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OSSEOINTEGRATION IN DENTAL IMPLANTS

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Abstract:- Osseointegration is a fundamental biological process responsible for the successful integration of dental implants with the surrounding bone tissue. It is defined as the direct structural and functional connection between living bone and the surface of a load-bearing implant without the presence of intervening soft tissue. The success of implant therapy depends on various factors including implant material, surgical technique, bone quality, loading conditions, and host factors. Over the years, dental implantology has evolved significantly with advancements in implant design, surface modifications, and biomaterials, particularly titanium and its alloys, which exhibit superior biocompatibility and long-term clinical success. This review aims to provide a comprehensive overview of the concept of osseointegration, its historical development, biological mechanisms, bone healing processes, factors influencing implant success, and the role of diagnostic imaging and biomaterials in implant dentistry. Understanding the principles and determinants of osseointegration is essential for achieving predictable implant stability and long-term functional outcomes. Continuous advancements in implant research and technology have contributed significantly to improving treatment success and patient quality of life.

Keywords: Osseointegration, Dental Implants, Titanium, Bone Healing, Implant Stability, Implantology

INTRODUCTION

Key biological concept in Dentistry and Orthopedics, especially for implants.

Definition

Osseointegration is defined as a **direct structural and functional connection between living bone and the surface of a load-bearing implant**, without any intervening soft tissue layer.

Brief Elaboration

- After an implant (usually titanium) is placed into bone, the body begins a healing process.
- Bone-forming cells (osteoblasts) grow and attach directly to the implant surface.
- Over time, the bone remodels and tightly binds with the implant, making it stable and strong.
- This integration allows the implant to function like a natural part of the body (e.g., a tooth root or joint component).

Key Features

- No fibrous tissue between bone and implant
- Strong, stable fixation
- Long-term functionality of the implant

Importance

Osseointegration is essential for the **success of dental and orthopedic implants**, ensuring they remain firm, functional, and durable.

In short: it is the process by which an implant becomes firmly anchored to bone by direct biological bonding.

The successful replacement of lost natural teeth by tissue-integrated tooth root analogues is a major advancement over last 25 years. Today the continued high rate of success achieved with these osseointegrated dental implants allow a greater number of patients to enjoy the benefits of fixed rather than removable restorations.[1]

There are many patients for whom both conventional removable and fixed prosthodontics procedures are compromised owing to a lack of adequate support, retention and stability of the resultant prosthesis. Implants offers the restorative dentist additional options to obtain these necessary requirements for a successful restoration.[2]

During the past two decades, dental implants have been used extensively to achieve osseointegration for prosthetic rehabilitation of edentulism. A surgical procedure is performed on a patient to insert a foreign material into bone**,** and then the body is called on to 'heal' the wound. Since the mid-1970s, the general consensus for successful implant healing shifted toward that of a direct bond of the implant to bone with no intervening fibrous tissue that is 'Osseous integration.

DENTAL IMPLANT

A prosthetic device of alloplastic material(s) implanted into the oral tissues beneath the mucosal and/ or periosteal layer, within the bone to provide retention and support for a fixed or removable prosthesis.[3]

They are classified as

a) Endosteal implant.

b) Subperiosteal implant.

c) Transosteal implant.

d) Mucosal implant.

ENDOSTEAL DENTAL IMPLANT: -

It is a device placed into the alveolar and/ or basal bone of mandible or maxilla and transecting only one cortical plate.

The endosteal implant is composed of an anchorage component termed, the" endosteal dental implant body ". Ideally, it is within the bone.

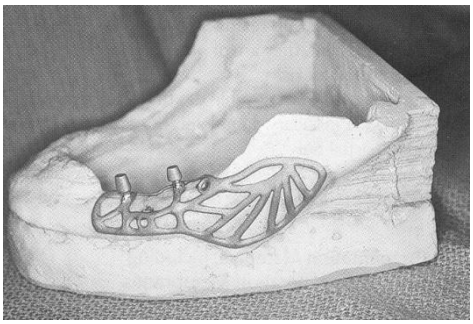
Another component of endosteal implant is the retentive component, termed as 'an endosteal dental implant abutment.

SUBPERIOSTEAL DENTAL IMPLANT: -

Any dental implant that receives its primary bone support by means of resting upon the bone.

Because there is often not enough bone in which to place an endosteal implant, dentists turned to placing implants on and around bone rather than in it in the form of subperiosteal implants.

In 1943 **Dahl** placed metal structures on the mandible and maxilla with four projecting posts. [4]



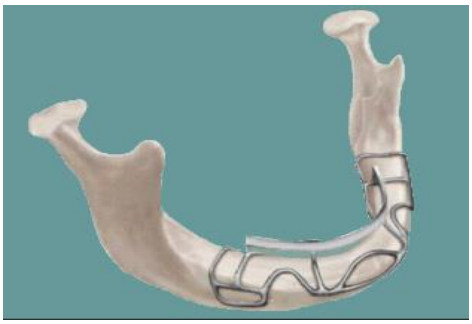


Fig1 subperiosteal implant fig 2

TRANSOSTEAL DENTAL IMPLANT

A dental implant that penetrates both cortical plates and passes through the full thickness of the alveolar bone.[5]

A dental implant composed of a metal plate with the retentive pins to hold it against the inferior border of the Mandible that supports transosteal pins that penetrate through the full thickness of the mouth and pass into the mouth in the parasymphyseal region -also called ‘Staple bone implant, Mandibular stable implant, Transmandibular implant.

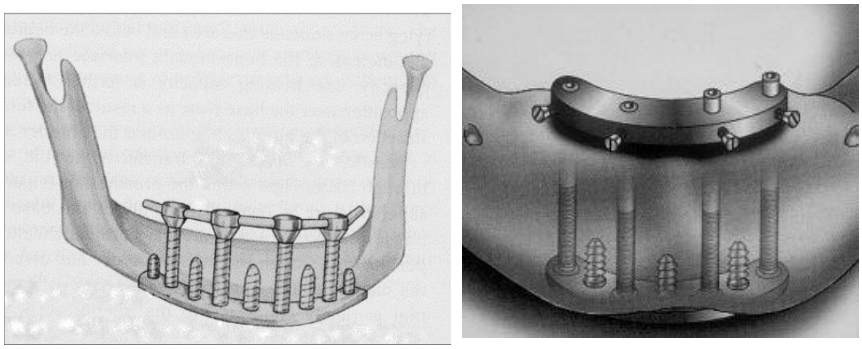


Fig. 3 transosteal dental implant

MUCOSAL IMPLANT

A metal insert attached to the tissue surface of a removable prosthesis that mechanically engages undercuts in a surgically prepared mucosal site. It is also called as ‘mucosal insert, button implants and intramucosal insert. [6]

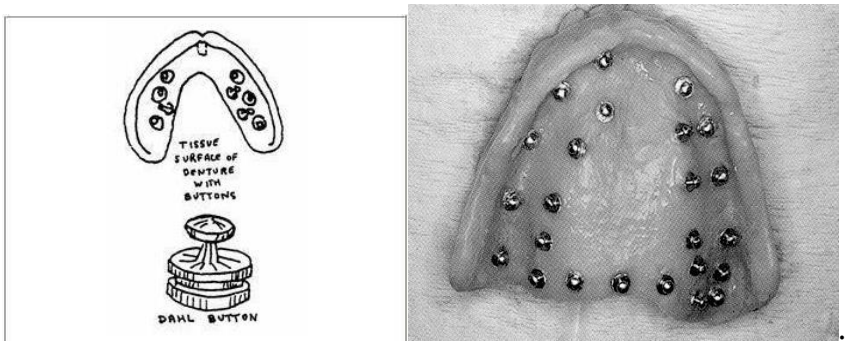


Fig 4 mucosal dental implant

OSSEOINTEGRATION

The word osseointegration is derived from Latin "os" which means bone and "integration" which means the state of being combined into a complete whole. Evidence of tooth replacement in the Americas was found in 1931 while Dr. and Mrs. Wilson Popenoe, an archeological team, were excavating in Honduras. They discovered a mandible of Mayan origin from about 600 AD that had tooth-shaped pieces of shells placed into the sockets of three missing mandibular incisors. The tooth-shaped shell implants and the jaw were examined radiographically and it was determined that compact bone had formed around 2 of the implants and the bone was radiographically similar to that which forms around blade implants. This may be the earliest example of any endosseous implant.[7]

1. Direct bone anchorage to an implant body provides a foundation to support a prosthesis and transmits occlusal forces directly to bone.
2. A direct structural and functional connection exists between living bone and the surface of a load-bearing implant.
3. An apparent direct connection occurs between an implant surface and host bone without intervening connective tissue.
4. An apparent direct attachment or connection of bone tissue to an inert alloplastic material occurs without intervening connective tissue.
5. The process and resultant apparent direct connection between an exogenous material's surface and host bone tissues occurs without intervening fibrous connective tissue.
6. An apparent direct attachment of bone tissue to an inert alloplastic material occurs without fibrous connective tissue, representing the interface between the material and bone.
7. Contact is established between normal remodeled bone and an implant without interposition of non-bone tissue, allowing sustained transfer and distribution of load within the bone.
8. A time-dependent healing process results in clinically asymptomatic rigid fixation of alloplastic materials in bone during functional loading.

ANCIENT IMPLANTS:

Attempts to replace lost teeth with an endosteal implants have been traced to ancient Egyptian and South American civilizations. There is a skull from the pre-Colombian Era in the Peabody Museum of Harvard University in which an artificial tooth carved from dark stone replaced a lower left lateral incisor.

Implanted animal and carved ivory teeth cited in ancient Egyptian writings are the oldest examples of primitive implantology. It is doubtful that any of these earliest attempts with crude materials and coarse methods enjoyed appreciable longevity.[8,9]

Implantation at that time was done by transplanting teeth from slaves or the poor who would willingly sell their teeth. Teeth from sources such as goats, dogs, and monkeys were also used for implantation purposes.

EARLY IMPLANTS:

In 1809, **Maggiolo**[10] placed a single stage gold implant without a crown to heal passively in a fresh extraction site just above the gingiva. The crown was added after healing.

The insertion of such teeth roots of gold was inevitably followed by intense pain and gingival inflammation. Roughened lead roots held a platinum post and a porcelain crown; tubes of gold and iridium were used.

In 1886, **Bugnot** tried to implant tooth buds.

In the same year Younger transplanted teeth into artificially created alveolar sockets.

During the period from late 1880 to 1900, gold, porcelain, gutta percha and platinum were used as implant materials.

Greenfield used a two-piece hollow basket fabricated from 24-gauge iridium wire soldered with 24-carat gold in 1913; this was clearly the forerunner of today's hollow-basket design.[11]

MODERN IMPLANTS:

Modern implantology began in 1940s with a screw–type implant introduced by Formiggina.

In 1967, **Hodosh**[12] used acrylic resin to make implants in tooth forms and tested its biocompatibility in monkeys. Acrylic resin could be made into any shape and have the advantage of corrosion resistance. The tooth-shaped implant had a porous root type structure that was said to allow for bony in growth. However, results did not support that claim.

Hodosh et al (1975)[13] stated that the connective tissue interface between the implant and bone was well organized and comparable to natural periodontal ligaments. Vitreous carbon was felt to have the advantage of superior biocompatibility including bone growth. They were used as single tooth replacements by embedding the implant into bone sockets.

In 1966, **Linkow**[14] developed the blade-type implant made from chromium, nickel, and vanadium. This used a one step procedure for placement of the implant through the mucosa into bone. Blade-implant use was common but had many problems with rapid bone resorption and soft tissue inflammation. **Albrektsson et al** in 1986 stated that blade-type implants were not proven clinically successful.

Ceramics, used in early 1890 as an implant material, are considered a biocompatible inert material. They are now used in the manufacture of certain types of implants. Ceramic material was brittle creating problems intraorally with excessive biting forces. Single crystalline forms have been developed to overcome the brittleness problem and increase hardness. Currently titanium and its alloys are used to obtain successful osseointegration.

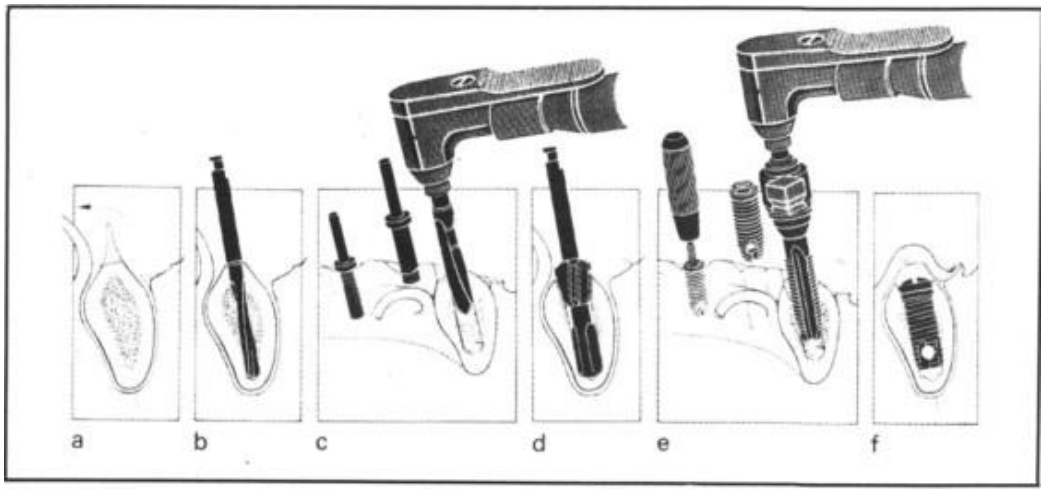


Fig 5 modern dental imlant

DEVELOPMENT OF CONCEPT OF OSSEOINTEGRATION:-

In the past, direct contact (without interposed soft tissue layers) between bone and metallic implants was regarded as impossible to achieve (Fibro-osseous integration).

The supporters of this theory were **Linkow** (1970) **James** (1975) and **Weiss** 1986.

They believed that there was a highly dense collagenous tissue intervening bone and implant which helped to distribute forces like periodontal membrane of natural tooth.

The concept of osseointegration was developed and the term was coined by DR. PER INGVAR BRANEMARK, professor at the institute for applied biotechnology, University of Goteborg, Sweden. He discovered a direct, strong bone anchorage of titanium chamber, he was using while studying micro-circulation in bone repair mechanism. The titanium chamber was surgically inserted into tibia of a rabbit. From additional information gathered in this study, he found titanium was the best material for artificial root placement. [Branemark][15]

Even though Branemark team was the first to suggest a direct bone anchorage and its potential clinical advantages, the scientific community remained unconvinced of this.

The reason for this reluctance to accept the new ideas was partly a methodological shortcoming. Literature suggests that the fact that bone becomes directly integrated with bone tissue was described by as early as 1939 by Strock and also by Schroeder from Switzerland. Schroeder worked from the mid 1970s, quite independently from Branemark, with research on direct bone anchored implants. Other pioneering work on osseointegration was conducted at roughly the same time by the German clinical scientist Schulte 1978. [16]

The history of implant dentistry is best viewed in terms of critical periods and landmark events. The earliest dental implants were of stone and ivory, sighted in the archeological records of China and Egypt. Gold and ivory dental implants were used in the 16th and 17th centuries.

Metal implant devices of Gold, Lead, Iridium, tantalum, stainless steel and cobalt alloy were developed in the early 20th century. Cobalt-chromium-molybdenum subperiosteal and titanium blade implants were introduced in the 1940s and 1960s respectively.

The first Dental Implant Consensus Conference, sponsored by the National Institutes of Health (NIH) and Harvard University in 1978 was a landmark event; it was entitled ‘Dental Implants: Benefits and Risks’. Retrospective data on implants were collected and analyzed using life table methods. The conference established criteria and standards for implant dentistry and issued a mandate to organized dentistry for input and involvement in this new field.

The osseointegrated dental implant system developed by **Branemark et al., (**1977; 1983)[17] has been reported to be highly successful when used in humans. It has the disadvantage, however, of being both complicated and costly to place, thus limiting its clinical applications. Consequently, there is a need to develop a simpler, less expensive system.

The **Branemark** implant incorporates a screw-threaded geometry which allows for an immediate mechanical interlock with bone. The implant is placed in a two-stage procedure, and sufficient time is allowed between the fixture placement (first) stage and the second stage (when the implant is made functional by the attachment of the transgingival component) so that remodeling of non-vital bone at the implant surface can be expected to be largely complete. Once this "osseointegration" has been established and the implant placed into function, the threaded design appears to result in bone formation and maintenance along the entire length of the threaded portion, suggesting that conditions for osteogenesis, including an appropriate distribution of stress, occur along the implant.

FIBRO-OSSEOINTEGRATION

John B. Brunski et al, (1979)[18] the tissue-implant interfaces of functional and non-functional endosseous dental implants were compared histologically for up to one year postoperatively. Nonmineralized connective tissue zones (a 'fibrous capsule") existed in all functional interfaces. Direct, or nearly direct, bone apposition to implants occurred in non-functional interfaces. The origin of this result and its significance in dental implantology is discussed. From results of this study on successful functioning implants with fibrous encapsulation, and from results cited from the literature on successful functioning implants without fibrous encapsulation, they concluded that the sole criterion for implant success cannot be based upon the presence or absence of a fibrous capsule.

There are three categories of variables which influence the interface: biomaterial, clinical and/or surgical, and biomechanical. Natiella et alobservedthat Titanium j and Vitallium endosseous blade implants in primates developed the same type of interface at the endosseous region.

Gourley et al[19] reported that identical, pure titanium blade implants in dogs frequently had non-identical interfaces.

Karagianeset al and Branemark et al[20] observed the same result in work withTi-6A14V plug-like endosseous implants in swine and dogs, respectively. Work withpolymeric, ceramic, and carbon implants provides evidence which supports the view that knowledge of the biomaterial alone will not permit prediction of the resulting interface tissues.

Again John B. et al[21] functional and non-functional endosseous dental implants were clinically compared in beagle mandibles for up to one year post-operatively. Differing biomechanical conditions led to clinical differences between functional and non-functional implants. Typical clinical tests, however, did not always reveal detailed histological differences between implant-tissue interfaces of functional and nonfunctional implants.

Natiella et al[22] have noted that titanium and Vitallium blade-vent implants cannot be distinguished on the basis of clinical results.

Branemark et al[23] and **Hassler** and **McCoy** showed it was possible to have nearly identical clinical results using different endosseous implant materials (Ti-6AI-4V and A12 03, respectively).

Klawitter et al[24] concluded that surface micro porosity of dental implants can predispose the gingival tissues of inflammation due to sequestering of bacteria in the pores of the material at the neck of the implant.

Linkow and Chercheve were among the first to suggest that the biomechanics of endosseous dental implants related to clinical performance. For example, these authors suggested that atrophy of an edentulous alveolar ridge might be slowed or stopped by using dental implants. They reasoned that dental implants would transmit stresses to the alveolar bone and thereby maintain the height of the alveolar ridge.

It is also evident from the clinical data of this study that biomechanical factors can play a role in determining the clinical status of implants. It is seen that those implants which were functional while having a relatively "loose" initial fit in their channels went on to show signs of clinical failure. The failures were particularly characterized by an extensive amount of bone loss (resorption) near implant necks and also extending almost half-way down the blade portions of the implants.

Larry J. Peterson et al (1949-58)[25] studied in which forty-three porous rooted poly methyl methacrylate (PMMA) dental implants were inserted into twenty four dogs. Successful implants were maintained for up to three years. Histological sections with the implants in situ revealed a soft tissue-implant interface similar to natural teeth. Bone and fibrous tissue in growth into the pores attached the implant to the bone. Failures were attributed to mechanical weakness of the implant, thin buccal cortical bone, and excessive

implant gingiva interface. According to them Bony in-growth occurred in two fashions: the bone grew completely into the depth of the pores, or alternatively the new bone adapted to the surface of the most lateral pores, and fibrous tissue in-growth filled the spaces around the deeper pores. Although the bone adapted to the convex surface of the root spheres, high power microscopic examination showed there was usually a fine layer of fibrous connective tissue between bone and implant material. Unexpectedly, both large and small pore implants exhibited bone in-growth.

The reaction of the soft tissue to porcelain root tips has been studied by **Immenkamp** and **Dewey** and **Zugsmith. Immenkamp** believed that the artificial pocket between the root tip and the surrounding soft tissue would not be epithelized and that it represented a permanent path of infection.

Kaare Langeland and Larz Spangberg, 1975[26] conducted Screening tests involving tissue culture and implantation in small animals and usage tests in monkeys were performed to evaluate biologic aspects of dental implants. They concluded that

1. Implanting any material in a canal drilled in bone caused tissue destruction and inflammation.
2. Corrosion products appeared in the tissue around metallic implants, but local reaction was mild.
3. Inflammation related to bacterial plaque occurred around all implants exposed to the oral cavity in animals and human beings.
4. Epithelial growth occurred around the implant.
5. After longer observation periods, implants having no communication with the oral cavity, or totally implanted in rat subcutaneous tissues, were surrounded by a fibrous tissue and showed only low-grade chronic inflammation, if any.

According to D.M. Brunette Dental implants vary markedly in the topography of the surfaces that contact cells. Four principles of cell behavior first observed in cell culture explain to some extent the interactions of cells and implants. (*1*) *Contact guidance* aligns cells and collagen fibers with fine grooves, such as those produced by machining. *(2) Rugophilia* describes the tendency of macrophages to prefer rough surfaces. *(3) The two-center effect* can explain the orientation of soft connective tissue cells and fibers attached to porous surfaces.(4) *Haptotaxis* may be involved in the formation of capsules around implants with low-energy surfaces.

K. Satomi et al (1988)[27] conducted the study on tissue response to implanted ceramic-coated titanium alloys in rats. They concluded that ceramic-coated titanium alloys showed good tissue compatibility, but this coating technique lacks uniformity. Thus, quality control of the implants which are produced is very important. Proper manufacturing and quality control of coated metals would minimize the potential problems of metals which were shown to be tissue-compatible.

