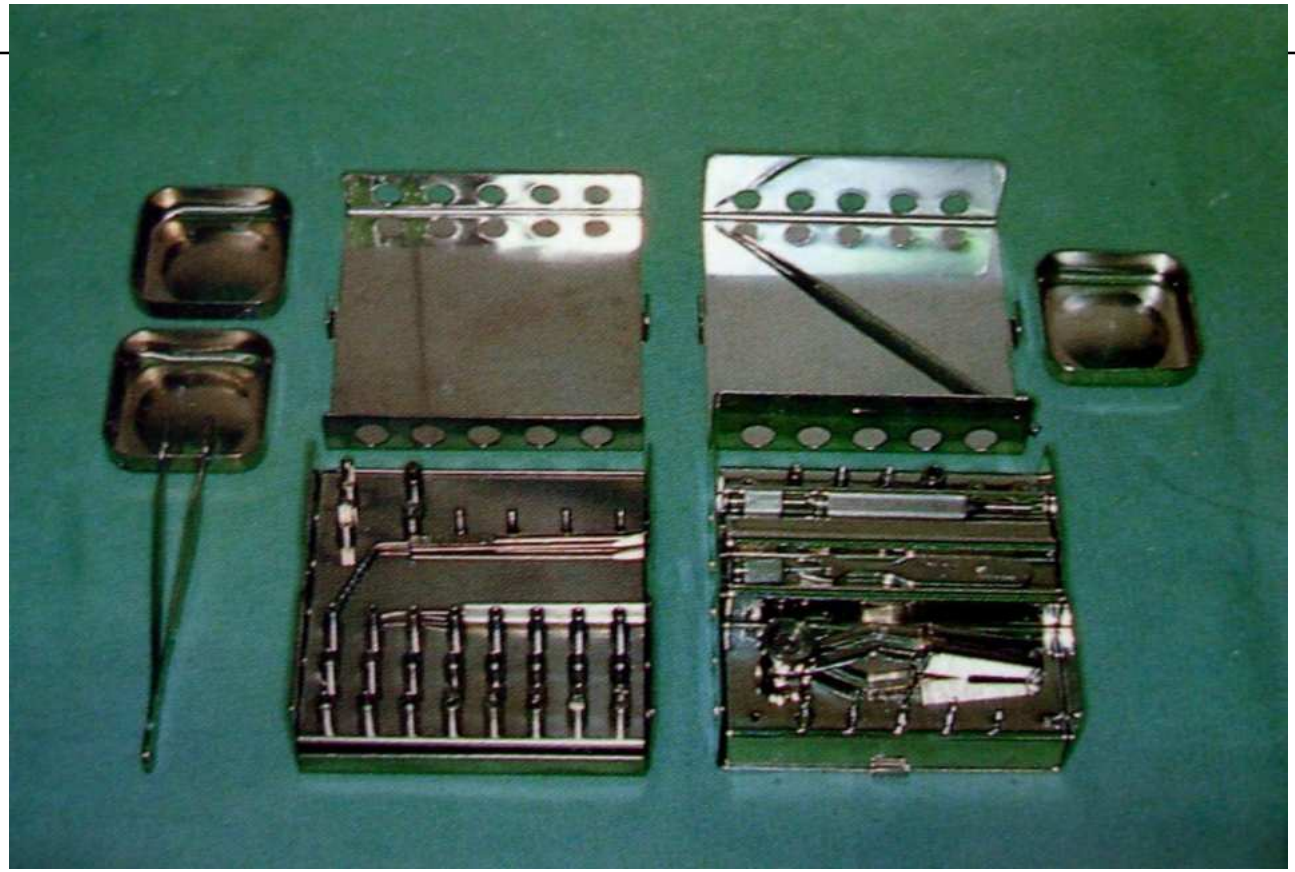
Porous

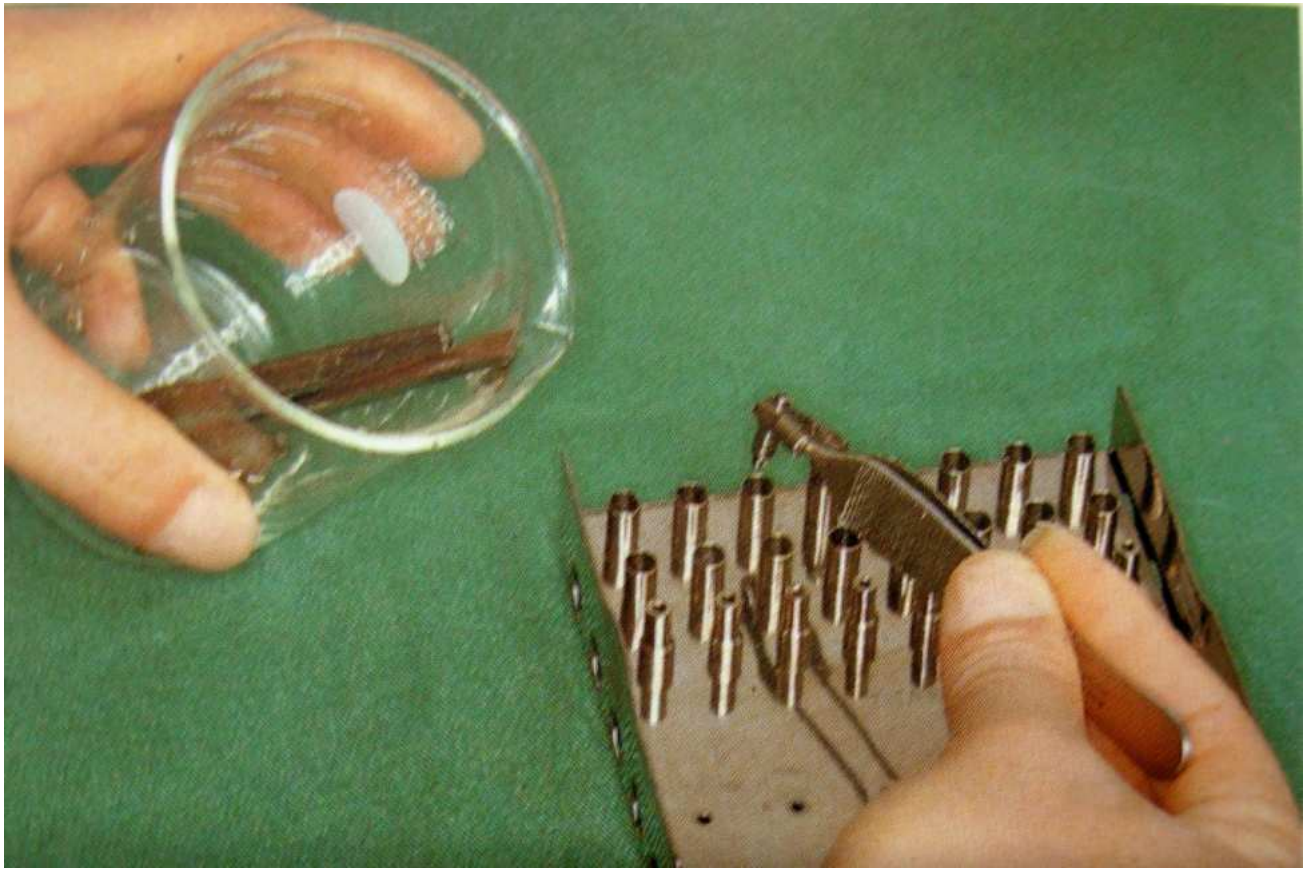
- Porous sintered surfaces are produced when spherical powders of metallic or ceramic material become a coherent mass with the metallic core of the implant body. Lack of sharp edges distinguishes it from rough surface.