Elin Barth et al (1990)[28] had compared the reparative processes around cylindrical glass-ceramic-coated and pure titanium implants placed in feline femurs. Six weeks after implant placement, bone specimens with inserted implants were prepared for histologic examination including histomorphometric quantification of the relative implant surface areas that were in contact with bone. The glass-ceramic implants were surrounded by a 0.2- to 0.5-mm envelope of fibrous connective tissue. By contrast, the major part of the titanium implants (81% ± 5%) was in direct contact with living lamellar or woven bone. Thus, titanium and glass ceramic evoked different reparative processes when implanted in bone, and only the titanium implants appeared to become osseointegrated.

A. Garcia et al (1990)[29] studied the bone reactions around transplanted roots. Results demonstrated that bone volume was higher in the proximal versus distal area in the maxilla and mandible preserved groups. The adipocyte content of the marrow spaces, an index of bone maturation, was less pronounced in the proximal

versus distal area in the preserved groups. The number of osteoclasts was higher in the proximal zone in the preserved groups as were the

Extents of the different bone remodeling activities. The results indicate that the organization of PDL around transplanted roots is associated with rearrangement of the bone tissue surrounding the grafts. This process of long duration might be an adaptation to the likely low mechanical strains applied on bone through the root.

Adriano Piattelli et al (1993)[30] had done the study on bone reactions to hydroxyapatite-coated dental implants in humans. Two hydroxyapatite-coated IMZ implants, extracted for psychiatric reasons, were prepared using a cutting-grinding system and studied with scanning electron microscopy and laser scanning microscopy. The examination showed tissue integration with a very intimate bone-implant contact. Laser scanning showed the presence of a layer of dark staining material, resembling a reversal line of bone tissue, at the bone-implant interface, which could be the result of a film of organic material deposited on the bone and hydroxyapatite surfaces.

Bodine and Mohammed examined a subperiosteal implant removed during an autopsy and reported that the tissue reaction around the metal was mostly a fibrous connective tissue encapsulation without active inflammation. However, in some areas, bone was directly apposed to the implant.

IMPLANT MATERIALS ON OSSEOINTEGRATION

Daniel A. Garcia et al, (1981)[31] also measured the biocompatibility of dental implant materials measured in an animal model. They found that neither material accelerated resorption, but formation was inhibited 12% by vitallium and 38% by PMMA.

O.T. Altay et al, (1991)[32] examined the biological effects of implanted magnetic fields on the bone tissue of dogs. Five titanium caps were implanted in the mandibles of five dogs. Three caps contained Sm-Co mini magnets and two caps were empty. The aim of this study was to determine if implanted magnetic fields had any biological effects on the bone tissue of dogs. At the end of 6 months, the animals were sacrificed and segments containing implants and segments from the side opposite the implants, for control, were removed. Sections were made from the specimens and no pathology was seen upon microscopic examination after 6 months.

Carl-Johan Ivanoff et al, (2003)[33] had done histologic evaluation of bone response to oxidized and turned titanium micro-implants in human jawbone. Surface roughness and enlargement were greater for the oxidized implants than for the turned implants. All micro-implants, except for 2 controls, were found to be clinically stable at the time of retrieval.

Histomorphometric evaluation demonstrated significantly higher bone-to-implant contact for the oxidized implants, whether placed in the maxilla or in the mandible. Significantly more bone was found inside the threaded area for the oxidized implants placed in the mandible and maxilla, but there was no difference between implants with regard to position (maxilla or mandible). The stronger bone response to the oxidized implants may have contributed to the fact that 2 control implants but no test implants were lost. The reason for these findings may depend on one or multiple differences of the surfaces between test and control implants: (1) the thicker oxide layer itself, (2) increased surface roughness, (3)different surface morphology in terms of porosity, or (4) change in crystal structure. The present histologic study in human jawbone demonstrated a significantly higher bone response for anodic oxidized titanium implants than for implants with a turned surface.

Darryl C. Tong et al, (1998)[34] reviewed the survival rates for implants placed in grafted maxillary sinuses using meta-analysis. A variety of materials and procedures are used to create adequate bone volume in the maxillary sinus for placement of endosseous implants in the posterior atrophic maxilla. This review

used the structured method of metaanalysis to evaluate the survival of the implants placed into various materials that have been used in the maxillary sinus with the sinus lift procedure.

M. T. Karagianes,(1976)[35] studied in porous metallic and ceramic dental implants were designed, fabricated, and implanted into fresh and healed alveolar sites of extracted mandibular premolar teeth in miniature swine. Bone in growth securely anchored the implants; intraoral devices were later attached to study the effects of stress on implant stability.

Bone is a specialized mineralized tissue. Tissues are group of cells embedded in a structural framework or matrix.

Bone is classified as either Compact bone (referred to as Cortical bone) or Spongy bone (referred to as Cancellous bone).

The difference between them depends upon the relative upon relative amount of solid matter and the size and the size and number of spaces in each. They both contain the same histological elements. The relative portions of these two types of bone vary according to the needs for strength or lightness of weight.

Compact bone has outer circumferential lamellae, inner circumferential lamellae, haversian lamellae, and interstitial lamellae which account for hardness and density of this bone. It is covered by periosteum and is attached tightly to the bone surface by Sharpey's fibers and serves as protection for bone.

Within compact bone, spongy bone has a three-dimensional network called bone trabeculae. Spongy bone architecture is cavernous and less dense such that the hardness is less when compared to compact bone. The bone trabeculae configuration creates a large surface area for an abundance of osteoblasts and osteoclasts. The osteoblasts and osteoclasts are associated with bone formation and resorption respectively. Large blood vessels traverse within bone trabeculae.

Spongy bone with less density and less hardness is not a stable base for primary fixture fixation. Only compact bone can provide a stable base for primary fixture fixation.

BONE CELLS:-

Bone cells are of 3 types:-

1. Osteoblasts
2. Osteocytes
3. Osteoclasts

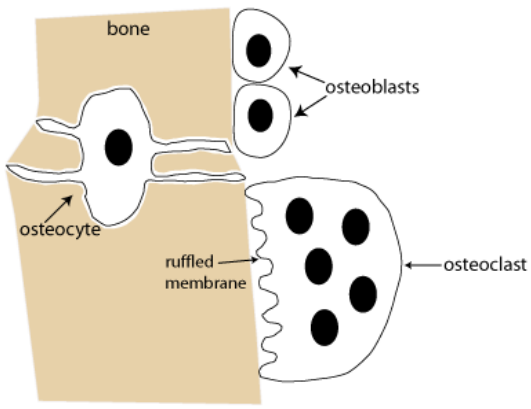


Fig 6 bone cells

OSTEOBLASTS:-

As their name suggests are associated with bone formation and are found on the margins of growing bone. During the period of growth they are arranged in cuboidal in low columnar cells joined together by cell processes. Osteoblasts synthesize collagenous and non collagenous bone proteins.

OSTEOCYTES:-

These are trapped osteoblasts in bone matrix. They are less active than osteoblasts, hence the organelles are less prominent. The osteocytes are not involved with bone formation but rather with bone maintenance and modification of bone matrix and with mineral balance. Osteocytes gradually lose their matrix forming capacity.

OSTEOCLASTS:-

They cause bone resorbtion, they are multinucleated cell and compared to other cells is a much larger cell.

STRUCTURE OF ALVEOLAR BONE:-

The alveolar process may be defined as that part of the maxilla and mandible that forms and supports the sockets of the teeth. Anatomically there exists no distinct boundary between the body of the maxilla or the mandible and their respective alveolar processes.

Two parts of the alveolar process can be clearly distinguished. The first consists of a thin lamella of bone that surrounds the root of the tooth and gives attachment to principal fibers of periodontal ligament. This is the Alveolar bone proper.

The second part that which surrounds the alveolar bone proper and gives support to the socket is known as supporting alveolar bone. It contains 2 parts:-

1. Cortical plates, which consists of compact bone and form the outer and inner plates of alveolar process.
2. The spongy bone, which fills the area between these plates and the alveolar bone proper.

In the mandible, the spongy bone is denser than the spongy bone present in the maxilla. Hence healing period in the maxilla is longer than in the mandible. When performing surgical procedures in the maxilla, it is crucial to obtain proper primary fixation for successful osseointegration.

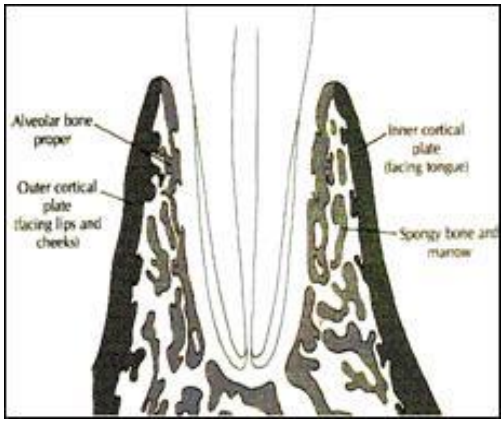


Fig 7 structure of bone

BONE HEALING

An injured bone heals either by primary or secondary process. 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.

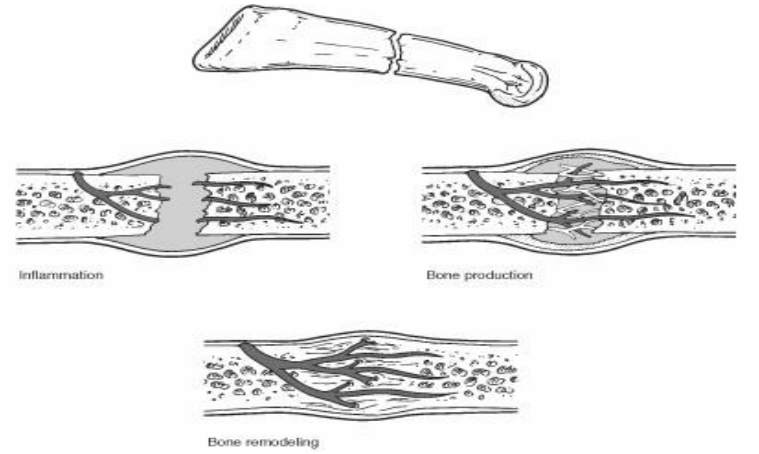


Fig 8 bone healing

Phases of bone healing:

a. Injury phase:

One way of looking at the initiation of bone repair is to regard ‘injury’ as the initiating mechanism. Injury is known to act as a releasing stimulus for various growth factors as well as to sensitize various cell types.

b. Granulation phase:

The second healing phase at a few weeks after injury has been termed the granulation stage. At this time new local connective tissue, new capillaries and supportive tissue appear, whereas an abundant new bone formation is generally not seen until the next healing stage.

c. Callus phase:

In the so-called of bone healing, a delicate balance establishes among the several tissues that proliferate in the case of a bone injury. Information between the different cellular subgroups is maintained via chemical signals-

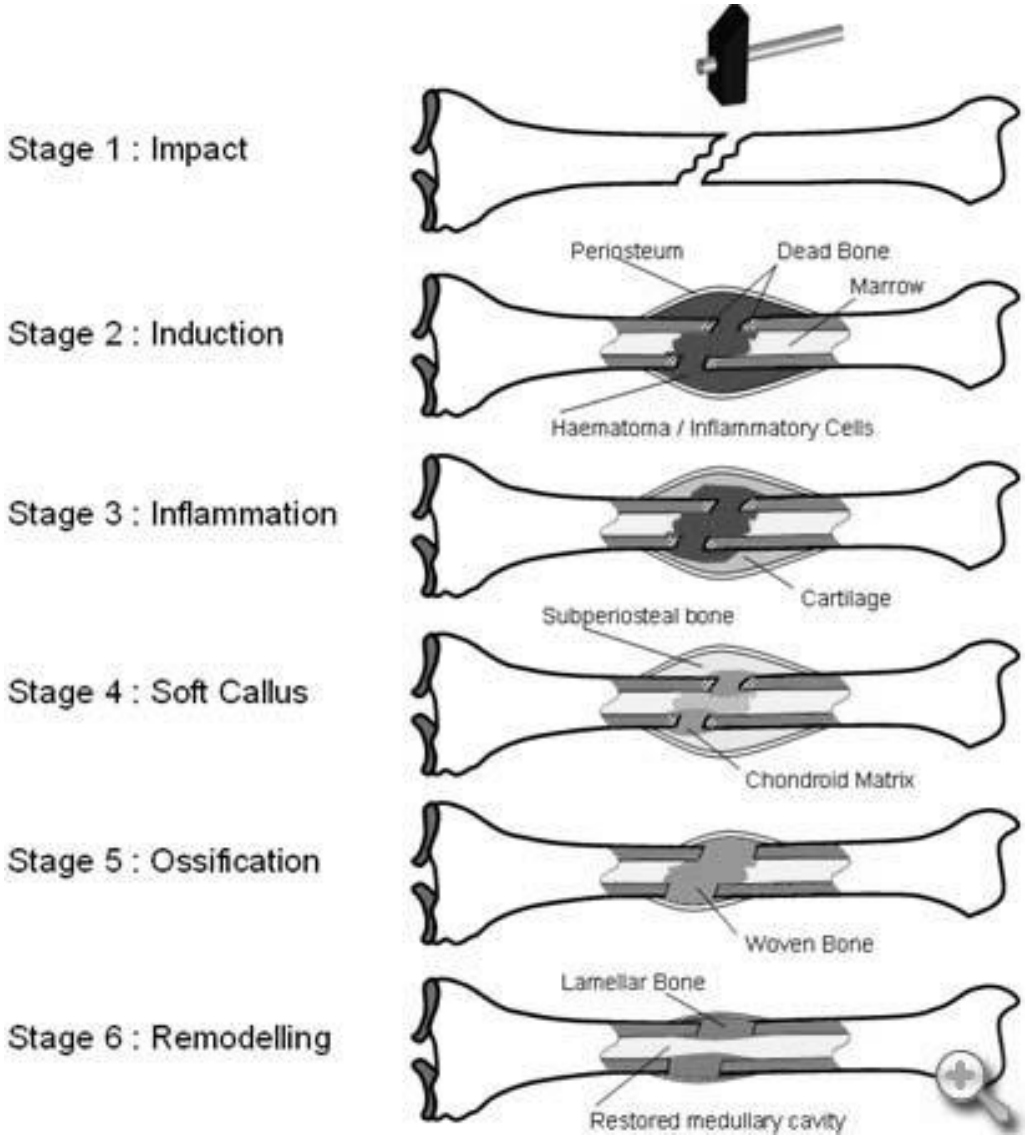


Fig 9 phases of bone healing

✓ Linkow in (1970) classified bone density into 3 categories:-

1. Class I Bone structure → Ideal bone type consist of evenly spaced trabeculae with small cancelated space.

2. Class II Bone structure →slightly larger cancelated space with less uniformity of osseous pattern.

3. Class III Bone structure →large marrow filled space exists between bone trabeculae.

✓ Linkow stated Class III → Loose fitting implant

Class II → Satisfactory

Class I → Very satisfactory foundation

✓ In 1985 Lekholm and Zarb listed 4 bone qualities

Quality Q1 → Homogenous compact bone

Quality Q2 → Thick layer of compact Bone surrounding a coarse dense trabecular bone

Quality Q3 → Thin layer of cortical bone surrounding dense trabecular bone

Quality Q4 → Thin layer of cortical bone surrounding low density trabecular bone

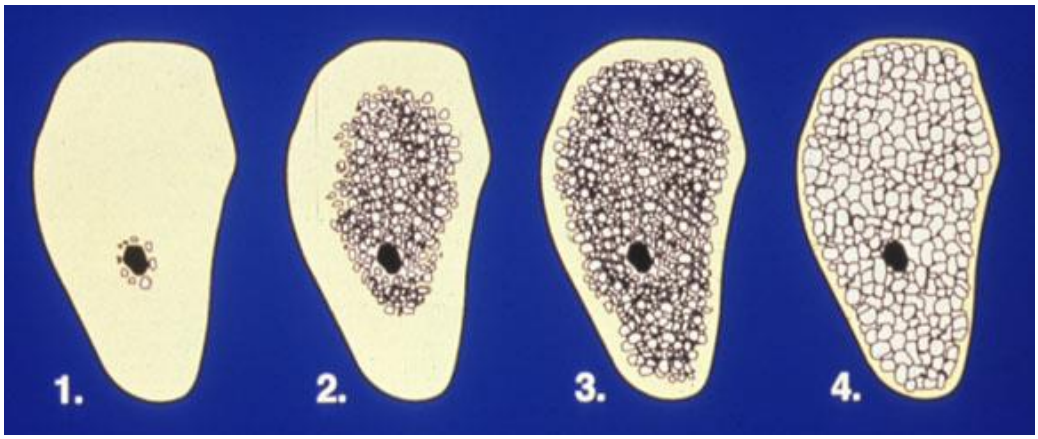


Fig 9. Bone density types

✓ Misch bone density classification

In 1985 Misch extended four bone density groups independent of regions of jaw based on macroscopic cortical and trabecular bone.[36]

Dense and/or porous cortical bone is found on the outer surface of the bone and includes the crest of the edentulous ridge.

Course and fine trabecular bone are found within the outer shell of cortical bone. [13]

Bone	Density
D1	Dense cortical bone
D2	Thick dense cortical bone on crest and course trabecular bone within
D3	Thin porous cortical bone on crest and fine trabecular bone within.
D4	Fine Trabecular bone
D5	Immature nonmineralized bone

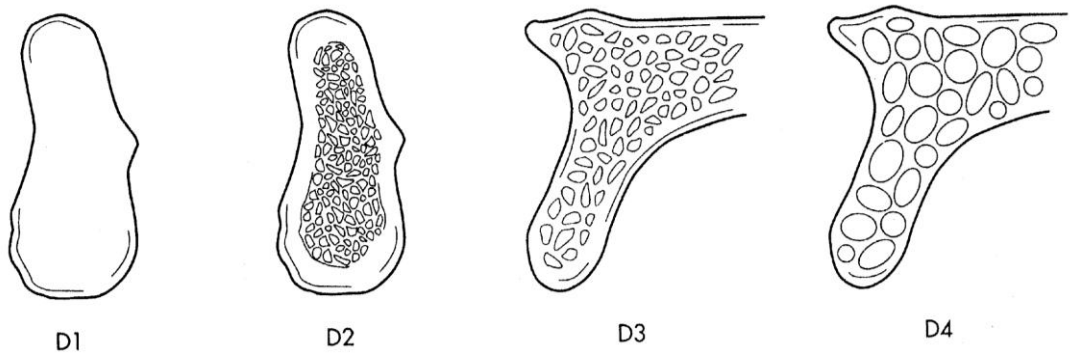


fig 10. **Site Classification for osseointegrated implant**

Diagnostic imaging and techniques help develop and implement a cohesive and comprehensive treatment plan for the implant team and the patient.

The objectives of diagnostic imaging depend on a number of factors, including the amount and type of information required and the time period of the treatment rendered.

The decision of when to image along with which imaging modality to use depends on the integration of these factors

And can be organized into three phases:-

- ✓ Phase one is termed *preprosthetic implant imaging* and involves all past radiologic examinations along with new radiologic examinations chosen to assist the implant team in determining the patient's final and comprehensive treatment plan.

  The objectives of this phase of imaging include all necessary surgical and prosthetic information to determine the quantity, quality, and angulations of bone; the relationship of critical structures to the prospective implant sites; and the presence or absence of disease at the proposed surgery sites.

- ✓ Phase two is termed *surgical and interventional implant imaging* and is focused on assisting in the surgical and prosthetic intervention of the patient.

  The objectives of this phase of imaging are to evaluate the surgery sites during and immediately after surgery, assist in the optimal position and orientation of dental implants, evaluate the healing and integration phase of implant surgery, and ensure that abutment position and prosthesis fabrication are correct.

- ✓ Phase three is termed *postprosthetic implant imaging.* This phase commences just after the prosthesis placement and continues as long as the implants remain in the jaws.

  The objectives of this phase of imaging are to evaluate the long-term maintenance of implant rigid fixation and function, including the crestal bone levels around each implant, and to evaluate the implant complex.

DIAGNOSTIC IMAGING

The decision to image the patient is based on the patient's clinical needs. Once a decision had been made to obtain images, the imaging modality is used that yields the necessary diagnostic information related to the patient's clinical needs and results in the least radiologic risk.

Many imaging modalities have been used for implant imaging, including devices recently developed specifically for dental implant imaging. Some of the imaging modalities that have been reported as useful for dental implant

Imaging include

- ✓ Periapical (analog)
- ✓ Panoramic (analog)
- ✓ Occlusal (analog)
- ✓ Cephalometric radiograbhy (analog)
- ✓ Tomographic radiography
- ✓ Computed tomography (three dimensional)
- ✓ Magnetic resonance imaging (three dimensional)
- ✓ Interactive computed tomography (three dimensional).

PRESURGICAL IMAGING: -

This phase of implant imaging is intended to evaluate the current status of the patient's teeth and jaws and to develop and refine the patient's treatment plan.

The global objective of this phase of treatment is to develop and implement a treatment plan for the patient that enables restoration of the patient's function and esthetics by the accurate and strategic placement of dental implants.

The specific objectives of preprosthetic imaging are to:-

1. Identify disease,
2. Determine bone quantity,
3. Determine bone density,
4. Identify critical structures at the proposed implant regions,
5. Determine the optimum position of implant placement relative to occlusal loads.

PERIAPICAL RADIOGRAPHY

Periapical radiographs are images of a limited region of the mandibular or maxillary alveolus. Periapical radiographs are produced by placing the film intraorally parallel to the body of the alveolus with the central ray of the x-ray device perpendicular to the alveolus at the region of interest, producing a lateral view of the alveolus.

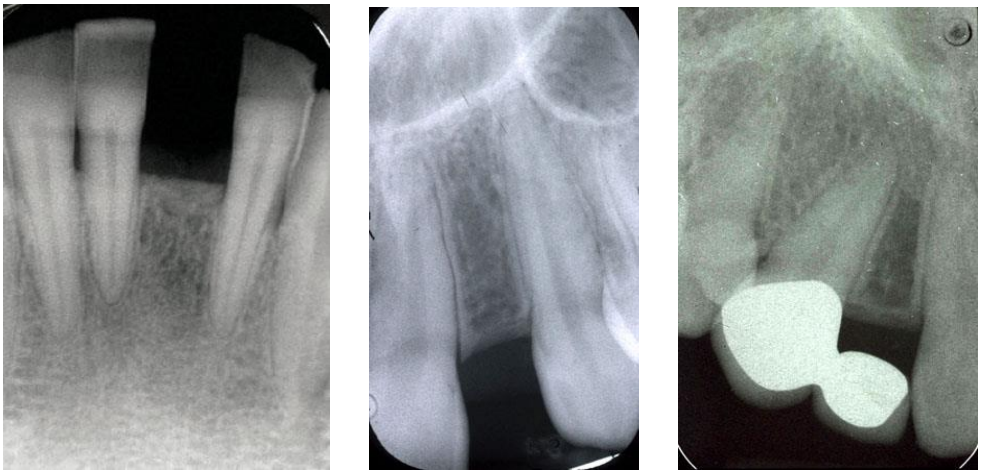


Fig 11 periapical radiograph

ADVANTAGES: -

- ✓ Low radiation dose.
- ✓ Minimal magnification with proper alignment and positioning.
- ✓ High resolution.
- ✓ Inexpensive.

LIMITATIONS: -

- ✓ Distortion and magnification.
- ✓ Minimal site evaluation.
- ✓ Difficulty in film placement.
- ✓ Technique sensitive.
- ✓ Lack of cross-sectional imaging.

INDICATIONS: -

- ✓ Evaluation of small edentulous spaces.
- ✓ Alignment and orientation during surgery.
- ✓ Recall/maintenance evaluation.

OCCLUSAL RADIOGRAPHY

Occlusal radiographs are planar radiographs produced by placing the film intraorally parallel to the occlusal plane with the central x-ray beam perpendicular to the film for the mandibular image and oblique (usually 45 degrees) to the film for the maxillary image.

Occlusal radiography produces high-resolution planar images of the body of the mandible or the maxilla.

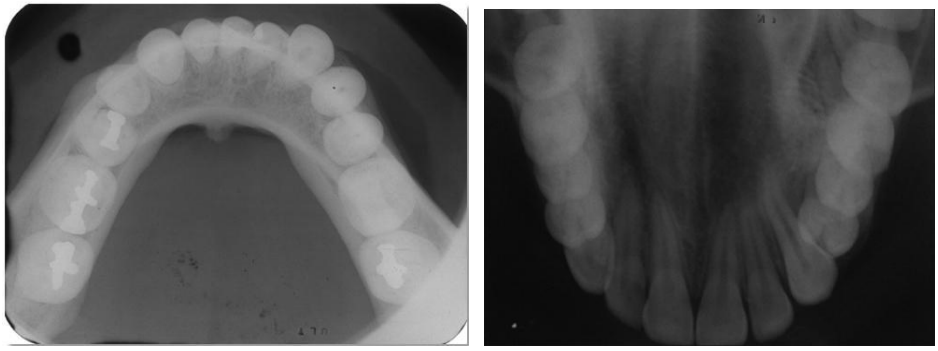


Fig 12. Occlusal radiograph

ADVANTAGES: -

- ✓ Evaluation for pathology.

LIMITATIONS: -

- ✓ Does not revail true buccolingual width in mandible.
- ✓ Difficulty in positioning.

INDICATIONS

- ✓ None.

LATERAL CEPHALOMETRIC RADIOGRAPHY: -

Cephalometric radiographs are oriented planar radiographs of the skull. The skull is oriented to the x-ray device and the image 'receptor using a cephalometer, which physically fixes the position of the skull with projections into the external auditory canal. The geometry of cephalometric imaging devices results in a 10% magnification of the image with a 60-inch focal object and a 6-inch object-to-film distance.

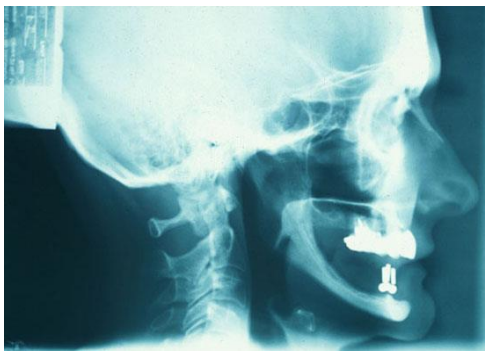


Fig 13. LATERAL CEPHALOMETRIC RADIOGRAPHY

ADVANTAGES: -

- ✓ Height/width in anterior region.
- ✓ Low magnification.
- ✓ Skeletal relationship.
- ✓ Crown-implant ratio (anterior).
- ✓ Tooth position in prosthesis.
- ✓ Evaluation of the quantity of bone in anterior region prior to symphysis grafting.

LIMITATIONS: -

- ✓ Availability.
- ✓ Image information limited to midline.
- ✓ Reduced resolution and sharpness.
- ✓ Technique sensitive.

INDICATIONS: -

- ✓ Used in combination with other radiographic techniques for anterior implants.
- ✓ Symphysis bone graft evaluation.

PANORAMIC RADIOGRAPHY: -

Panoramic radiography is a curved plane tomographic radiographic technique used to depict the body of the mandible, maxilla, and the lower one half of the maxillary sinuses in a single image. This modality is probably the most used diagnostic modality in implant dentistry. However, for quantitative preprosthetic implant imaging, panoramic radiography is not the most diagnostic. This radiographic technique produces an image of a section of the jaws of variable thickness and magnification.

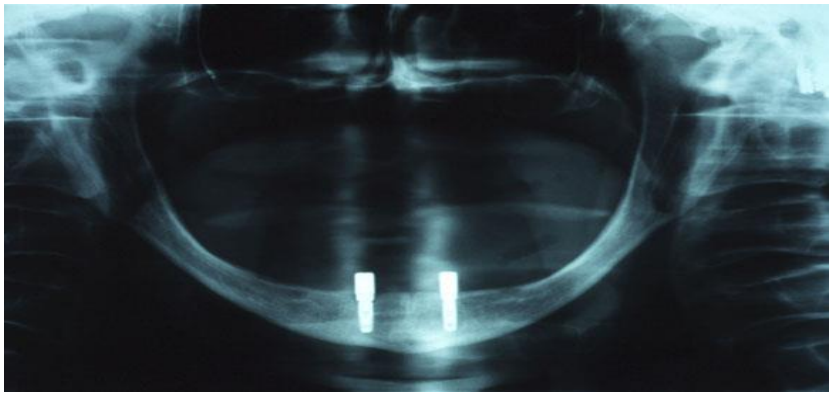


Fig 14. PANORAMIC RADIOGRAPHY

ADVANTAGES:-

- ✓ Easy identification of opposing landmarks.
- ✓ Initial assessment of vertical height of bone
- ✓ Conveniences, ease, and speed in performance in most dental offices.
- ✓ Evaluation of gross anatomy of the jaws and any related pathologic findings.

LIMITATIONS:-

- ✓ Distortions inherent in the panoramic system.
- ✓ Errors in patient positioning.
- ✓ Does not demonstrate bone quality.
- ✓ Misleading quantitate because of magnification and no third dimension.
- ✓ No spatial relationship between structures.

TOMOGRAPHY: -

Tomography is a generic term formed from the Greek words *tomo* (slice) and *graph* (picture) that was adopted in 1962 by the International Commission on Radiological Units and Measurements to describe all forms of body section radiography. Body section radiography is a special x-ray technique that enables visualization of a *section* of the patient's anatomy by blurring regions of the patient's anatomy above and below the section of interest.[37]

ADVANTAGES: -

- ✓ Cross-sectional views.
- ✓ Constant magnification.

LIMITATIONS: -

- ✓ Availability.
- ✓ Cost.
- ✓ Multiple images needed.
- ✓ Technique sensitive.
- ✓ Blurred images.
- ✓ High radiation dose.

INDICATIONS: -

- ✓ Single-site evaluation.
- ✓ Vital structures evaluation.

COMPUTED TOMOGRAPHY

The discovery and development of CT revolutionized medical imaging. CT is a digital and mathematical imaging technique that creates topographic sections where the topographic layer is not contaminated by blurred structures from adjacent anatomy. In addition, and probably most important, CT enables differentiation and quantification of soft and hard tissues. Thus for the first time in medical imaging, the radiologist could view hard and soft tissues on an image without performing an invasive procedure on a patient, such as the injection of contrast media.

CT was invented by Sir Hounsfield and was announced to the imaging world in 1972, but it had its origins in mathematics (1917) and in astrophysics (1956). The first CT scanners appeared in medical imaging departments during the mid-1970s and were so successful that they largely replaced complex tomography by the early 1980s.[38]

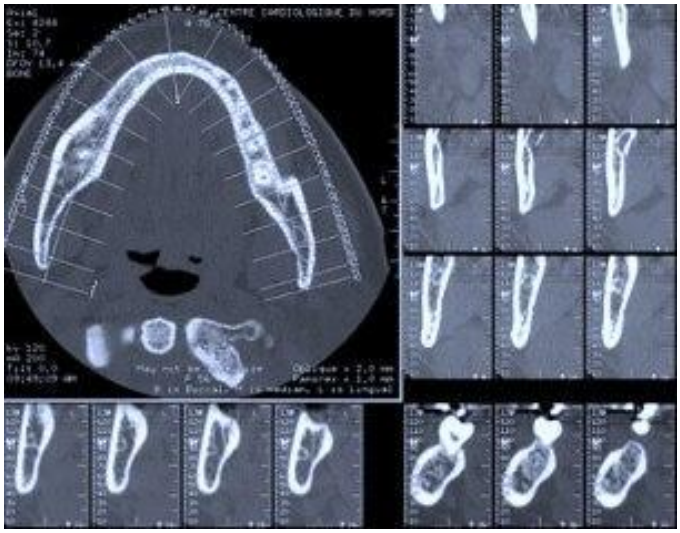


Fig 15. COMPUTED TOMOGRAPHY

ADVANTAGES: -

- ✓ Negligible magnification.
- ✓ Relatively high-contrast image.
- ✓ Various views.
- ✓ Three-dimensional bone models.
- ✓ Interactive treatment planning.
- ✓ Cross-referencing.

LIMITATIONS: -

- ✓ Cost.
- ✓ Technique sensitive.

INDICATIONS: -

- ✓ Interactive treatment planning.
- ✓ Determination of bone density.
- ✓ Vital structure location.
- ✓ Subperiosteal implant fabrication.
- ✓ Determination of pathology.
- ✓ Preplanning for bone augmentation.

MAGNETIC RESONANCE IMAGING: -

MRI is a technique developed in medical imaging that is probably the most innovative and revolutionary other than CT. MRI is a technique to image the protons of the body using magnetic fields, radio frequencies, electromagnetic detectors, and computers. The technique was announced first by Lauterbur in 1972. Useful medical images were produced in the early 1980s, and MRI now is a cornerstone of medical imaging.[39]

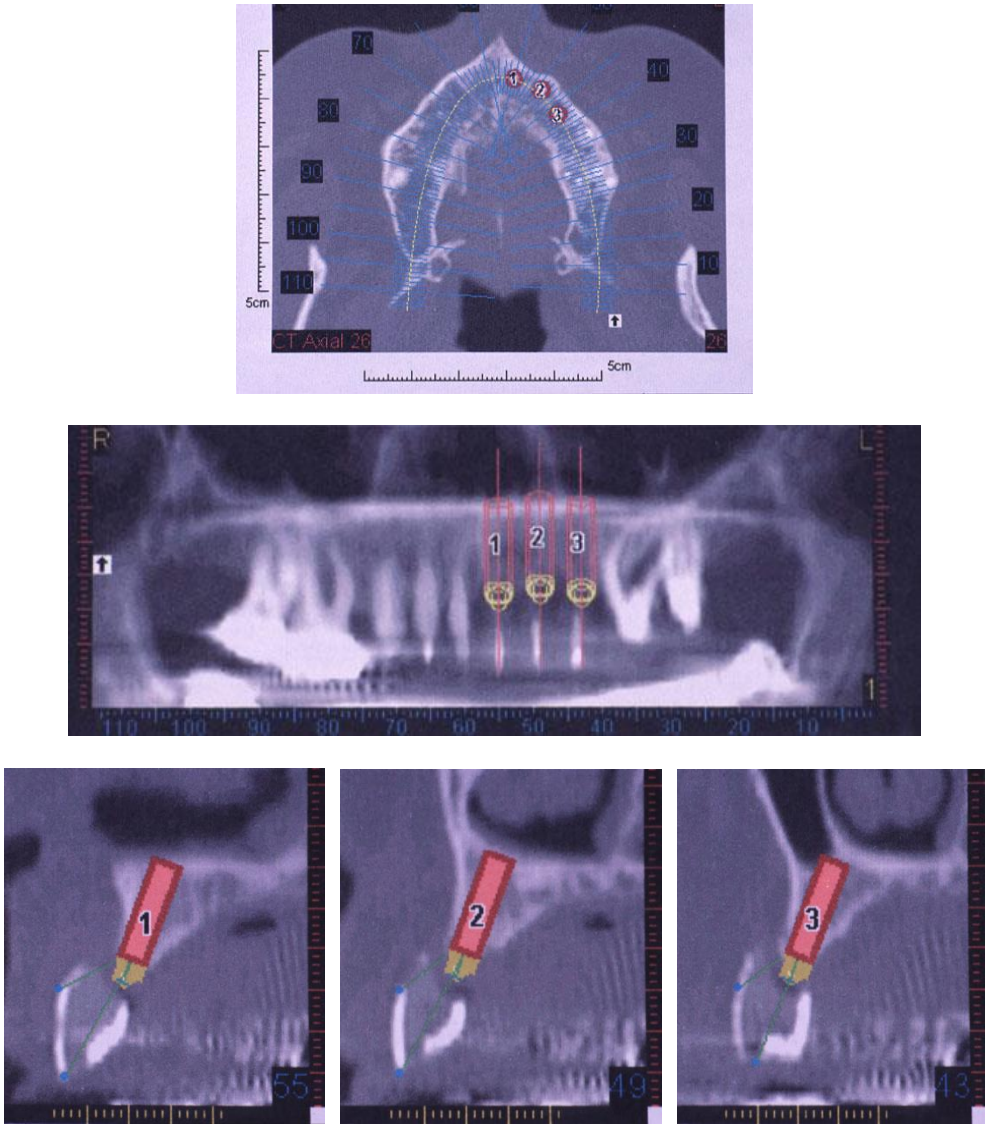


Fig 16. MAGNETIC RESONANCE IMAGING

ADVANTAGES: -

- ✓ No radiation.
- ✓ Vital structures are easily seen.

LIMITATIONS: -

- ✓ Cost.
- ✓ Technique sensitive.
- ✓ No reformatting software.
- ✓ Availability.
- ✓ Nonsignal for cortical bone.

USES: -

- ✓ Evaluation of vital structures when computed tomography is not conclusive.
- ✓ Evaluation of infection.

IMPLANT IMAGING IN PERSPECTIVE:-

The purpose of implant imaging is to assist the implant team in restoring the patient's occlusion and function by providing accurate and reliable diagnostic information on the patient's anatomy at the proposed implant sites. CT andICT fulfill more of the objectives of preprosthetic imagingthan periapical radiography, cephalometric radiography, panoramic radiography, and tomography. Computed tomography and ICT determine the absolute bone quantity, bonequality, and the relationship to critical structures at a level of precision considerably greater than that of tomography,periapical radiology, br-panoramic radiology.

For instance, bone quantity determination to accuracy of +1 mm occurs in about'95% of cases that use CT and only 30% of cases that use panoramic radiology. Furthermore, for mandibular cases, the inferior alveolar canal cannot be identified in more than 30% of cases that use periapical, panoramic, or tomographic techniques, whereas CT can identify them. Inferior alveolar canal in almost 100% of cases.

With the use of ICT and ES the implant team can determine bone quality directly at the prospective implant sites and develop an electronic three-dimensional treatment plan that can be converted into a stereotactic surgical guide to assist in executing the treatment plan at surgery. For surgical imaging, periapical or digital periapical radiography should be considered the modality of choice.

FACTORS AFFECTING OSSEOINTEGRATION

EVALUATION OF OSSEOINTEGRATION

Dale E. Smith,(1990)[41] had given the review of endosseous implants for partially edentulous patients:-

Schnitman et al, (1991)[42] have suggested the following advantages of implants over traditional restorative techniques:

1. The need to prepare teeth for retainers is reduced or eliminated.
2. Abutments can be provided to eliminate the need for distal extension base removable partial dentures.
3. Interdental abutments can be provided for long-span fixed partial dentures.
4. Teeth with questionable periodontal prognoses need not be maintained but can be replaced by an implant with an improved prognosis.[16]

Clark M. Stanford et al, (1991)[43] had given the review on the concept of osseointegration and bone matrix expression. This review evaluates the basic science work performed on this concept and then applies the concept to the principle of osseous healing. Specific studies are cited where alterations in the healing response are due to clinical management of implant placement and how studies of surface properties may lead to further insights on implant design and prognosis. In addition, a review of bone expression as a function of *in vitro* stress applications is given. This is followed by an in-depth review of the collagens and noncollagenous proteins, described to date, within isolated bone matrix.

Bo Rangert et al, (1991)[44] Johan Gunne, and Daniel Y. Sullivan had done the study on mechanical aspects of a Branemark implant connected to a natural tooth. They concluded that the therapy of a single Branemark implant connected to a natural tooth should be considered without any additional element of a flexible nature. Mechanical tests and theoretical considerations, however, indicate that the transverse mobility of the connected tooth should be limited and that the attachment of the prosthesis to the tooth should be of a rigid design to avoid gold-screw loosening**.**

Edwin L.C. Scher, (1991)[45] had given a case report on the use of osseointegrated implants in long-span fixed partial prosthesis. They found two osseointegrated Core-Vent implants were successfully used to provide the necessary support.

Daniel Buser,(1991)[46] had done the study on tissue integration of one-stage ITI implants. They concluded that one-stage ITI implants can achieve successful tissue integration on a predictable basis and that it can be maintained over a period of at least 3 years. Fifty-four implants were placed in 38 partially edentulous patients. Following healing (at least 3 months), all 54 implants were free of peri-implant infections and revealed no detectable mobility. Radiographs showed no signs of peri-implant radiolucencies, and the implants were in favorable positions for prosthetic restoration. Following incorporation of fixed partial dentures, patients were enrolled in a hygiene recall program with 3-month intervals and were examined once a year.

Based on predefined criteria, each implant was classified as successful or failing. After the 3-year observation period, 51 of 53 implants (96.2%) were considered successfully integrated. (One patient with one implant dropped out of the study.) Two implants exhibited recurrent peri-implant infections and were classified as late failures.[20]

Edwin A. McGlumphy, (1992)[47] had done the study on implant superstructures. This study compared the force necessary to cause failure in many of the more commonly used implant and abutment combinations. An 18-mm cantilever test prosthesis was constructed for each system and loaded on an MTS machine until failure occurred (n = 5 for each sample). The mean failure forces ranged from 1.22 to 17.23 kg. The failure force and location of failure for each individual system are reported.

Paul P. Binon et al,(1992)[48] had done the study on surface analysis of an original branemark implant and three related clones. They found considerable differences in surface and near-surface contaminants were demonstrated. The fixture treated with radiofrequency glow discharge (plasma) demonstrated the thinnest titanium oxide layer and the cleanest surface.

Lawrence A. Weinberg had done the study on the biomechanics of force distribution in implant-supported prostheses. Force distribution with natural teeth depends on micro movement induced by the periodontal ligament. The location and cusp inclination of the tooth qualitatively alter the force pattern.

Osseointegrated implants do not have micro movement associated with force distribution. Force distribution to the osseointegrated implant interface is completely different than with natural teeth. Alterations in tooth location and cusp inclination are suggested to limitimplant overload. Force distribution in splinted natural teeth and osseointegrated prostheses are compared. The mechanism of interface force distribution and the consequences of poor interface fit are interrelated. The differential mobility of splinted natural teeth affects diagnosis and treatment. However, combining natural teeth with an osseointegrated prosthesis requiresnew design principles.

Douglas V. Ciiayt,(1993)[49] had given the reviewed on clinical criteria for determining implant success. The development of performance criteria for implants has been linked to technical progress and related to clinical practice. Clinicians can define reasonable treatment goals, acceptable to patients, to their own consciences and to the profession. In evaluating progress toward these goals, the clinician will make judgments about the merit and worth of the treatments and the goals. The framing of research questions, and the defining of criteria for measuring progress, will benefit from these judgments. In the cycle of knowledge creation and evaluation, the clinician's judgment will be informed by the researcher's criteria.

Torsten jemt,(1993)[50] had done the study on implant treatment in elderly patients. A group of 46 patients, all more than 80 years old (mean age 82.7 years) at first implant surgery, who received a total of 254 implants, were followed in one clinical center. Of the exposed implants, 6 of 238 (2.5%) were found to be loose at second-stage surgery, and another 3 implants were lost during the follow-up period. Most patients had minimal post placement problems, similar to what has been observed in younger patients. However, some patients (10%) experienced obvious problems with general adaptation and muscle control, which has not been observed in younger patients. Patients in this study eventually adapted to their new prostheses, despite obvious problems. These problems seemed to relate to the muscular learning process, which is prolonged in elderly

patients. Marginal bone response around the neck of the implant showed a pattern of modeling and remodeling which was similar to that found in younger age groups. Healthy, vital elderly patients can be provided with osseointegrated dental implants with implant prognoses comparable to those found for younger patients.

Ana Rita Nóbrega et al, (2012)[51] conducted a comparative study in the rabbit for the osteotome versus conventional drilling technique for implant site preparation. A total of 20 implants (4-mm diameter, 8.5-mm long) were placed in the distal femural condyle of 10 New Zealand White rabbits. The implant sites were prepared by using either the conventional drilling technique as a control group (group A) or the osteotome technique (group B). Cutting torque and resonance frequency analyses (RFAs) were conducted at and after implant placement. The resulting values were subjected to correlation and comparative analyses between groups. Insertion torquemeasurements were conducted at three different levels of implant insertion: crestal, middle, and apical. Group B showed higher mean insertion torque and RFA values ($P < .05$). No statistically significant correlation could be observed when comparing the mean torque values with RFA values ($P > .05$). Bone condensation before implant insertion in low-density bone led to higher mean insertion torque and RFA values. Within the limits of this experimental study, a benefit in using the osteotome technique was observed when dealing with low-density bone. Bone condensation can improve primary stabilization of implants.