- A pore depth of 150-300 μm appears to be the optimal size for bone in growth and maximum contact with the walls of pore.
- Since three fold increase in the surface area it can be used in short length endoseous implant .

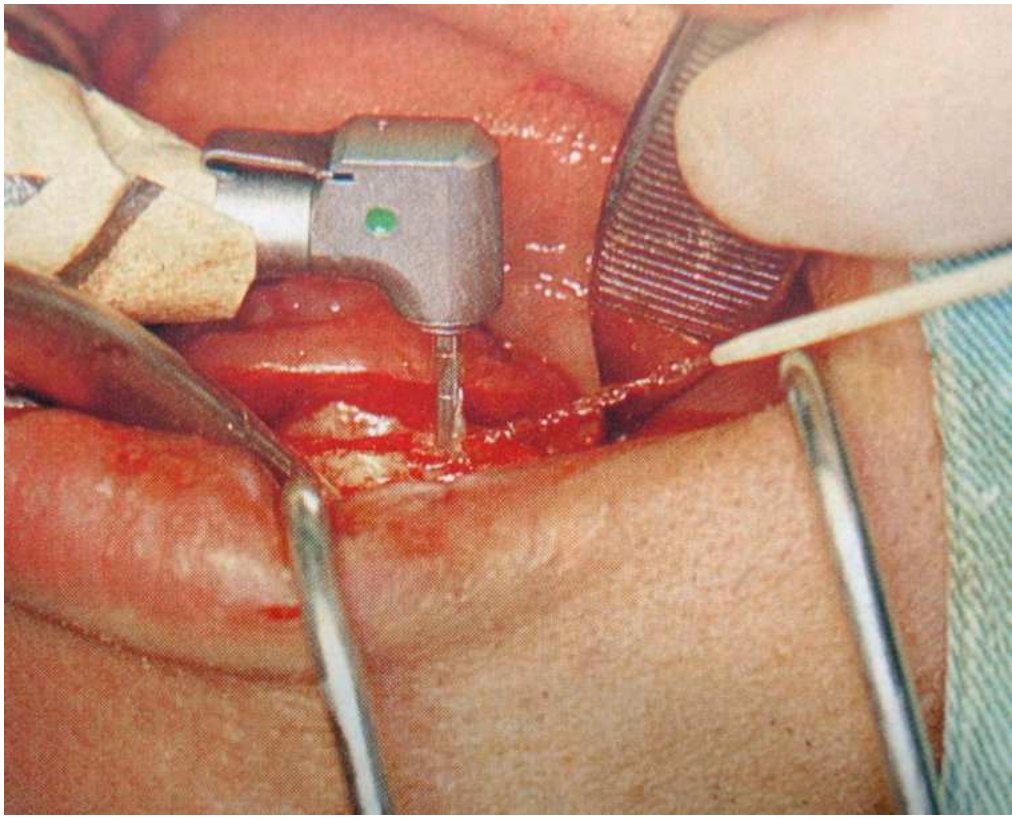
Surgical factors

- Correct diagnosis and treatment planning
- Placement site should be free from infection or necrotic tissue .
- The implant oxide layer should not be contaminated
- use the forceps made up of any inert material or same material to avoid implant contamination





- Specific critical temperature is 56 ^{o} C.
- If the temperature rises of 47 ^{o} C for 1-2 minute will cause damage to the bone tissue.
- A combination of copious irrigation system and sharp drill should be used



- A healing period of 4 to 6 months , in this period the implant should be passive without loading .
- Premature loading is avoided

- Oral hygiene

Systemic factors

- NSAIDS –affects bone ingrowth.
- Caution should be exercised when using these medications immediately after surgery in patients with a porous-coating implant .

Irradiation

- Radiation induces cellular changes in bone where osteocytes in direct pathway of irradiation are killed
- regenerative potential of the periosteum is compromised because of reduced cellularity, vascularity and osteoid formation potential.
- Blood vessels patency is reduced leading to diminished hematopoietic turnover .