GENERALISED SURGICAL WOUND HEALING

The generalized healing of tissues around an implant involves a complex array of events that occur between the initial placement of the implant and the eventual healed result.

Wound healing can be broken down into three fundamental phases:

- Inflammation.
- Proliferation.
- Maturation.

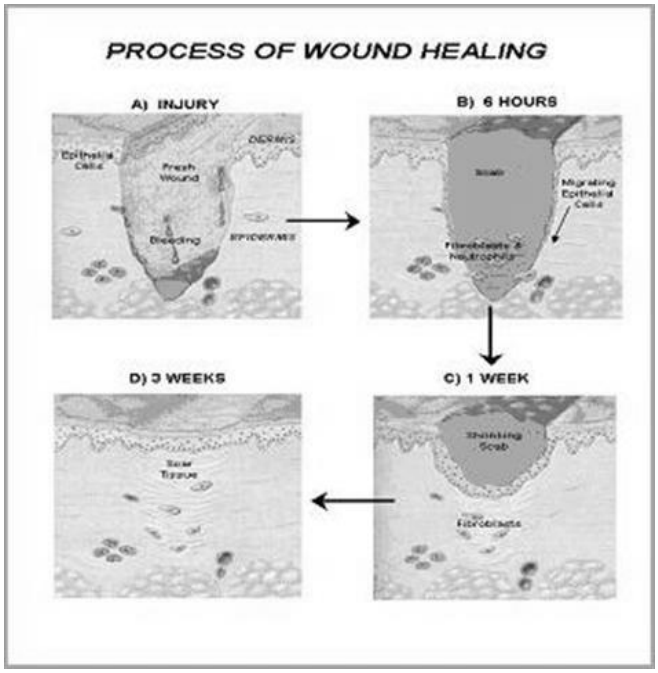


Fig 18. GENERALISED SURGICAL WOUND HEALING

There is significant overlap between these three phases, but each one can be noted to be dominant during certain periods of the healing process.

Replacement of lost or damaged tissues occurs by one of two methods: Repair or Regeneration.

Regeneration results in tissues that are structurally and functionally indistinguishable from their pre-injured state. Normal fracture healing is an example of regeneration.

Not all tissues, however, have the capacity for regeneration. Some tissues, for example skin, heal by formation of fibrous connective tissue "scar" that is structurally and functionally different from the pre-injured state, so called Reparative healing.

After the surgical placement of implants into their endosteal locations, reparative healing occurs relatively predictably for the mucoperiosteal complex. [1]

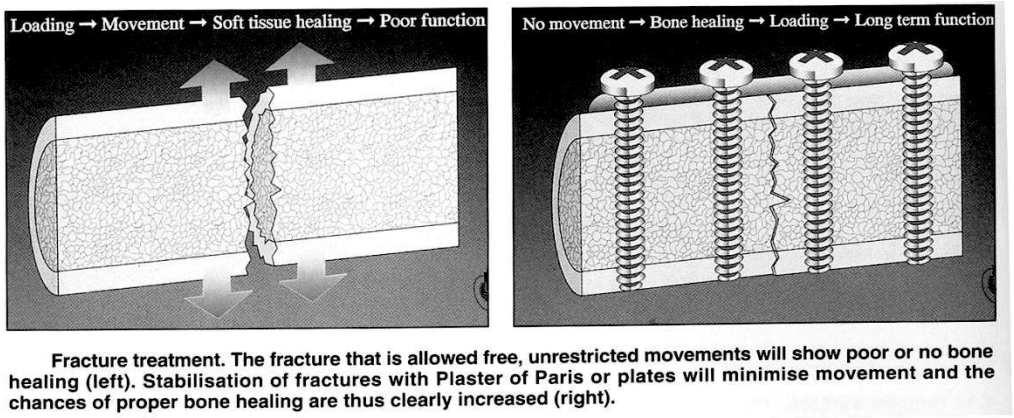
PHASES OF GENERALIZED WOUND HEALING

PHASE	TIMING	SPECIFIC OCCURENCE
Inflammatory phase	Day 1-10	Platelet aggregation and activation Clotting cascade activation Cytokine release Nonspecific cellular inflammatory response Macrophage-mediated inflammation.
Proliferative phase	Day 2-42	Neovascularization Differentiation, proliferation, and activation of cells Deposition of immature collagen, elastin, and ground substance
Maturation phase	After day 21	Connective tissue remodelling

BONE HEALING

After the surgical placement of implants into endosteal locations, the traumatized bone around implants begins the process the wound healing, which can be separated into:

- Inflammatory phase.
- Proliferative phase.
- Maturation phase.



Fracture treatment. The fracture that is allowed free, unrestricted movements will show poor or no bone healing (left). Stabilisation of fractures with Plaster of Paris or plates will minimise movement and the chances of proper bone healing are thus clearly increased (right).

Fig 19.

PHASES OF GENERALIZED BONE HEALING

Phase	Timing	Specific occurrence
Inflammatory phase	Day 1-10	Adsorption of plasma proteins Platelet aggregation and activation Clotting cascade activation Cytokine release Nonspecific cellular inflammatory response Specific cellular inflammatory response Macrophage-mediated inflammation Neovascularization
Proliferative phase	Day 3-42	Differentiation, proliferation, and activation of cells Production of immature connective tissue matrix
Maturation phase	After day 28	Remodeling of immature bone matrix with coupled resorption/deposition of bone Bone remodeling in response to implant loading Physiologic bone recession

ROLE OF GROWTH FACTORS

Growth factors play a central role in **osseointegration**—the direct structural and functional connection between living bone and the surface of an implant . They regulate cellular activity, tissue healing, and bone regeneration around the implant.

- Promotion of Cell Recruitment & Migration

Growth factors attract key cells (osteoprogenitor cells, mesenchymal stem cells) to the implant site. These cells are essential for new bone formation. Example: Platelet-derived growth factor (PDGF) enhances chemotaxis (cell movement toward the implant).

- Stimulation of Osteoblast Differentiation

Growth factors drive immature cells to become **osteoblasts** (bone-forming cells). Example: Bone morphogenetic proteins (BMPs), especially BMP-2 and BMP-7, are critical for initiating bone formation.

- Extracellular Matrix Formation

Growth factors promote production of:Collagen, Non-collagenous proteins.
These form the scaffold for mineral deposition and bone maturation.

- **Angiogenesis (Blood Vessel Formation)**

New blood vessels are essential for delivering oxygen, nutrients, and cells. Example: Vascular endothelial growth factor (VEGF) is key for angiogenesis.Better blood supply shows improved healing and integration.

- Regulation of Bone Remodeling

They help balance: Osteoblast activity (bone formation),Osteoclast activity (bone resorption) This ensures long-term stability of the implant.

- Improved Bone-to-Implant Contact (BIC)

Growth factors accelerate and enhance: Direct bonding between bone and implant surface, Mechanical stability

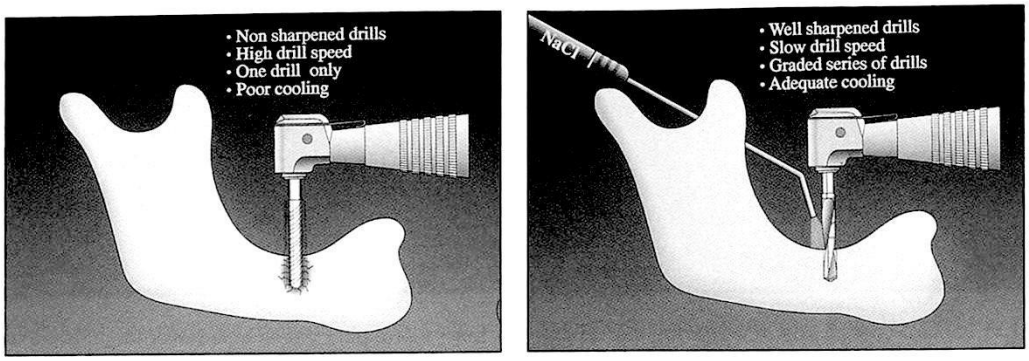
A large number of factors must be taken into account before the selection of a material for implantation in the human body. In the development work of oral titanium implants *ad modum* Brånemark, the following six factors

Were considered to be of importance for a reliable outcome of an osseointegrated implant:-

1. Surgical technique
2. Loading
3. Host tissue
4. Material
5. Surface structure
6. Design

There are many factors that can affect the healing process. Some of these factors deal with surgical technique and treatment protocol, whereas others deal with patient selection, hygiene, loading pattern, and site selection.

SURGICAL TECHNIQUE



Surgical technique. A poor surgical technique results in healing problems and can be due to blunt drills, high drill speed or poor cooling (left). Optimal surgery is achieved by control of these factors and by the use of a graded series of drills instead of the initial use of the largest size (right).

Fig 20.

All surgical procedures are considered to be traumatic to the host tissue, but the level of trauma induced is one of the critical factors that determine whether healing will progress toward fibrousintegration or osseointegration.

Studies by Albrektsson reveal that all surgical preparations on hard tissue cause a necrotic zone of bone at the implant bone interface owing to cutting of blood vessels, frictional heat generated during instrumentation, and vibrational trauma. Excessive trauma leads to fibrous encapsulation of the implant.

Surgical trauma must be minimized during all aspects of implant surgery to optimize success rates.

Surgical instrumentation of bone produces heat that can elevate the local temperature of bone.

Rotary instruments used during preparation of implant site can cause bone necrosis that can impair local bone viability and eventually leads to fibrous encapsulation of the implant.

In vivo studies have shown that traumatic surgical manipulation of bone can cause poor vascularization of implant border zone with delay or absence of ossification.

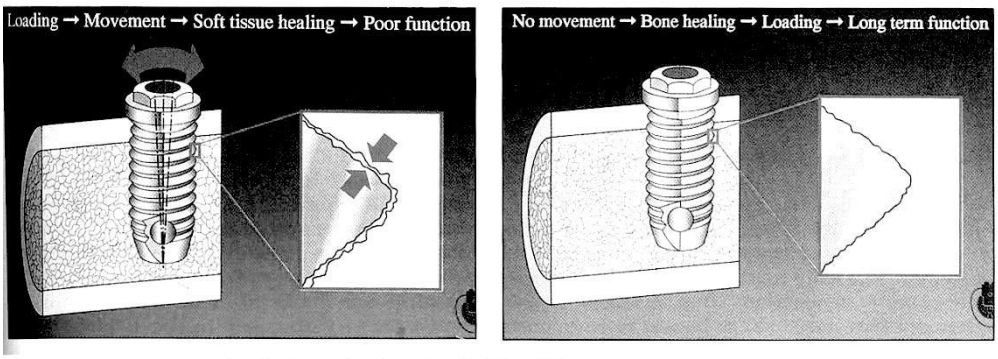
The effect of elevated temperature on bone tissue has been postulated to cause denaturation of alkaline phosphatase. The crucial threshold temperature for impaired bone regeneration has been shown to be as low as 44’C to 47’C when applied to bone for periods of 1 minute. Possible explanation for this lower threshold temperature could possibly be interference with local circulation, capillary leakage, and dehydration and osmotic changes that occur with traumatic manipulation of bone.

These effects could cause enough changes in bone physiology to result in altered differentiation of local progenitor cells, which leads to fibrous encapsulation.

Bone temperature of 60’C can be found during bone surgery using conventional instrumentation even with copious external irrigation. It has been shown, that gentle surgical technique using a graduated series of sharp drills run intermittently at slow speeds with copious amounts of internal and external irrigation can help to maintain the local bone temperature below the crucial threshold. This allows for the escape of debris from the bur flutes during preparation, which minimizes frictional heat and enables the irrigant to control local temperatures effectively.

Delicate manipulation of soft tissue around the implant site must also be observed during implant placement. Maintenance of periosteal integrity allows for preservation of local osteoblastic function and maximization of local bone vascularity, which is essential for implant healing to occur.

PREMATURE LOADING



As the bone implant inevitably will be surrounded by soft tissue during the early healing stages, loading then will result in movement with a subsequent soft-tissue healing and poor function (left). Premature movement of the implant is assured by postponing loading until the foreign material has had time to become properly anchored in bone, a process that takes about 3 months in the mandible. Long-term function is now possible (right).

Fig 21

Surgical preparation of bone for the placement of implant inevitably causes a zone of necrotic bone around the implant as a result of the surgical procedure. This zone of dead bone must be resorbed and replaced by new vascularized bone for osseointegration to occur.

Significant movement of implants during this healing phase results in fibrous encapsulation by inhibiting new bone formation and by inhibiting revascularization of necrotic bone. This movement can also cause activation of local macrophages, causing them to release cytokines, eicosanoids, and metalloproteinases, which can create conditions that promote wear and corrosion of implant material, yielding particulate debris and metal ions. This can further activate inflammatory cells to elaborate other cytokines and enzymes, with the net effect being altered differentitiation of local mesenchymal cells, leading to bone resorption and fibrous encapsulation.

In an investigation comparing titanium blade type implants that were either unloaded or loaded during the third implantation day, Brunski et al demonstrated significantly different interface morphology between these two groups. The loaded implants seemed to demonstrate a fibrous type of encapsulation, whereas the unloaded implants attained direct bone contact.

In a series of animal experiments, Pilliar et al have shown that micromovement in the magnitude of 28 um can allow for bone in growth into porous- surfaced implants, whereas excess movement (150 um or more) results in attachment by mature connective tissue in growth.

For these reasons, it is recommended that these implants remain in unloaded state for a period of 2 to 8 months, depending upon clinical situation, implant material used, location of implantation, and whether the implant is placed into bone grafts.

SURGICAL FIT

Technical difficulties and inconsistencies between an implant and instrument diameter make it virtually impossible to obtain perfect microscopic contact between bone and implants. Even in the best situation, bone contact only portions of the implant.

With the lack of significant initial bone contact comes the potential for micro motion between the implant and bone.

Cameron et al have demonstrated that with implant stabilization, bone regeneration can occur porous surfaced chromium-cobalt alloy implants in situation with an interfacial gap of 1.5 mm, but it appears that smaller gaps were filled by bone earlier. This has significant implications with respect to timing of implant loading in situations with imprecise implant fit.

Carlsson et al studied bone regeneration around titanium implants with interfacial gaps of 0, 0.35 and 0.85 mm. they demonstrated that even after 6 weeks the only implants to achieve significant osseointegration were the ones without interfacial gaps.

In an animal investigation examining the healing of a 1 mm interfacial gap with HA-coated implants and titanium implants. Soballe et al demonstrated that there was significantly more bone contact with HA-coated implants than with titanium implants at a 4-week interval.

These results would seem to indicate that longer healing periods may be required before loading implants when surgical fit is less than optimal and that earlier loading may be possible when using HA-coated implants.

BONE QUALITY

Bone quality and quantity are factors that can affect osseointegration. There are significant differences between bone of the mandible and that of the maxilla.

The mandible generally has a denser cortex and coarser, thicker canaliculi than does the maxilla. Bone in more posterior locations of both jaws tends to have a thinner, more porous cortex and finer canaliculi.

If implants are placed in bone with a dense cortex and a thick cancellous component, initially stabilization is more likely to be obtained when compared with implants placed in areas of thinner cortex with fine canaliculi. Stable implants are more likely to heal with osseointegration than implants that are mobile. In addition, regeneration of a cortical rim of bone around the implant from the surrounding cancellous bone is more likely to progress at a faster rate if the surrounding bone is denser.

Thus, before functional loading, it is recommended that the implant healing period be anywhere from 2 to 8 months, depending on the quality of bone at the surgical site, implant material used, and whether the implant is placed into bone grafts.

Differences in bone architecture are one of the reasons for the differences in success rates experienced between mandibular and maxillary implants.

PHYSICAL COMPOSITION OF THE PATIENT

The healing of implants involves a dynamic process in which the physical composition of a patient may alter the course of events.

NUTRITIONAL STATUS:-

Couverture de la revue Science, issue 5681 du 9 Juillet 2004, vol. 305.

A patient's nutritional status could be of paramount importance in determining whether implants will heal.

Certain vitamins, trace elements, and amino acids are critical for healing to occur.

Amino acids are the building blocks for protein and enzyme synthesis, and it would thus stand to reason that a deficiency in these building blocks would prevent appropriate wound healing.

Vitamin C is required for the hydroxylation of proline and lysine during collagen synthesis. Collagen is produced by the osteoblasts and fibroblasts during the healing of implants, and a deficiency in vitamin C, called scurvy, is associated with inefficient collagen synthesis with resultant poor wound healing.

Vitamin D, together with parathyroid hormone, estrogen, and possibly other peptides and hormones, is critical for calcium and phosphorus homeostasis. Altered calcium and phosphorus homeostasis can lead to impaired mineralization of the deposited osteoid with resultant implant failure.

AGING:-

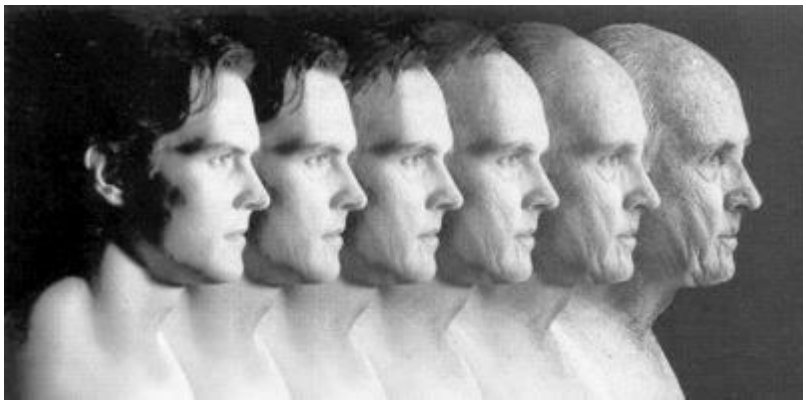


Fig22 .aging

Edentulism commonly occurs in the aging patient. Along with increasing age, changes occur in mineral composition, matrix, and cellular constituents of the skeletal system.

Osteoporosis is also a condition of the elderly that results in decreased mineral composition of bones. Studies do not provide a compelling theoretical or practical basis to confirm osteoporosis as a risk factor for osseointegration for dental implants.

The rate of calcium exchange between bone and serum in nontraumatized bones is significantly decreased with increasing age. Fracture healing has also been demonstrated to be delayed with increasing age, and aged bones do not appear to be able to form an external callus as readily as do younger bones.

Although endosseous implants are not contraindicated in the elderly, but the success rates may be less than optimal with advancing age because of changes discussed above.

Special consideration should thus be placed on timing of initial loading when determining implantation protocol because of the potential for delayed healing in aged bone.

DIABETES MELLITUS:-

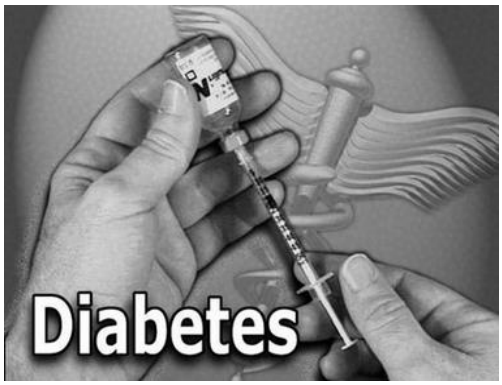


Fig 23. insulin

Diabetes mellitus is a systemic disease that may alter the healing capacity of the host. Diminished neutrophil chemotaxis and decreased phagocytic activity are responsible for the increased susceptibility to infection in diabetic patients.

Microvascular and macrovascular abnormalities may alter local circulation and lead to impaired healing.

Diabetes is not a specific contraindication to implant therapy, but it must be considered in therapeutic planning.

HEMATOLOGIC DERANGEMENTS:-

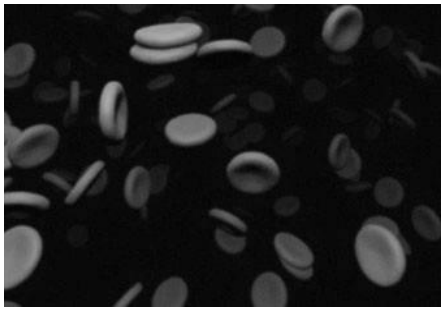


Fig. 24 HEMATOLOGIC DERANGEMENTS:-

Wounds in patients with acquired or hereditary coagulopathies can be complicated with excessive extravasations of blood into surgical site.

This blood, being an excellent bacterial culture medium, would also increase the susceptibility to wound infections.

Aside from delayed healing associated with wound infections, implant success is severely compromised.

CORTICOSTEROIDS:-

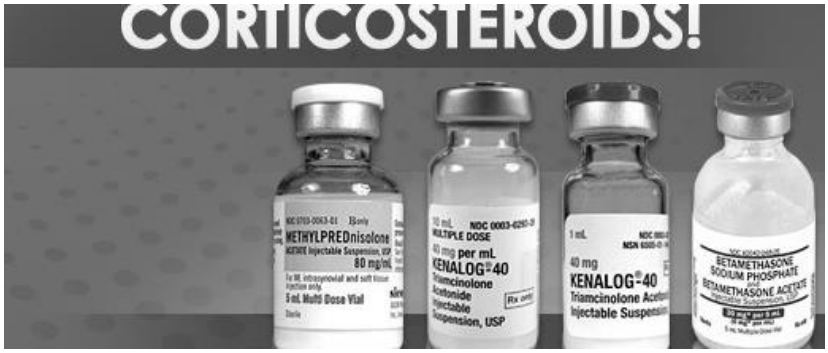


Fig 25

Long-term therapy with high doses of steroids has been shown to inhibit formation granulation tissue, retard mesenchymal cell differentiation; inhibit epithelial regeneration; inhibit collagen and ground substance production; inhibit macrophage migration and fibroblast proliferation; and inhibit leukocyte chemotaxis, phagocytosis, and intracellular killing.

Many of these effects are likely related to the impaired inflammatory cell function, particularly macrophage, with resultant decrease in the release of cytokines and growth factors.

Single-dose steroid therapy probably has no effect on wound healing.

HYPERTENSION

Because of high percentage of patients having hypertension, the dentist and staff members must be knowledged about the measurement, detection, and treatment of hypertension.

The accurate measurement of blood pressure, along with a review of all medications including herbal and over-the-counter medications, should be an integral part of the implant consultation and examination.

An increased blood pressure is not uncommon in the dental office setting, because stress associated with treatment (white coat syndrome) leads to increased level of catecholamine, which causes increase in blood pressure. This can be reduced by strictly following the stress reduction protocol and proper management of pain and discomfort.

THYROID DISORDERS

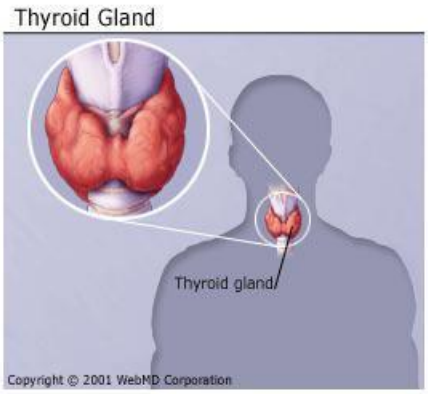


Fig 26. Thyroid gland

Patients with hyperthyroidism are especially sensitive to catecholamines and epinephrine in local anesthetics and gingival retraction cords.

When exposure to catecholamones is coupled with stress and tissue damage, an exacerbation of the symptoms of hyperthyroidism may occur. If left untreated, these symptoms may result in CHF and life-threatening arrhythmias.

The hypothyroid patient is particularly sensitive to CNS-depressant drugs, especially narcotics and sedative drugs as diazepam or barbiturates. The risk of respiratory depression or cardiovascular depression or collapse must be considered.

OSTEOPOROSIS

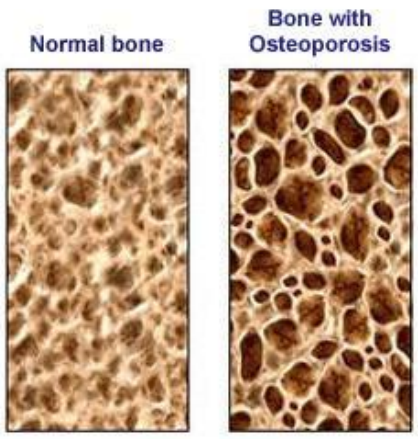


fig 27. osteoporosis

The most common disease of bone metabolism the implant dentist will encounter is osteoporosis, an age-related disorder characterized by decrease in bone mass, increased micro architectural deterioration, and susceptibility to fractures.

Patients with osteoporosis present the implant dentist with many challenges. Although not contraindicated, immediate stabilization of dental implants is a common concern because of decreased trabacular bone mass. Healing periods and implant surface characteristics should be selected for poorer-quality bone. Additionally, a large percentage of these patients are being treated with bisphosphonates, which have been attributed to various surgical complications.

The bone density does affect the treatment plan, surgical approach, length of healing, and need for progressive loading. Implant designs should be greater in width, and surface conditions of implant bodies

should be designed to increase bone contact and density. Bone stimulation to the healed interface will increase bone density, even in osteoporotic changes.

RADIATION:-

Implants are often used for the reconstruction of maxillofacial defects resulting from surgical ablation of malignant tumors. Radiation to head and neck region can produce both early and late changes in tissues.

Early clinical changes usually involve the intrinsic soft tissues in the field of radiation and include mucositis, dermatitis, and xerostomia.

The delayed effects of radiation are demineralization of bone, fibrosis, and increased susceptibility to infection, delayed wound healing and avascular necrosis.

The end results of radiation are hypocellular, hypovascular and hypoxic tissue.

Preliminary results indicate that significant improvement in integration can be obtained when patients are pretreated with hyperbaric oxygen (HBO). It is thus recommended that implant insertion be delayed for a period after radiation therapy and that patients be pretreated with an HBO regimen before the procedure.

The value of using relatively atraumatic surgical technique cannot be overstated when dealing with irradiated tissue. These tissues cannot have the capacity to respond to significant surgical manipulation, and implant failure would be inevitable. Traumatizing irradiated bone can also lead to osteoradionecrosis.

BIOMATERIALS FOR IMPLANT AND ITS SURFACE CHARACTERIZATION

The implant design and surface condition influences the dynamics of osseointegration. The following four distinct phases occur in the development of the bone-implant interface:-

1. Surgical integration.
2. Healing dynamics.
3. Early dynamics.
4. Mature loading period.

Studies that evaluated the role of implant design and surface condition on the bone-implant interface

Phases	Implant surface v/s design	Authors	Findings	Experimental design
Surgical integration	Surface condition Implant design	Shalabi et al O'Sullivan et al	Removal torque values higher for roughed surface v/s machined surface. In tibia, resonance frequency values at placement were higher for 1-degree tapered implants compared with control.	Implants with etched or mechanical surfaces were evaluated after surgical insertion into femoral condyle of goats. Experimental implants were compared with slanderedBranemarkimplants (control); implants were evaluated after surgical insertion into the tibiae and femurs of rabbits.
Healing dynamics	Thread type Surface condition	Steigenga et al Hermann et al	Square threaded implants had higher BIC value compared with V-shape and reverse buttress-threaded ones. No significant changes concerning bone loss around implants with rough surface; however implant inserted with the smooth collars of 1.5 mm below the crest resulted in bone loss to the level of the rough/smooth implant surface.	Implants were placed in tibiae of rabbits and evaluated after a 12-weak healing period. Implant were placed in mandible of dogs and evaluated at a monthly interval until sacrifice at 6 months.
Early loading period	Surface condition Implant design	Degidi et al Degidi et al	Immediately loaded implants, despite the surface condition, presenting high BIC values. Vertical bone loss was more pronounced for cylindrical implants.	Immediately loaded implants were retrieved from two patients and evaluated after a 6 months loading period. 11 implants submitted to immediate loading were retrieved from patients after a loading period between 10 and 11 months.

Mature loading period	Implant design	Jeffcott et al	HA cylindrical implants had the highest success rate 5 years after restoration followed by HA threaded implants.	Implants were inserted between the mental foramina of 120 edentulous patients; prosthesis were attached no sooner than 3 months after implant placement; patients were observed for 60 months.

BIOMATERIALS FOR IMPLANTS:-

The body is harsh chemical environment for foreign materials. An implanted material can have its properties altered by body fluids. Degradation mechanisms, such as corrosion or leaching, can be accelerated by ion concentrations and pH changes in body fluids.

The body's response to an implant can range from benign to a chronic inflammatory reaction, with the degree of biologic response largely dependent on the implanted material. For optimal performance, implanted materials should have suitable mechanical strength, biocompatibility, and structural biostability in physiologic environments.

TISSUE RESPONSE TO IMPLANT MATERIALS

The most commonly used biomaterials for dental implants are metals and their alloys. Commercially pure (CP) titanium and titanium-aluminum-vanadium (Ti-6Al-4V) alloy are most often used for endosseous implants, whereas cobalt-chromium-molybdenum (Co-Cr-Mo) alloy is most often used for subperiosteal implants. Calcium phosphate ceramics, particularly hydroxyapatite (HA), have been used in monolithic form as augmentation material for alveolar ridges and as coating on metal devices for endosseous implantation.

SURFACE-ACTIVE CERAMICS

Glass ceramics, such as Bioglass and Cervital, are polycrystalline ceramics produced by controlled crystallization of glasses.

Glass ceramics have poor mechanical properties for load-carrying applications because they are extremely brittle. Controlling grain size however, increases both tensile strength by a factor of two (from 100 to 200 Mpa) and abrasion resistance.

The implant surface responds to local pH changes by releasing by releasing sodium ions in exchange for phosphorus or hydrogen ions. A calcium phosphate layer forms on the surface. Osteoblasts proliferate at the surface, and collagen fibrils become incorporated into the calcium phosphate-rich layer.

Calcium phosphate ceramics, classified as polycrystalline ceramics, have a material structure derived from individual crystals that have become fused at the grain boundaries during high-temperature sintering processes.

Hydroxyapatite (HA), $[Ca_{10}(PO_4)_6(OH)_2]$, commonly called tribasic calcium phosphate, is a geologic mineral that closely resembles the natural mineral in vertebrate bone tissue.

The biocompatibility of the calcium phosphate ceramics is well documented. The body's typical response to these implanted ceramics is:

1. No local or systemic toxicity.
2. No inflammatory or foreign body reaction.

3. Functional integration with bone.
4. No alteration to natural mineralization processes.
5. Chemical bonding to bone via natural bone cementing mechanisms.

The biocompatibility and close chemical composition to natural bone mineral are factors that make the calcium phosphate ceramics desirable bioactive material.

HA implant surfaces have been characterized as being capable of forming direct, intimate bonds with the surrounding bone. The bonding area (approximately 500 to 2000 A^o) contains biologic apatite crystals that are highly oriented at interface with a 100 A^0 periodicity similar to that of calcified tissue, as determined by electron diffraction studies.

The bone apatite crystals are arranged against the implant surface in a palisade fashion, resembling the natural bonding between two bone fragments. The bonding area contains a ground substance that is heavily mineralized, although devoid of collagen fibrils, and has been likened to the natural bone-cementing substance.

The natural bone-cementing substance is amorphous in structure, heavily mineralized, and rich in mucopolysaccharides.

Because the bond area contains a substance biologically similar to the natural bone cement substance, it is reasonable that the bond between bone and calcium phosphate ceramic is strong.

TITANIUM AND TITANIUM-BASED ALLOYS

CP titanium and titanium-based alloys are low density metals that have chemical properties suitable for implant applications.

Titanium has a high corrosion resistance attributed to an oxide surface layer, which also creates a chemically nonreactive surface to the surrounding tissues.

The modulus of elasticity is half the value for cobalt based alloys but still five times greater than bone.

The higher the impurity content of the metal, the higher the strength and brittleness.

Owing to the low density, titanium and titanium based alloys have superior specific strength (strength per density) over all other metals. Titanium has poor shear strength and wears resistance, however making it unsuitable for articulating surface or bone screw applications.

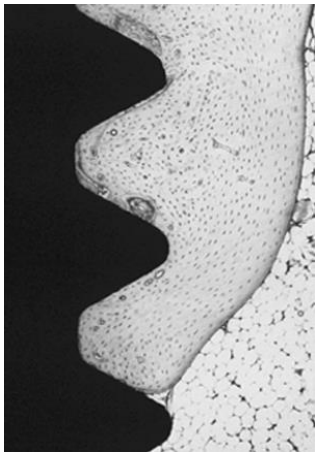


Fig 29. TITANIUM AND TITANIUM-BASED ALLOYS

A c.p. titanium implant after 6 months of insertion in rabbit tibia. Note that the bone in this Sample is more mature than the bone tissue inside the threads in the 6-week sample pictured Above.

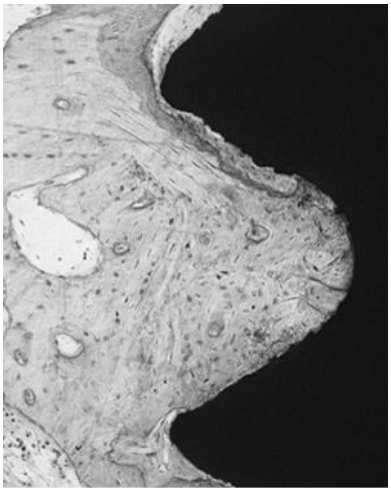


Fig 30. TITANIUM AND TITANIUM-BASED ALLOYS

A c.p. titanium implant retrieved after 6 weeks of insertion in rabbit bone. A close contact of the bone tissue to implant can be observed inside the thread while the thread tips are surrounded with soft tissue. The distance between the thread peaks is 600 mm.

TI-6AL-4V

This alloy has been used since the mid 1970s, particularly to fabricate orthopedic implants. The literature review in the thesis by Johansson concluded that a lack of data supported "better" hard tissue reactions to the alloy compared to the pure titanium. Most recent scientific papers include more specific documentation about materials and methods used. One oral implant system that seems to work well is the the Endopore system discussed by Pilliar.

Several investigations have compared c.p. titanium to Ti-6Al-4V implants after various times of insertion in rabbit bone. It has been shown that turned implants of c.p. titanium had significantly higher removal torque values than Ti-6Al-4V screws (23 versus 16 Ncm, respectively) and significantly higher bony contacts (59 versus 50%) after 3 months of insertion.

Titanium ions could be detected by secondary ion mass spectroscopy (SIMS) in the tissues surrounding both types of implants while aluminum ions (and vanadium in very small amounts) could be observed outside the alloy implants. No obvious qualitative differences could be observed on the cut and ground sections. Regardless of material, multinucleated giant cells and macrophages were revealed in close vicinity to the implant materials.

TITANIUM ALLOYS OTHER THAN TI-6AL-4V

In addition to alloys containing vanadium, other titanium alloys have been evaluated under experimental conditions. Examples include Ti-5Al-2.5Fe, Ti- 6Al-7Nb, and Ti-6Al-6Nb-1Ta. Experimental studies performed by Perren et al. showed no major differences in biocompatibility between Ti-5Al-2.5Fe, Ti-6Al-7Nb, or Ti-6Al-6Nb-1Ta in comparison with c.p. titanium and Ti-6Al-4Vafter 1, 3, and 9 weeks' subcutaneous implantation in mice. The Ti-5Al-2.5Fealloy was introduced in 1980 and marketed as Tikrutan LT35 for hip prostheses. Similarly, the Ti-6Al-7Nb T67 alloy (Protasul-100, Sulzer Orthopedics, Austin, Tx) has been used for hip arthroplasty components since 1986. The use ofvanadium-free titanium alloys in oral implantology has been limited.[52]

SURFACE-MODIFIED C.P. TITANIUM AND TI-6AL-4V

Han and coworkers performed qualitative and quantitative comparisons of bone tissue reactions to c.p. titanium and Ti-6Al-4V implants, blasted with TiO2 particles of mean sizes of 25 and 75 μm after 3 months of insertion in rabbit bone. The smoother implants had a mean Sa value of 1.1um and the rough ones around 1.5um. In general, the rough implants were better integrated than the smooth ones.

Nitrogen ion-treated and nonion-implanted commercially pure titanium and Ti-6Al-4V implants were inserted for 3 months in rabbit cortical bone. The histomorphometrical results did not reveal any significant differences between the materials. However, the untreated c.p. titanium had a tendency to be better integrated than untreated alloy implants although no significant differences were found (bone contacts of 26 versus 21%, respectively).

An implant surface is spontaneously covered with an oxide layer. The surface oxide properties of titanium implants have been investigated in several *in vivo* experiments. Morphometric evaluation of different machined, electropolished, and electropolished anodized titanium implants in rabbit tibiae revealed the highest bone contact for anodized titanium with a 180 nm crystalline oxide.

The electropolished implants that were additionally oxidized (180-nm oxide thickness) showed a higher degree of mineralization compared with the smooth, electropolished implants (2- to 4-nm oxide thickness). Thus, the combination of increased surface topography and oxide thickness presented favorable conditions for bone growth.

TANTALUM

Scientific interest in the *in vivo* effects of tantalum started more than 60 years ago when Burke53 introduced the metal to surgery. Subsequent *in vitro* studies on the effects of tantalum on cells showed that it and titanium had less effect on the proliferation rates of fibroblasts than aluminum oxide debris and its combination with stainless steel and gold which caused inhibition of cell growth. Similar conclusions were reached by Zetner and coworkers, who showed insignificant effects of titanium and tantalum, whereas Vitallium and gold (Au) caused significant decreases of fibroblast growth.

Experimental studies *in vivo* on the tissue response to tantalum included performance both in bone and soft tissue. Initial studies in canine bone and soft tissues indicated that tantalum was encapsulated by fibrous tissue (also in bone) but without evidence of bone or soft tissue irritation in follow-up periods up to 3 1/2 months.

Subsequent studies in soft tissues indicated that placement of tantalum in rabbit muscle resulted in a fibrous encapsulation that was thicker than around c.p. titanium and titanium alloys.

Fig 31. TANTALUM

A cut-and-ground section of an oxidized titanium implant after 6 weeks of insertion in rabbit Cortical bone. This section is stained for visualization of alkaline and acidic phosphatase activity.

Remodeling areas are observed around the thread tips. The distance between the thread peaks is 500 mm.

NIOBIUM

The chemical and mechanical properties of niobium are similar to those of Tantalum. The modulus of elasticity of niobium ($1.1x10^{11}$ Pa) is closer to that of bone ($0.1x10^{11}$ Pa) in comparison with most other metals. Further, niobium (and tantalum) is highly corrosion-resistant.

As discussed above, niobium, stainless steel, and tantalum were implanted (porous and grooved cylinder) in rabbit tibiae and evaluated after 3 to 6 weeks and 3 to 6 months. A growth of osseous tissue into the pores was found after 3 weeks, whereas after 6 weeks, a reduction of bone formation was observed. All three types of implant materials were enveloped by newly formed bone. Examination of only the niobium and tantalum cylinders after 3 and 6 months revealed a reduction of the surrounding bone tissue. The authors concluded that niobium and tantalum were just as biocompatible as stainless steel.

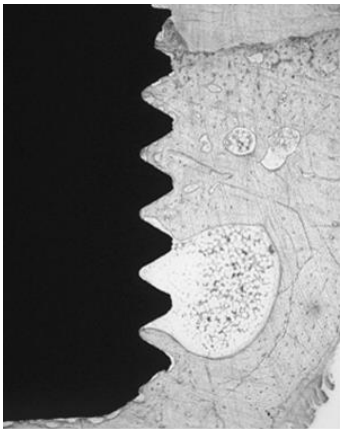


Fig 32. NIOBIUM

This c.p. niobium implant was inserted in rabbit cortical bone for 3 months. Compared to the

c.p. titanium implants, the tissue reactions were similar. The distance between the thread peaks is 600 mm.

ZIRCONIUM

Experiments on Zirconia alloy (Zr 98%, Sn 1.5%, Fe 0.15%, Cr 0.1%), Vitallium, stainless steel, Ti-6Al-4V, and c.p. titanium revealed little or no corrosion in any specimen. Until recent years, few studies focused on tissue response to zirconium and Zircalloy materials. A qualitative ultra structural interfacial analysis of c.p. zirconium and c.p. titanium coatings on plastic plugs inserted for 6 months in rabbit bone showed that both materials were well accepted and no adverse reactions or fibrous encapsulations were demonstrated.

A slightly thicker amorphous layer of noncollagenous material was detected between the calcified bone and Zr than around Ti. A histomorphometric evaluation showed that Ti and Zr had similar bone area and bone–implant contacts after 1 and 6 months, in contrast to Au.

Rod-shaped implants of Ti, Zr, and Vi, with similar rugosity (Ra = 0.6, 0.8, and 0.9, respectively) were inserted in rabbit bone and tested in terms of push-out at 4 and 24 weeks. The push-out data were rather similar between the groups and increased over time; values were 1.9, 1.1, and 1.3 MPa, respectively, after 24 weeks.

HAFNIUM

In relation to the other metals discussed above, very little information is available on the use of hafnium (Hf) in a biologic environment.

Wire-shaped implants (mean Ra = 155 nm) of titanium, hafnium, niobium, tantalum, and rhenium were investigated after 2 and 4 weeks of subcutaneous insertion and in femur bone marrow in rats. The authors reported all implants were encapsulated in fibrous connective tissue after 2 weeks and became thinner after 4 weeks, with the absence of inflammatory response.

The bony contacts were rather similar after 2 weeks (about 10% around all implants) compared to the 4-week follow-up when Ti and Ta demonstrated the largest integration (about 40%). No metal dissolution could be observed in soft or hard tissue. The authors concluded that all the tested materials had “good biocompatibility and osteoconductivity.”

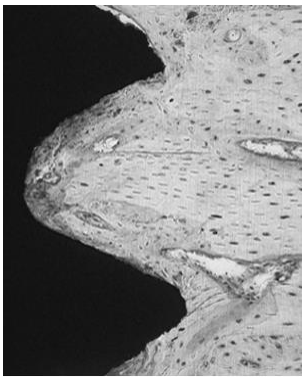


Fig 33. HAFNIUM

Hafnium implant inserted in the contralateral leg of the rabbit shown inalso for 6 weeks. Qualitatively, similar tissue reactions were observed around c.p. titanium and hafnium implants. The distance between the thread peaks is 600 um.

VITALLIUM (COBALT/CHROMIUM ALLOY)

Vitallium has been used as an orthopedic and dental implant material for about 80 years. Bone studies dating back to the early 1940s include reports on good bone apposition to Vitallium screws but lack quantitative data. It was reported that Vitallium implants were associated with greater extraction forces than unthreaded Ti implants (7.2 kp versus 5.8 kp, respectively).The same authors reported similar qualitative tissue reactions to both materials on thick-ground (300 to 500 um) sections. In other qualitative histological comparisons of bone to implants made of Vitallium, stainless steel, Ti-6Al- 4V, and c.p. titanium, the authors reported that the tissue reactions were similar to all materials.

Screw-shaped implants of Vitallium and c.p. titanium were inserted in rabbit bone for 3 months prior to biomechanical and histomorphometrical tests. Both *in vivo* tests revealed the c.p. titanium implant to be significantly better integrated in bone than the Vitallium implants. One reason for the biomechanical results may be that the c.p. titanium screws were rougher (mean Ra = 4.1) than the Vitallium (mean Ra = 1.7, as deduced from Form Talysurf measurements). Qualitative observations on the cut-and-ground sections revealed multinucleated giant cells in close vicinity to the implants, irrespective of materials.

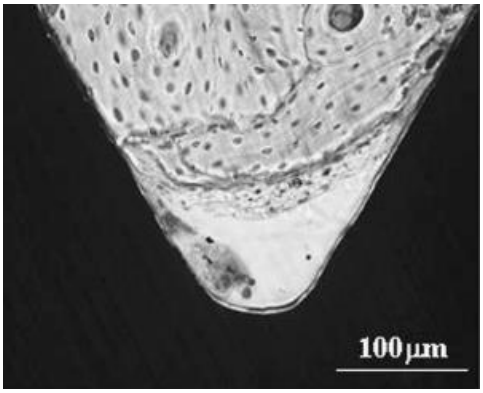


Fig 34. VITALLIUM (COBALT/CHROMIUM ALLOY)

Implant made of cobalt–cromium (Vitallium). As compared to the niobium implant in , the Vitallium implant is smooth although one can observe a multinucleated giant cell with black particles internalized. Irrespective of materials, these cells are observed, sometimes darker or lighter stained and, as in this case, as an elongated droplet formation. Scale bar = 100 um.