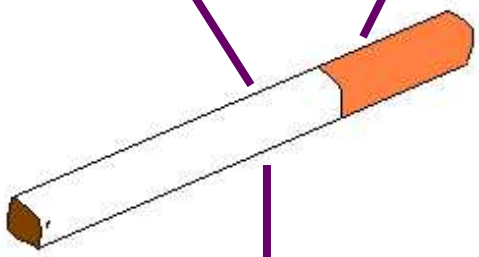
- Irradiation therapy in which more that 55 gray(Gy) has been associated with increased risk of implant failure .

Smoking

NICOTINE AND ACRYL-HYDROCARBONS –

Depress osteoblastic activity ,reduces collagen synthesis ,inhibits osteosynthesis .

Also causes local vasocontriction



CARBON MONOXIDE

Forms carboxyhemoglobin

HYDROGEN CYANIDE

Inhibits cellular respiratory enzymes

Tissue hypoxia & altered tissue healing

Uncontrolled Diabetes

- More prone to develop infection and vascular complication
- Healing is affected by impaired vascular function, chemotaxis, impaired neutrophil function

Pregnancy

- Implant surgery procedures are contraindicated
- Almost 15% pregnancies are terminated by spontaneous abortion or miscarriage during first trimester
- Dental prophylactic appointments are suggested in 2nd and 3rd trimester.

- Hygienist and dentist should realize that in middle and late 3rd trimester ,hypotension can occur in supine mother as a result of pressure of the fetus on the inferior vena cava .

Parafunctional habits

- Bruxism
- Clenching
- Tongue thrusting

- Bruxism and clenching are the most critical factors to evaluate in any implant reconstruction .
- No long term success will be obtained with severe parafunction of bruxism and clenching
- Dentist should always make an effort to diagnose the presence of these conditions .

Failure of osseointegration

- Sign and symptoms

1. Horizontal mobility beyond 0.5 mm or any clinically observed vertical movement under less than 500 gm force
2. Rapid progressive bone loss regardless of the stress reduction and periimplant therapy .
3. Pain during percussion or function
4. Continued uncontrolled exudate in spite of surgical attempts at correction.

5. Generallised radiolucency around an implant
6. More than one half of the surrounding bone is lost around an implant
7. Implant insertion in poor position, making them useless for prosthetic support

Summary

- osseointegration is a term to describe a direct bone to implant interface observed in experimental and clinical investigations. This bony interfacial reaction differed from that with intervening fibrous tissue, regarded as an inevitable result when a metal device is inserted in bone.
- An initial necrotic border zone is nevertheless inevitable around a dental implant. This necrotic border zone must heal with highly differentiated bone tissue instead of fibrous tissue if proper bone integration is to ensue.

- Conventional surgical techniques lead to high temperature elevations at the interface, which in turn leads to scar tissue formation instead of the bone healing possible only with a controlled surgical technique .
- Another important factor is related to control of the loading of the implant to ensure proper bone integration. Movements will stimulate formation of fibrous tissue; therefore, a dental implant should be prevented from premature loading before the interfacial tissues have healed with newly formed bone

- Different biomaterial has different way of interacting with biomolecules leading to osseointegration .
- Some biomaterials are not bioactive like polymers , thus used as shock absorption component due to their flexibility .
- Surgical placement of implant comprises of a series of events that should be carefully followed to achieve osseointegration .

Conclusion

- We know from extensive research and clinical trails that osseointegration is possible ; and succeeds when prudent patient selection, use of biocompatible materials, and meticulous adherence to the recommended surgical protocol, skillful prosthetic managements and long term maintenance is carried out
- The surgical and prosthetic stages are highly technique- sensitive.

- The body’s wound healing processes must occur orderly to achieve osseo integration and conditions of overloading must be avoided in order to destroy osseo integration.
- This biological phenomenon has found a wide range of applications in clinical dentistry like complete dentures, craniofacial reconstruction and oral rehabilitation cases .

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