SURFACE CHARECTERIZATION OF IMPLANT BIOMATERIALS

TURNED SURFACES

The turned surfaces were the most commonly used surfaces in the past; they were submitted only to a decontamination process after the turning process.

These surfaces are also called MACHINED OR SMOOTH, but microscopic examination reveals the presence of a slight roughness because of the grooves and ridges produced during the turning process.

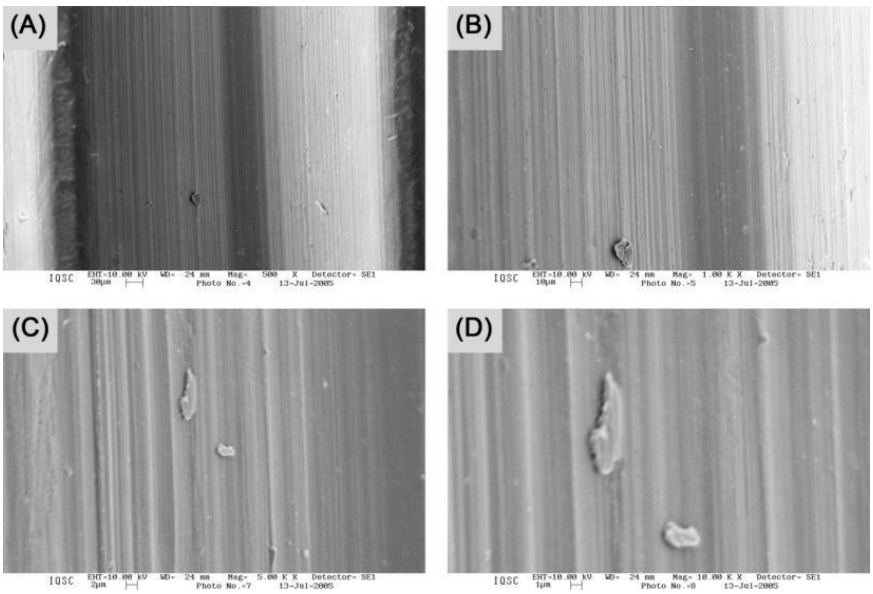


Fig 35. IMPLANT BIOMATERIALS

One of the main characteristics of the turned surfaces is that it is possible to observe a distance osteogenesis.

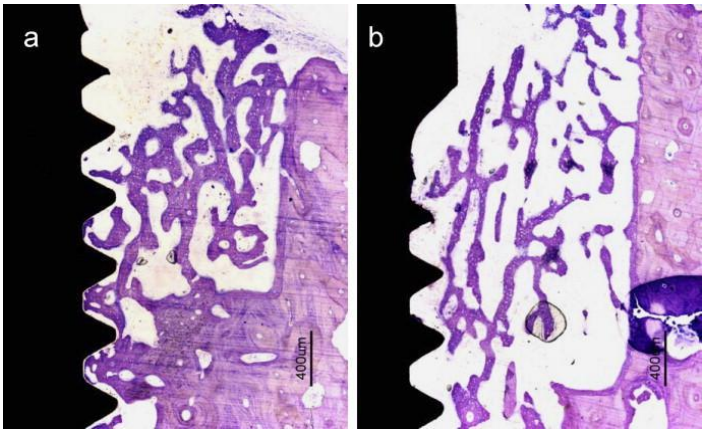


Fig. 36 IMPLANT BIOMATERIALS

SANDBLASTED SURFACES

Sandblasting the metal core with gritting agents creates these modified surfaces. This process is influenced by the number and the speed of rotations to which the implant is submitted, as well as by the pressure and the size of the particles used.

The blasting procedure is performed with the aim of increasing the irregularity of the surface of the implant, using agents such as Aluminium oxide (Al_2O_3, also known as Alumina) and TiO_2.

Fig 37. **SANDBLASTED SURFACES**

Sandblasting has been shown in some studies to allow the adhesion, proliferation, and differentiation of osteoblasts. On the other hand, fibroblasts were found to adhere with more difficulty to this surface; this could limit the soft tissue proliferation and potentially bone formation (contact osteogenesis).

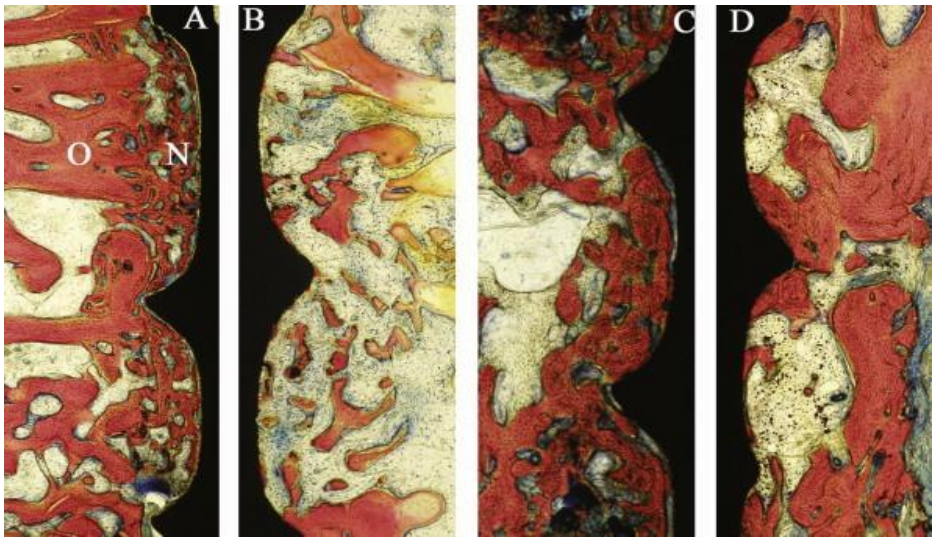


Fig 38. **Plasmated surface**

PLASMA-SPRAYED SURFACES

The use of implants with plasma-sprayed surfaces has been reported in orthopedics studies since the 1970s. Later it was observed that, around dental implants, bone was formed without an intervening layer of connective tissue.

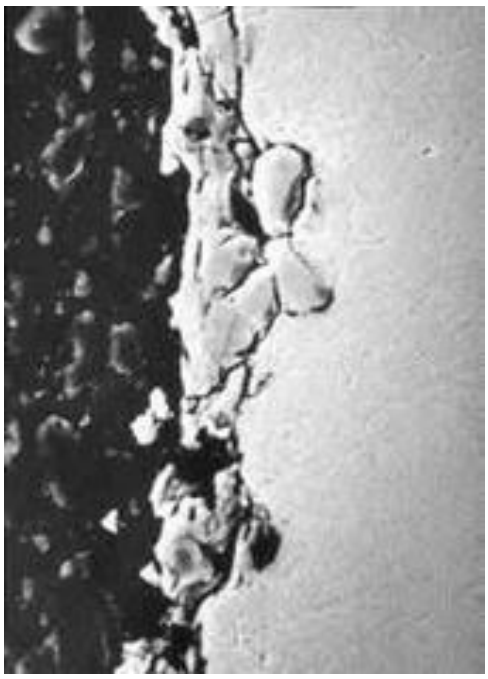


Fig 39. **PLASMA-SPRAYED SURFACES**

Plasma-sprayed implants are prepared by spraying molten metal on the titanium base, which rests in a surface with irregularly sized and shaped valleys, pores, and crevices, increasing the microscopic surface area by 6 to 10 times.

This topography may improve the fixation of implants by the growth of bone into the coating, forming a mechanical interlock.

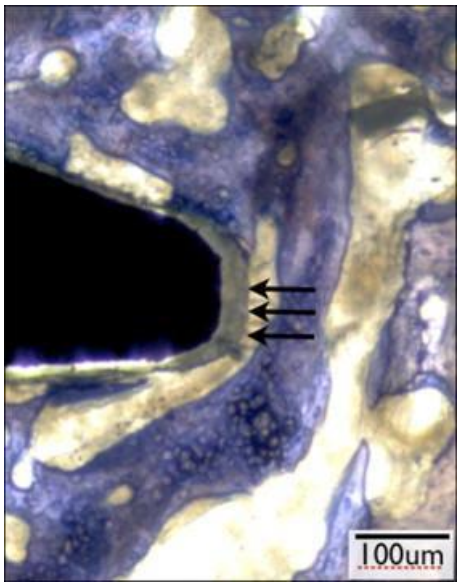


Fig 40. microscopic surface area

SURFACE COATING

TITANIUM PLASMA SPRAY

The titanium plasma spray (TPS) surface has been reported to increase the surface area of the bone-implant interface and acts similarly to a three-dimensional surface, which may stimulate adhesion osteogenesis.

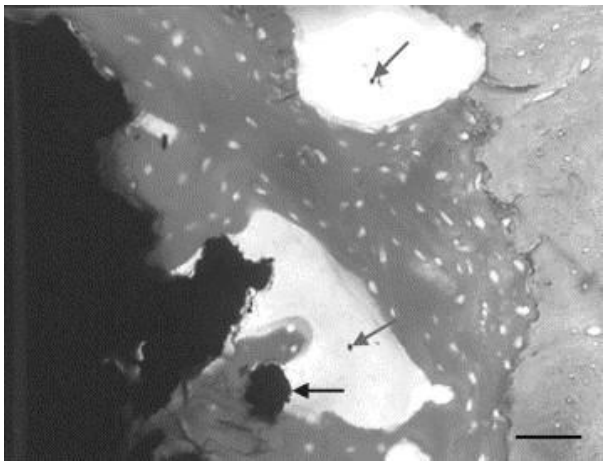


Fig 42. ***TITANIUM PLASMA SPRAY***

The surface area increase has been reported to be as great as 600%. Although tremendous increase in total surface area occurs at the microscopic level, the actual load-bearing capability of the coating increases the functional area by 25% to 30%, which is still substantial.

Porous surface in the range of TPS (150 to 400 um) also increase the tensile strength of the bone-implant interface, resist shear shear forces, and improve load transfer. The increased surface roughness may also improve the initial fixation of the implant, especially in softer bone.

Some evidence indicates that the interface may form faster, but no consensus exists regarding whether that may shorten clinical healing times.

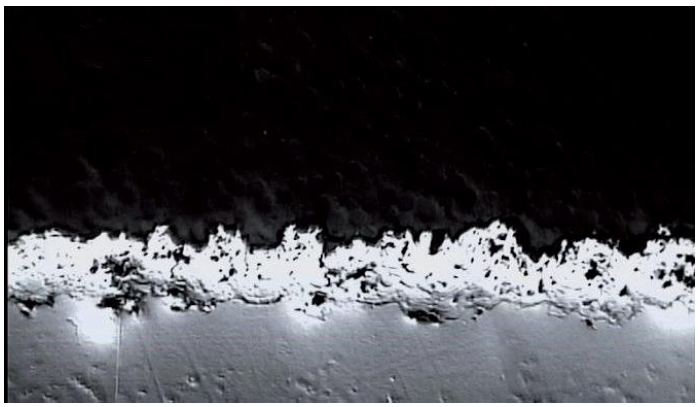


Fig 43. Porous surface in the range of TPS (150 to 400 um)

ACID-ETCHED SURFACES

Acid-etching a titanium base was proposed to modify the implant surface without leaving the residues found after the sandblasting procedure, to avoid the nonuniform treatment of the surface, and to control the loss of metallic substance from the body of the implant. This is performed using baths of hydrochloric acid (HCl), sulfuric acid (H_2SO_4), HF, and nitric acid (HNO_3) in different combinations.

The roughness before etching, the acid mixture, the bath temperature, and the etching time all affect the acid-etching process.

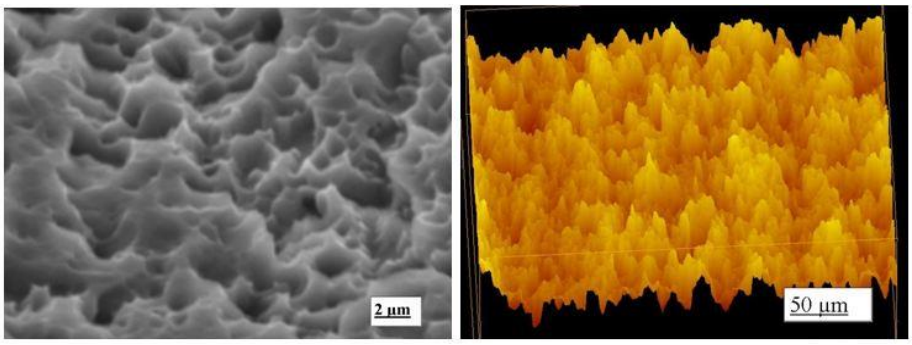


Fig 44. **ACID-ETCHED SURFACES**

Researchers compared etched (HCl and H_2SO_4) and turned surfaces by inserting implants in rabbit femurs. The roughened surface was characterized by "an even distribution of very small (1 to um) peaks and valleys." The resistance to torque removal was evaluated 2 months after implant placement in rabbits, and it was found to be four times greater for acid-etched implants (20.50N-cm) compared with turned ones (4.95 N-cm).

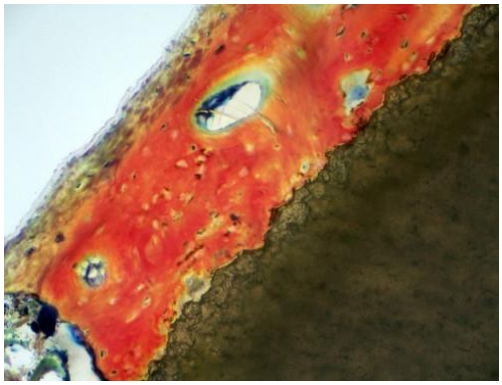


Fig 45. (HCl and H_2SO_4)

SAND BLASTED AND ACID-ETCHED SURFACES

In the 1990s the study of a modified surface resultant from blasting (to produce a micro texture) followed by acid etching (to produce a final micro texture) showed promising results.

The resultant surface was constituted by uniformly scattered gaps and holes, and it appeared to be slightly less rough than the plasma-sprayed surface, which presented a deeply irregular texture that provided a less favorable environment for cell spreading.

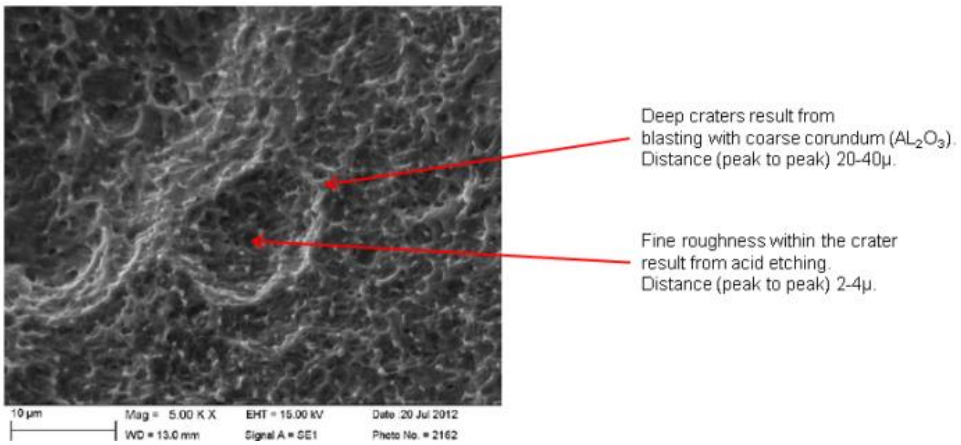


Fig 46.

A comparison study between sandblasted and acid-etched surfaces (R_a=2.0um) and acid-etched surfaces (R_a=1.3um) was performed in miniature pigs. Up to 3 months, implants with sandblasted and acid-etched surfaces presented significantly high torque removal values (186.8 N-cm), which were 75% to 125% higher than those observed in acid-etched sites (95.7 N-cm).

Sandblasted and acid-etched implants tend to promote greater osseous contact at earlier time points compared with plasma-sprayed, coated implants. This conclusion was derived from a dof study in which the test surface was prepared by blasting with 250 to 500-um corundum particles, and the acid etching was done with HCl and H_2SO_4. Histogic analyses were performed 3 months after implant placement, 3 months after loading, and 12 months after loading. Sandblasted and acid-etched implants had a significantly higher percentage of BIC than did the plasma-sprayed implants after 3 months of healing (72.33% and 52.15%, respectively). Differences were not observed after 6 months of healing on sand-blasted and acid-etched and plasma-sprayed implants (68.21% and 78.18%, respectively). After 12 months of loading, BIC values were significantly higher in sandblasted and acid-etched than in plasma-sprayed sites (71.68% and 58.88%, respectively). Sandblasted and acid-etched surfaces also present better osteoconductive properties and a higher capability to induce cell proliferation than plasma-sprayed surfaces.

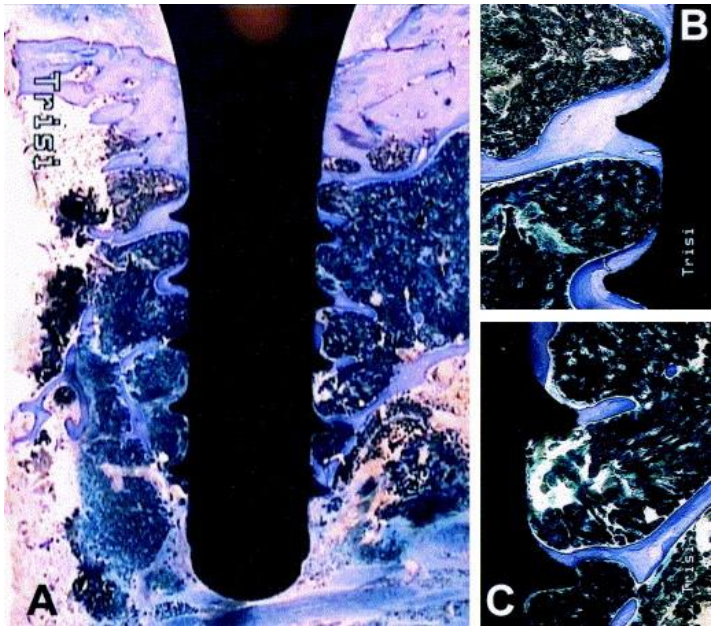


Fig 48 plasma-sprayed surfaces.

ANODIZED SURFACES

The oxidation process has been used in dental implants to change the characteristics of the oxide layer and, consequently, to improve the biocompatibility of the surface. The advantage is to modify the surface without depositing grit particles. Anodized surfaces are prepared by applying a voltage on the titanium specimen immersed in an electrolyte. The resultant surface presents micropores of variable diameters and demonstrates lack of cytotoxicity; more-over, cell attachment and proliferation are enhanced as compared with turned surfaces.

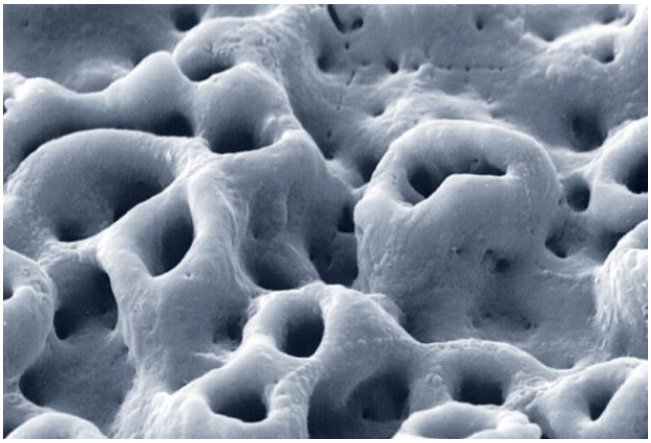


Fig 49. ***ANODIZED SURFACES***

The removal torque of anodized surfaces with different oxide thickness (oxide thickness of approximately 200, 600, 800, or 1000nm; $S_a$ranging from 0.96 to 1.03um) was also investigated in comparison with turned implants (oxide thickness of 17.4 nm; S_a=0.83um). 6 weeks after implant placement in rabbit tibiae, the values obtained (11.3, 12, and 12.9 N-cm, respectively) in anodized sites were significantly higher than those reported for the turned sites (removal torque value of 7.5 N-cm).

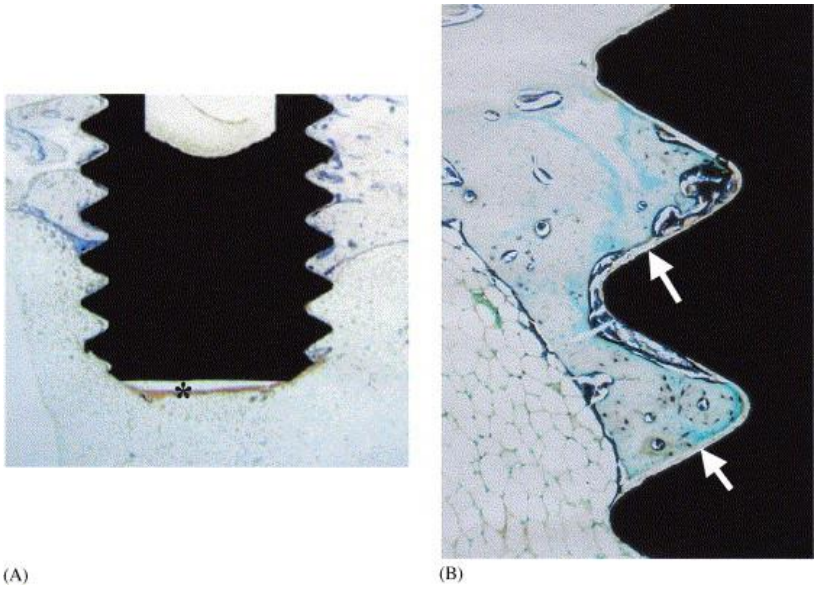


Fig 50. ***HYDROXYAPATITE COATINGS***

HYDROXYAPATITE COATINGS

Hydroxyapatite coatings have a similar roughness and increase in functional surface area as TPS. A direct bone bond shown with HA coating and the strength of the HA-to-bone interface is greater than titanium to bone and even greater than TPS to bone. In addition, accelerated interfacial bone formation and maturation have been observed is dogs.

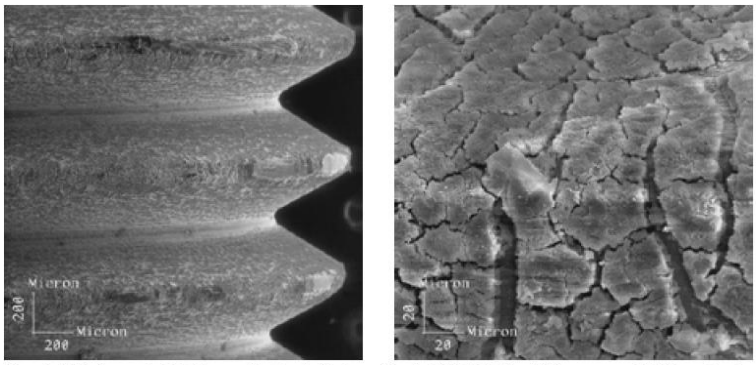


Figure 2. SEM micrograph of the HA-coated implant (original magnification X50) (left). "Crackled" appearance of the HA coating after calcination (original magnification X1000) (right).

Fig 51

An initial implant-to-bone interface contact is essential for a predicable interface to form. The space or "gap" between the implant and bone may affect the percentage of bone contact after healing. Gap healing may be enhanced by the HA coatings. The corrosion rate of metal is also reduced, which is more significant for cobalt chrome alloys.

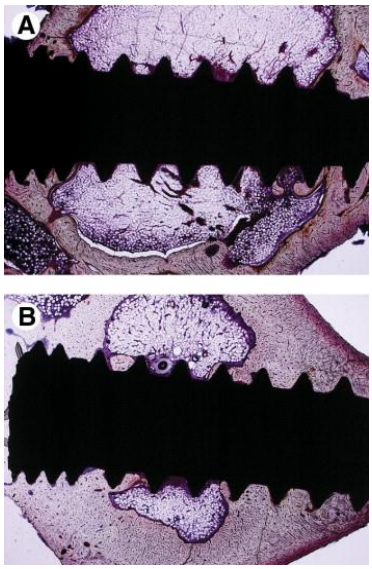


Fig 53 cobalt chrome

DISADVANTAGES OF COATINGS

Although coatings on implant bodies have benefits, several disadvantages exist. The coating may flake, crack, or scale on insertion, especially when being inserted into dense bone. In addition, the increased surface increases the risk of bacterial contamination when present above the bone. Coatings may not only increase plaque retention when exposed but also may act as a nidus for bacteria, and bacterial endotoxins may be more adherent because of the surface charge and characteristics.

Therefore the disadvantages of coatings include the following:-

1. Flaking, cracking, or scaling on insertion.
2. Increased plaque retention when above bone.
3. Increased bacteria and nidus for infection.
4. Complication of treatment of failing implants.
5. Increased cost.

IMPLANT DEESIGN AND BIOMECHANICAL PROPERTIES

Fig 54. IMPLANT DEESIGN AND BIOMECHANICAL PROPERTIES

A common method of implant fixation is impaction into the alveolar ridge. The implants are held in place by compressive stress interaction, and the devices are designed to remain in compression relative to the surrounding tissue. Static and dynamic masticatory forces are then transmitted from the implant to the surrounding tissues.

The precision required obtaining uniform contact between the devices and surrounding bone is limited by skills of surgeon and design of instrumentation with which the site is prepared.

The surface area of actual contact is probably small relative to the implant surface area. These contact points tend to induce areas of stress concentrations rather than an even distribution of stresses.

Bone maintains its structural integrity by responding to stress; high areas of stress concentration are often associated with bone resorption. Additionally, fibrous encapsulations of varying thicknesses are common occurrences that further alter the ability of the implant to distribute stress uniformly. This situation often manifests itself in eventual implant loosening and migration, leading to patient discomfort and the need for eventual removal.

Several types of implant fixation methods and surface texture designs have been investigated to obtain better surgical fit and stress distribution at the implant-bone interface. These methods include:-

1. Direct bone apposition to the implant surface.
2. Bone growth into porous-surfaced implants.
3. Chemical bonding between bone and surface-active chemical implant coatings.

DIRECT BONE APPOSITION

Optimal osseointegration at bone-implant interface is affected by the material properties and design of the implant. Implant design encompasses both the surface texture and the geometry of the implant.

The mechanical properties of the bone-implant surface have been investigated with various surface preparations: smooth finish, roughened or grit-blasted finishes, and grooved surfaces.

Histologically,implants with smooth finishes have interfaces characterized by fibrous encapsulation, whereas implants with grit-blasted finishes have interface characterized by areas of areas of direct bone apposition. Several studies determined that surface texture is a significant factor in obtaining adequate implant fixation with direct bone apposition methods.

Mechanical results indicate a statistical correlation with implant length and no correlation with implant diameter.

POROUS INGROWTH ATTACHMENT

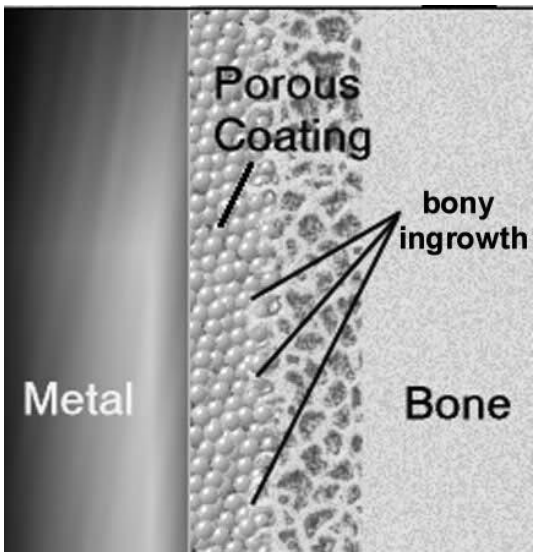


Fig 55. POROUS INGROWTH ATTACHMENT

It is generally accepted that an implant can achieve stabilization by tissue growth into the surface porous structure if the material is bioinert, if there is direct apposition of the bone at the implant interface, if there is minimal or no movement at the implant site, and if the porous structure has appropriate pore size and morphology.

Several different porous structures have been evaluated: irregular, fiber mesh, and bead.

To maintain optimal bone growth into a porous structure, the pores must be large enough accommodate bone tissue development. Several investigators have studied the degree and rate of bone in growth for several different pore size ranges. They concluded that that a pore size range of 50 to 400um obtained the maximum attachment strength in shortest time. Histologically, however, it was observed that osteon formation was not observed and did not appear to be a prerequisite to attain maximum attachment strength.

Besides a minimal pore size, an effective porous coating must also have appropriate pore morphology. The available porous layer for bone growth must be large enough to accommodate enough bone for adequate fixation without compromising the mechanical properties necessary for a load-bearing prosthesis.

A volume fraction porosity of 35% to 40% is accepted as optimum for effective biological fixation for a strongly bonded porous layer. The volume fraction porosity is related to the interconnection pore size, particle interconnectivity, and particle size of the porous coating.

CALCIUM PHOSPHATE CERAMIC COATINGS

HA-coated and uncoated macro textured titanium implants were evaluated from 3 to 32 weeks by Thomas et al. Histologically the HA-coated implant demonstrated direct bone mineralization on the coating surface, whereas the uncoated implants often demonstrated areas of fibrous tissue at the interface.

HA-coated and uncoated dental implants both have been evaluated in dog models to compare both mechanical and histologic response. The grit-blasted implants demonstrated osseointegration after 4 months implantation. Even at 10 months, however, the bone was not continuous at the implant interface. The HA-coated implants exhibited direct bonding off bone to HA surface at 1 month. By 4 months, lamellar bone was observed at the HA-bone interface.

OPTIMIZING BIOLOGIC ATTACHMENT METHODS

Optimal attachment at the bone-implant interface is affected by the material properties and design of the implant. Other conditions that affect osseointegration are instrumentation design, surgical technique, initial implant stability, and direct contact with the surrounding bone.

MOTION AT BONE-IMPLANT INTERFACE

Initial implant stability and apposition with bone are not always achievable, but are vital for implant longevity. Persistent micromotion at the bone-implant interface has been an established cause of bone resorption and necrosis. Necrosis and destructive bone remodeling often result in fibrous tissue infiltration at the interface and may cause implant loosening. Also, any initial gap between the implant and surrounding bone may adversely alter the amount and rate at which osseointegration occurs. Initial implant stability is essential for early tissue infiltrate within the porous structure to differentiate into bone by either direct bone formation or appositional bone growth. When excessive early movement occurs at the bone-implant interface, bone formation within the pores is inhibited. It is generally accepted that micromotion of 150um is the upper limit of acceptable motion. In a carefully controlled study, Bragdon et al determined that 150um of implant motion did not allow bone in growth.

SURGICAL FIT

The technical difficulties in cutting bone precisely to provide an exact fit around the implant often result in a poor surgical fit.

Difficulties in achieving initial implant-bone interface apposition are due to implant and instrumentation design and surgical technique. Numerous researchers have investigated the effect of interface gap spaces on the histologic response to implants. These studies demonstrate that the closer the fit between the bone and the implant (<0.5 mm) the earlier osseointegration is achieved, and the quality of bone is superior.

Surgical fit is also a concern for HA-coated prosthesis because HA coatings do not make up for improper surgical placement of the implant. The concentrations of the physiologic components necessary for bone formation are decreased across large interfacial gaps as compared with concentrations for press-fit situations. Therefore the rate of gap filling, and subsequent in growth, is delayed. Large gaps may reduce the quality of bone at the interface as compared with that of press-fit interfaces.

FIBRO-OSSEOUS RETENTION V/S OSSEOINTEGRATION

The two basic means of retention of an endosteal implant in function are

1. Fibro osseous retention
2. Osseointegration

According to American Academy of Implant Dentistry (AAID) Glossary of Terms (1986) the term fibro osseous retention is defined as tissue implant contact, inter position of healthy dense collagenous tissue between the implant and the bone.

Two mechanisms have been described whereby these phenomenons occur.

1. Development of ankylotic like relationship between the implant and the bone.
2. Development of an intermediate ligamentary system.

The direct bone to implant interface without intervening connective tissue was described by Strock early as 1939 and more recently by Branemark et al.

A connective tissue structure interposed between dental implants and bone has been a long recognized entity but its role in load transfer was considered to be only as some form of cushion or pad.

Bone is ideally suited to withstand compressive loading whereas ligaments and tendons are best suited to transfer tensile stress

A. Fibro Osseous Retention.

A proponent of the fibro osseous theory of implant fixation Weiss defends the presence of collagen fibers at the interface between the implant and the bone, and interprets as a peri implant membrane with an osteogenic effect. He believes that the collagen fibers invest the implant, originating at the trabeculae of cancellous bone on one side, weaving around the implant and re-inserting into the trabeculae of other side.

When function is applied to the implant, tension is applied to the fibers forces closest to the implant interface causes compressing of fibers with a corresponding tension on the fibers placed or inserting into the trabeculae.

The difference between the inner aspect (compression) and the outer aspect (tension) of the connective tissue component results in a bioelectric current, and this current (a piezoelectric effect induces differentiation into connective tissue components associated with bone maintenance.

As stated earlier, plate form and sub periosteal implants can function either in ankylosed state or by a way of suspensory ligament.

The inability of root form implant to function in a ligament may possibly be explained on the basic of biomechanics.

The deflection of viscoelastic material such as tendon or ligament high exponentially with its length. Therefore base on the size alone, a ligament that must extend around the smallest possible root form implant will be at least 3 times as long as one around the plate form implant that would result in beyond the scope of physiologic load bearing.

There is no real evidence to suggest, however that those fibers are functioning in the periodontal ligament mode (from tooth to bone) at the bone to implant interface.

Histological studies demonstrate either parallel fiber arrangement to the long axis of implant.

B. Osseo integration

Dr. Per Invar Branemark[53] who coined the term Osseo integration. According to American Academy of Implant Dentistry (AAID) glossary of terms.

Osseo integration is a contact established between the normal and remodeled bone and an implant surface without the interposition of nonbone or connective tissue.

The proponents of the two theories of implant retention and stabilization are entirely at odds in their philosophies of tissue maintenance as related to function.

According to Weiss, it is the difference between a function and hypo function, or between submerging the endosteal portion of the implant for 3 to 6 months of protecting it into a hypofunctional mode from the day of insertion until placing it into full function 1 to 2 months after placement.

Weiss agrees that a functional, submerged system will allow for direct bone apposition (osseointegration) but think that submerging the implant would actually retard healing and that when implant is placed in full function from a non functional mode, failure will soon result.

Branemark theorizes that the implant must be protected and completely out of function, as he envisions a period of healing of at least 1 year, in which new bone is formed close to the immobile resting implant, a remodeling phase of 3 to 18 months.

After this time period there is a balance between the force acting on the implant and the remodeling capacity of the anchoring bone.

Work by Adel et al. cited that bone loss of 1 to 1.5mm occurs during the first year as a result of surgical trauma and subsequently marginal bone loss of .05 to 0.1mm occurs annually after the first year.

Roberts et al. reported that when an implant is placed within the bone a bridging callus originates within a few mm from the implant site and a lattice of woven bone reaching the implant surface is approximately 6 weeks.

The lattice structure of woven bone is filled with well organized lamellae and this does not occur to achieve maximum load carrying capability in human being at less than 18 weeks.

Furthermore a compact / composite bone formation at the interface is achieved approximately 1 year of implant placement.

Tomas Alberektsson[54] concluded that generally speaking, a connective tissue anchorage of dental implants is an indication of failure. The achievement of a solid bone anchorage for a dental implant can lead to long term predictable clinical success. This appears to depend on the control of surgical trauma, condition of tissue bed and biocompatibility.

Donley Timothy and **Gillette B. William**[55] provided background information about normal periodontal anatomy and titanium used in endosseous implant. Literature is reviewed concerning epithelial and connective tissue attachment to titanium. A chemical attachment between titanium implant surface oxide layer and epithelium has been demonstrated. This attachment is mediated by a glycoprotein similar to that seen between epithelium and natural tooth surface. While only minimum histological evidence exist connective tissue fiber adjacent to titanium implanted surfaces may bring the tissue in tight opposition to the implant without a biologic attachment between implant and connective tissue. Alternation of titanium surface morphology may selectively enhance the attachment of epithelial cells or fibroblast, theoretically enhancing the formation of the biologic seal between the implanted titanium surface and its adjacent tissue.

BONE-IMPLANT INTERFACE

The type of interface that develops between the implant and bone depends on many variables. Microscopic studies between implants and bone in areas of osseointegration shows a zone of amorphous material between the implant and the bone.

The exact chemical nature of interface that forms between this amorphous layer and the metallic implant surface is yet to be determined. It has been theorized, however, that weak Van der Wals bonding, direct chemical bonding like ionic and covalent bond or a combination of two may be present.

The implant material in question is the most important factor that determines the chemical nature of this interface. Chemical bonding of the implant-material to surrounding bone is a well-described phenomenon with certain materials, such as calcium phosphate ceramics.

Other materials like alloys, carbon, aluminum oxide, and most polymers, have a minimal to nonexistence interfacial chemical bond, but they have excellent bone contact.

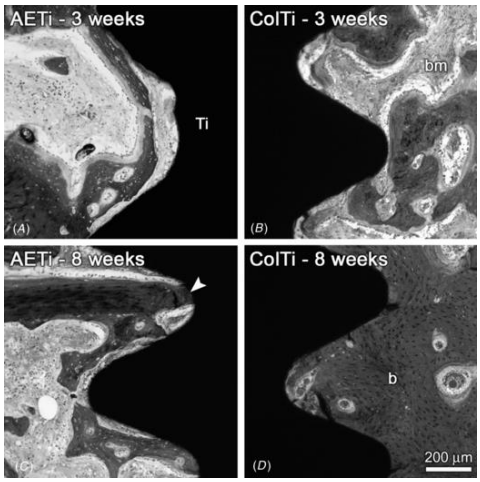


Fig 56. Bone implant interface

MUCOPERIOSTEAL-IMPLANT INTERFACE

Dental implants have the unique feature of penetrating through lining epithelium. Establishment of an adequate connective tissue seal around an implant provides a barrier to the ingress of oral toxins and bacteria into the internal environment.

Some authors believe that maintenance of this seal is essential for preventing the initial peri-implant tissue inflammation that can lead to eventual destruction of implant support.

Ten Cate indicates that lack of a biological seal will not doom implants to failure, but rather the connective tissue response is more likely to be the critical factor involved in implant loss.

Epithelial regeneration around well-integrated implants results in a structure similar to the gingival tissues around natural teeth.

The keratinized oral epithelium is continuous with nonkeratinized sulcular epithelium adjacent to the implant in the peri-implant sulcus. This sulcus is analogous to the periodontal sulcus around natural teeth and is approximately 3 to 4 mm deep in healthy sites.

Junctional epithelium is located in the apical portion of the sulcus, and this portion of the epithelium is adherent to the implant surface.Microscopic studies of this attachment reveal that the junctional epithelial cells attach to the implant surface with a basal lamina and hemidesmosomes in the same way that they would attach to teeth. The basal limina-hemidesmosomal complex is thought to be chemically bonded to the implant surface by a 10 to 20 nm amorphous glycoprotein layer similar to that found at the bone implant interface. These hemidesmosomes become evident 2 to 3 days after implant insertion.

Fig.57 MUCOPERIOSTEAL-IMPLANT INTERFACE

PERIODONTAL CONSIDERATIONS FOR DENTAL IMPLANTS

The development of osseointegrated dental implant has had a major effect on periodontal education and periodontal practice. Once the implants have integrated and have been uncovered, clinical evaluation of implant health is necessary on continuing basis and includes many soft tissue considerations.

Peri-implant health should appear as noninflamed surface tissues; minimal, stable probing depths without bleeding on probing; and stable bone levels.

Determination of the condition of the peri-implant soft tissues includes surface evaluation for the presence and severity of inflammation. Color, contour, and consistency of the circumferential gingival tissues can be judged in descriptive terms or can be judged in descriptive terms or can be objectively scored by means of the Gingival Index or similar scoring systems. Persistence presence of inflammation suggests ongoing irritation of the tissues from plaque accumulation, rough component parts, or mobility of component parts.

Probing depth is another measure of implant health, and, as with natural teeth, minimal probing depth (<4 mm) is preferable. It is recommended that measurements of probing depths be made with calibrated plastic or nylon probe rather than metal probes to minimize scratching of metal titanium surface of the implant abutment components. Often the suprabone/supraimplant probing depth can be determined based on the known length of the abutment head, which provides a clinical reference.

More important than the actual millimeter probing measurement is the stability of the measurement. Increasing probing depth measurements at recall evaluations are worrisome and suggest progressive disease and possible failure of the implant. This is especially true if the probing depth increases to the point at which the body of the implant is "probable". Such a situation reflects crestal bone loss around the neck of the dental implant and, if progressive, suggests loss of integration of the dental implant.

An indicator of relative health of the peri-implant pocket is the presence or absence of bleeding on probing. Bleeding on gentle probing suggests irritation and ulceration of the soft tissue wall facing the abutment head. Although isolated instances of bleeding on probing in a particular site may not be of consequence, continued bleeding on probing on sequential examinations strongly suggests increased potential for continued attachment and bone loss.

There is continued argument about the requirement for keratinized gingival rather than alveolar mucosa next to dental implant head (as there continues to be concerning the type of soft tissues next to natural teeth). Although reports evaluating the health of the soft tissues adjacent to dental implants supporting complete denture-type restorations suggest no detrimental effects if the marginal tissues are composed of alveolar mucosa, subjective evaluation and patient responses suggest that an adequate zone of dense, thick keratinized gingival is preferable. Nonkeratinized mucosa is too readily abraded and tends to be tender to the patient during mastication and oral hygiene procedures. Additionally, it can be an aesthetic problem because the metal components can be seen through the thin mucosal tissues, and it is more subject to recession. A good band of keratinized tissue is less movable, is more resistant to physical trauma, and provides better and more aesthetic contours.

Bone loss around dental implants can occur owing to a multitude of factors. Although ongoing research strives to elucidate the role of several factors, current findings suggest that plaque accumulation and excessive occlusal forces are the primary causes of implant failure after integration has occurred and restorations have been placed into function. There are also several preloading causes of bone loss, primarily improper surgical technique that overheats the bone.

Crestal and peri-implant bone levels are best determined by regular accurate radiographic evaluation. Although panaromic radiographs are commonly used for dental implant evaluation, periapical and vertical bite-wing dental radiographs used with a grid generally provide more definitive information. Progressive bone loss suggests a failing dental implant. Although a well-known criteria list for dental implant success suggests that less than or equal to 0.2 mm of crestal bone loss annually is acceptable, it must be realized that same rate of bone loss reflects progressive advancing periodontal disease around natural teeth.

The mechanism and nature of bacterial accumulation around dental implants and on dental implants and on dental implant parts is under investigation. Current knowledge suggests that although bacterial attachment to titanium occurs at a less rapid rate than on natural teeth, once the initial bacterial colonies have been established, the sequence of bacterial accumulation and change in flora to a more pathologic complex occurs in the same manner. Such plaque accumulation accounts for much of the peri-implantitis that is seen. This is especially true in a "mixed dentition" situation in which both natural teeth and dental implants are present in the same mouth. It appears that the bacterial flora of the natural tooth pockets may seed the interface area of the soft tissue/dental implant. This circumstance makes obtaining periodontal health around natural teeth imperative before exposing dental implants for restoration.

Excessive occlusal forces are another major cause of peri-implant bone loss. Lateral forces, such as are present in excursive interference or in bruxism, appear to be an important initiating factor of bone loss that then may allow pocket formation and progression into peri-implantitis with eventual implant loss. Care must be taken to establish the least amount of lateral forces possible. For patients who are suspected or known to have parafunctional habits, a soft bite-guard for protection against these forces is highly recommended.

The follow-up care and periodontal requirements for success are similar for dental implants as for natural teeth. In general, the follow-up and maintenance frequency for patients with dental implants would be similar to those for periodontal patients.

It is recommended that for the first year after implant uncovering, the patient be seen every 3 months for evaluation of oral hygiene practices, tissue health, radiographic bone levels, appropriate occlusal forces, stability of the restorations, and general comfort. On a 6-month or annual basis, the superstructure (when retrievable) should be removed and the individual implant parts and peri-implant tissues evaluated more critically. This retrievable situation allows for polishing and modification of the superstructure as well as more specific hygiene instruction for the patients for any problem areas.

The more that patients can do on their own, the less they may need the dental office to help ensure long-term implant health.

ORAL BACTERIA AND DENTAL IMPLANTS IN HEALTH AND DISEASE

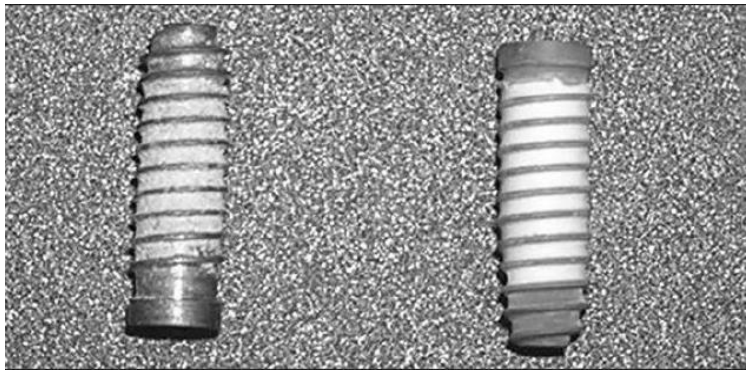


Fig 58.

Even though the failure rate is low, dental clinicians and researchers are motivated to understand implant failure to improve the success rate and to reduce pain and suffering and improve quality of life for patients. Implantable devices have become important in medicine as well as dentistry and have played a central role in the restoration of function and form in previously intractable cases. In normal surgical practice, these devices are sterile and are placed, using aseptic surgical techniques, in microbiologically sterile body sites. Occasionally, contaminating or hematogenously disseminated bacteria and establish a biofilm on the implant surface. Such biofilms act as sources of inflammation and sites for seeding of disseminated infection, thus destroying the function of the implant and even causing systemic disease. Bacteria in biofilms are notoriously resistant to antibiotics, and surgical intervention and implant removal often are necessary.

MICRO-ORGANISMS AND SURGICAL PLACEMENT OF DENTAL IMPLANTS

Endosseous root-form dental implants are sterile as provided by the manufacturers and are placed using sterile instruments and aseptic surgical techniques. If good surgical technique is practiced, loss of endosseous implants to infection during healing and osseointegration should be rare.[59] After healing and osseointegration, endosseous implants are exposed and abutments attached which projects into the oral cavity. Such sites can be colonized both with natural oral flora and with “classic” implant pathogens such as *Staphylococcus aureus and Pseudomanas aeruginosa.*

BACTERIAL COLONIZATION OF INTRAORAL HARD SURFACES, INCLUDING IMPLANTS

Osseointegrated implants and associated abutments in the oral cavity can be regarded as analogous to natural teeth. Studies have indicated that teeth and implants are colonized by similar groups of oral bacteria, that the principles and mechanisms of colonization are similar, and that similar groups of periodontopathogens are involved in both periodontal diseases and *peri-implantitis.*

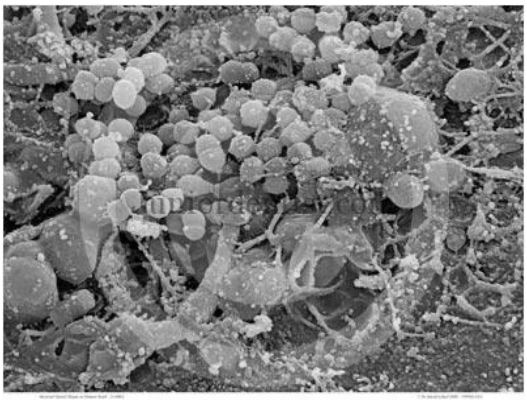


Fig 59. BACTERIAL COLONIZATION OF INTRAORAL HARD SURFACES,

ADHESION OF BACTERIA TO ORAL HARD SURFACES: TEETH AND IMPLANTS

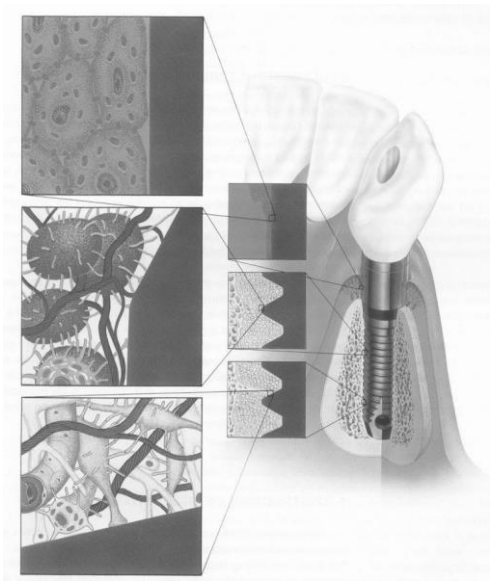


Fig 60. ADHESION OF BACTERIA TO ORAL HARD SURFACES: TEETH AND IMPLANTS

Bacterial adhesion to surfaces is driven by short-range weak bonds, primarily hydrophobic interactions. In the human oral cavity, bacterial adhesion is influenced by other factors as well.

All oral surfaces are bathed in saliva, and oral hard surfaces, such as teeth, implants, restorations, and prostheses, are coated by an acquired pellicle derived from saliva. Receptors in acquired pellicle can serve as specific binding sites for adhesions on bacterial cell surfaces; adhesions are specific adhesion-mediating bacterial proteins. This type of interaction has been invoked as a mechanism to explain the specific distribution of different groups of oral bacteria on different oral tissues. For example, Streptococcus sanguis is pioneer species in the colonization of tooth surfaces and form complexes in vitro with pellicle.

Colonization is mediated by an adhesion and can be blocked or inhibited by protease treatment of bacterial cell surfaces or by incubation of bacterial cells with antibody directed against the adhesion protein.

The preferred materials for implants are titanium or hydroxyapetite (HA)-coated titanium, for reasons of biocompatibility and osseointegration. These materials provide high-energy surfaces, and high-energy surfaces are regarded as important for successful osseointegration. Regardless of composition of root-form portion, the exposed part of these implants is smooth-surface titanium. Plaque accumulation on this high-energy surface has been reported to be less than on natural teeth, and this may be due to the smoothness of the surfaces. It follows that implant maintenance procedures should roughening, scratching, or marring the exposed portion of the implant because this may have the undesirable effect of enhancing plaque accumulation.

Despite the importance attached to understanding of interactions between oral bacteria and implant materials, few such studies are found in the literature. With the use of an in vitro adherence model, it was found that S. sanguis bound approximately equally to saliva-treated enamel and saliva treated titanium, whereas *Actinomyces viscosus* bound significantly less to saliva-treated titanium than to saliva treated enamel. Furthermore, three times as many S. Sanguis cells bound to saliva-coated titanium as did A. viscosus cells, despite equal binding of the two organisms to saliva-coated enamel.

In an in vivo study, plaque formation was studied on discs of a variety of implant materials placed in splints, which were worn intraorally for 4 or 48 hours. Materials studied included single-crystal and polycrystal alumina (PA), polycrystal zirconia, HA, and titanium. PA and HA had the greatest surface roughness, with average roughness (Ra) values approximately nine and five times greater than enamel. After 4 hours, pellicle adherence and bacterial colonization were seen on all materials, with PA and HA accumulating twice as many bacterial cells as the other materials. After 48 hours, the greatest bacterial numbers still were found on PA and HA, although the relative differences with other materials were somewhat smaller than at 4 hours. Statistical analysis was not presented, and significance of the differences with respect to material and time cannot be assessed. For all materials, *Streptococcus* species were the predominant early colonizers, and anerobes were present in significant numbers only in the 48-hours sample.

The general picture to be drawn from all of these studies is that implant materials are coated with salivary pellicle and colonized by oral bacteria essentially as is seen with natural teeth. Surface roughness of implant material is an important variable, with increased roughness promoting bacterial accumulation. For this reason implant maintenance procedure should avoid roughening, scratching, or marring the exposed portion of the implant.

PLAQUE ACCUMULATION ON IMPLANT ABUTMENT CYLINDERS

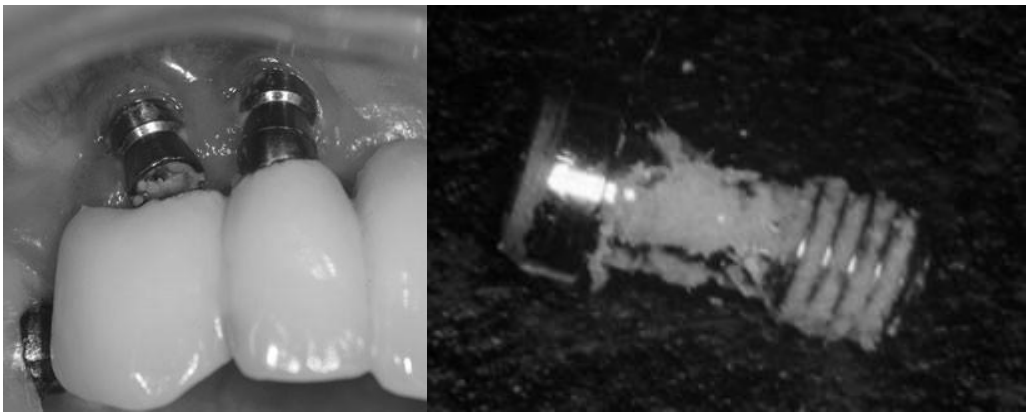


Fig 61.

Plaque accumulation is regarded as a risk factor for implant loss. In an animal study, poor oral hygiene after implant placement appeared to lead to looser junctional epithelium with fewer hemidesmosomes and intercellular desmosomes

A study of edentulous patients with mandibular implants found that lack of oral hygiene was the most significant factor associated with bone loss around the margins of the implants. It is accepted that disruption of the mucosal seal around implants and loss of supporting bone are effects produced by oral bacteria, but definitive studies relating this pathogenesis to accumulation of plaque on exposed implant abutments have not yet been done.

Studies investigated the effect of scrupulous control of supragingival plaque on the amount and composition of subgingival bacterial accumulations in periodontal pockets. The general findings of these investigations were that scrupulous, frequent removal of supragingival plaque resulted in marked reduction of total viable counts in pockets, increase in numbers of subgingival gram-positive organisms, and decrease in numbers and proportions of presumed periodontal pathogens such as spirochetes and porphyromonas gingivalis. It was concluded that saliva and supragingival plaque could serve as reservoirs for colonization of subgingival by periodontopathogens. (2)

SUBGINGIVAL MICROBIOLOGY AND DENTAL IMPLANTS

PERIODONTAL SUBGINGIVAL MIROFLORA OF HEALTHY AND FAILING DENTAL IMPLANTS

ASSAY SYSTEM	HEALTHY	NONIFECTIOUS	INFECTIOUS
Microscopic examination	Cocci Nonmotile rods Spirochetes	Cocci Nonmotile rods	Cocci Nonmotile rods Motile rods Spirochetes
Culture	Streptococcus spp. Actinomyces spp.	Streptococcus spp.	Gram-negative and gram-positive periodontopathogens Staphylococcus sp. Gram-negative enteric and facultative rods Yeasts

GOOD ORAL HEALTH

It is well established that in good oral health, the microflora of teeth is relatively sparse, mainly gram-positive, and mainly facultative, with the genera Streptococcus and Actinomycespredominating. With established gingivitis, the plaque is more abundant and has shifted to predominantly gram-negative and anerobic, with presence of putative periodontal pathogens such as P. gingivallis, Prevotella intermedia, and Spirochetes. Colonization and plaque formation seem to follow the same pattern on implants as on teeth.

Colonization and plaque formation on implants have been investigated in humans receiving transmucosal titanium or permucosal HA implants and after exposure and loading of titanium or HA endosseous implants and in beagle dogs with exposed titanium implants. The general approach in these studies was for several weeks or months to obtain samples of subgingival microflora for culturing and for microscopic

assay and at the same time to take clinical measurements at the sampled sites, including gingival and plaque indices, probing, and in some instances radiographs. The predominant subgingival morphotypes in healthy sites were cocci and nonmotile rods. The predominant cultivable subgingival bacteria were streptococci and actinomycetes, in terms of both percent of cultivable microflora and frequency of isolation. Putative periodontopathogens such as Porphyromonas gingivalis, Prevotella intermedia and Spirochetes were minor components of the microflora in healthy sites or were not found at all.

EDENTULOUS VERSUS PARTIALLY EDENTULOUS PATIENTS

Several investigations indicated that supragingival plaque on teeth could serve as reservoir for periodontopathogens and other organisms that colonize subgingival habitats. These results suggests that microflora of remaining teeth could serve as the source of inoculum for colonization of implants in partially edentulous patients, however, showed significant differences.

Culturing studies showed significantly higher percentage of so-called black-pigmented Bacteroides and Capnocytophaga species around implants of partially edentulous patients. With microscopic analysis, Quirynen and Listgarten found that implant sites in partially edentulous patients have significantly fewer cocci and significantly more motile rods and spirochetes than similar sites in edentulous patients, although Apse et al found such a difference for motile rods only.

Overall, these studies suggest the strong possibility that subgingival microflora of teeth can influence the subgingival microflora of implants in partially edentulous mouths. This reinforces the importance of rigorous oral hygiene programs in implant patients, especially in partially edentulous patients.

PERI-IMPLANTITIS AND IMPLANT FAILURE

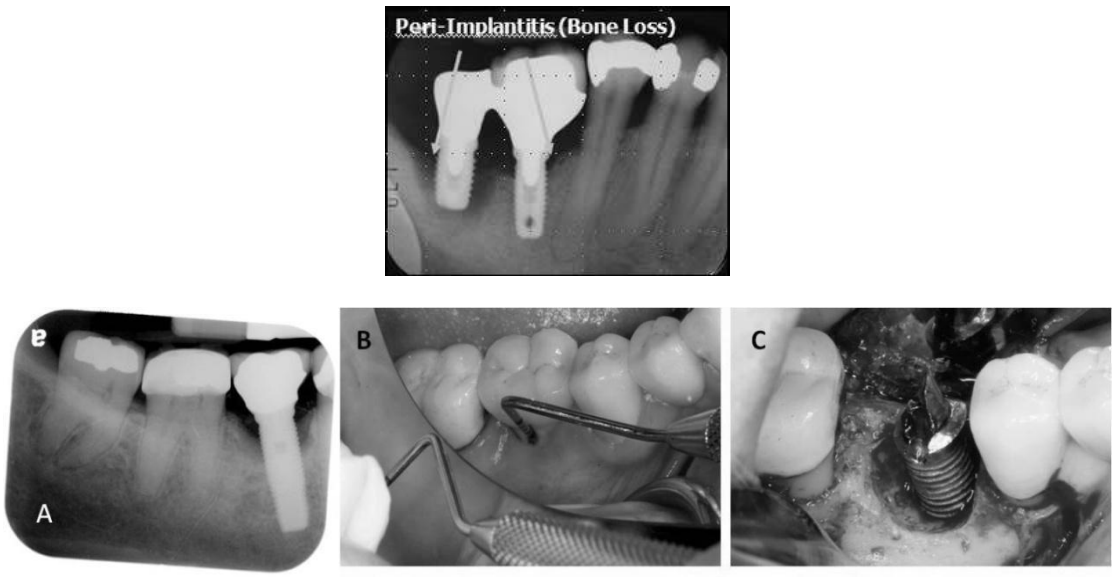


Fig 62. PERI-IMPLANTITIS AND IMPLANT FAILURE

Despite the success rate of well-designed, well-executed implant programs, there still are occasional failures. Early studies concluded that implant failure after primary healing and osseointegration was due to infection or extensive and excessive occlusal stress and suggested that in failure due to infection, the microflora was similar to that which produces periodontal disease.

The microbial cause of periodontal diseases has been clarified greatly over the past 15 years, and strong associations of microorganisms with various classes of periodontal disease have been developed. Because of the age distribution of patients receiving implants, adult periodontitis is the most realistic model for peri-implant disease or peri-implantitis.

The species associated with adult periodontitis include Actinobacillus actinomycetemcomitans, Bacteroides forsythus, Porphyromonas gingivallis, Prevotella intermedia, and Wolinella recta. Oral spirochetes are associated with increasing severity of periodontal disease and may constitute as much as 50% of the microscopic count in active periodontal lesions. They may be involved with the progression rather than the initiation of such lesions.

All failing implants are characterized by mobility and peri-implant radiolucency. Implants failing as a result of infection are additionally characterized by pain, bleeding on probing, suppuration, increased probing depth, high gingival and plaque indices, attachment loss, and granulomatous tissue on removal. Implant failing for traumatic reasons (surgical trauma, faulty design of prostheses, or overloading) may be painful, but otherwise lack the additional characteristic associated with infectious failure.

Implants suffering traumatic failure have subgingival microflora resembeling that of periodontal health, with cocci and nonmotile rods as the predominant morphotypes and Streptococcus and actinomyces species as the predominantcultivablemicroflora. In contrast, with infectious failure, spirochetes, motile rods, nonmotile rods, and cocci were seen in approximately equal numbers by microscopic analysis.

Predominant cultivable subgingival flora in infectious failure included Porphyromonas gingivallis, Prevotella intermedia, W. recta, Peptostreptococcus micros, Fusobacterium species, Candida species, Pseudomonas aeruginosa, and entric gram negative rods.

POSSIBLE PATHOGENIC MECHANISMS IN IMPLANT FAILURE

The hallmarks of implant failure are disruption of the perimucosal seal and loss of peri-implant bone, analogous to destruction of soft and hard tissue seen in periodontitis. The mechanisms leading to implant failure have not yet been defined. The subgingival microfloras associated with implant failure and periodontitis are similar, however, and it is reasonable to expect that the pathogenic mechanisms also would be similar. Current thinking is that destruction of periodontal tissue is a consequence of interactions involving endotoxin, cytokines, and cells of the periodontal region.

The key bacterial virulence factor for destruction of periodontal tissue is endotoxin, a ubiquitous component of the cell walls of all gram-negative bacteria. Gram-negative bacteria associated with periodontitis include A. actinomycetemcomitans, B. forsythus, Porphyromonas gingivalis, Prevotella intermedia and W. recta. Oral spirochetes are also gram-negative. In periodontal tissue, the primary target of endotoxin is the macrophage. Endotoxin-activated macrophages produce proteases that can degrade collagen and proteoglycans, ultimately producing degradation of extracellular matrix. Furthermore, activated macrophages produce the cytokines interleukin-1 (IL-1) and prostaglandin E_2 (PGE_2).

IL-1 has two targets: macrophages and fibroblasts. In an autocatalytic feedback loop, IL-1 stimulates macrophages to produce more IL-1. Fibroblasts are activated in two ways by IL-1. First, they are activated to produce additional proteases, which can degrade collagen and proteoglycans. Second, they are activated to produce PGE_2.

The PGE_2 produced by endotoxin-activated macrophages and IL-1-activated fibroblasts has as its target the osteoclast. PGE_2 activates osteoclasts, leading to resorption of alveolar bone and loss of support. This completes the circuits leading to destruction of soft and hard periodontal tissue. The likelihood is that these mechanisms are active in implant failure.

This picture is complicated by the finding that in in vitro systems implant materials are not physiologically inert and activate pathways that possibly could lead to loss of alveolar bone.

It is obvious, however, that further studies are required to determine wheather implants are contaminated with endotoxins during the manufacturing/sterilizing process and to determine the exact mechanisms causing loss of soft and hard tissue supporting implants.

FAILURE OF OSSEOINTEGRATION

Although osseointegrated dental implants have been shown to be successful, they are not perfect therapy. Because some dental implants encounter problems of increasing pocket depth and advancing bone loss, protocols must be established to manage these problems.

First, the cause of the adverse clinical changes should be determined, if possible. Among the reasons for dental implant failures are:

1. Hard tissue problems.
2. Soft tissue problems.
3. Bacterial accumulation (hygiene).
4. Host factors.
5. Combination of the above reasons.

HARD TISSUE PROBLEMS

Hard tissue problems are most often initiated at the dental implant placement surgery. Overheating of the bone, improper fit of the dental the implants, and lacks of stability of the dental implants at placement, all have the potential to create a fibrous tissue interface rather than osseointegration. This histologic situation may not become clinically manifest until uncovering and loading of the dental implants.

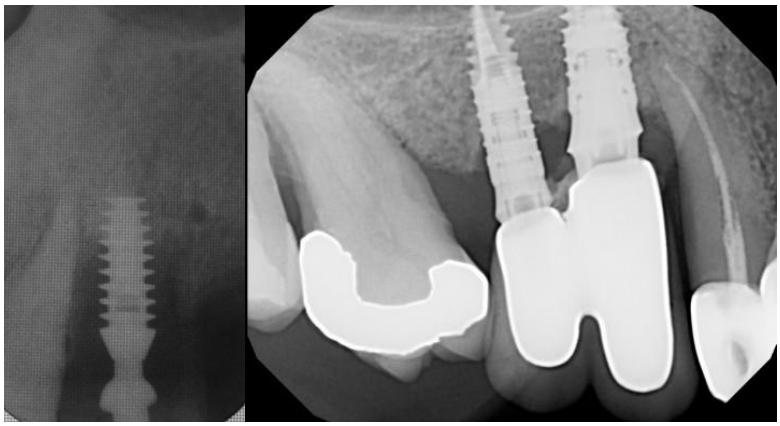


Fig 63. HARD TISSUE PROBLEMS

SOFT TISSUE PROBLEMS

Soft tissue problems can include tissue hyperplasia or recession. Both of these are often related to the presence of alveolar mucosa rather than keratinized gingiva adjacent to the implants and their abutment heads. Lack of firm adherent tissue adjacent to dental implants can foster food and bacterial accumulations with subsequent inflammation and patient discomfort.

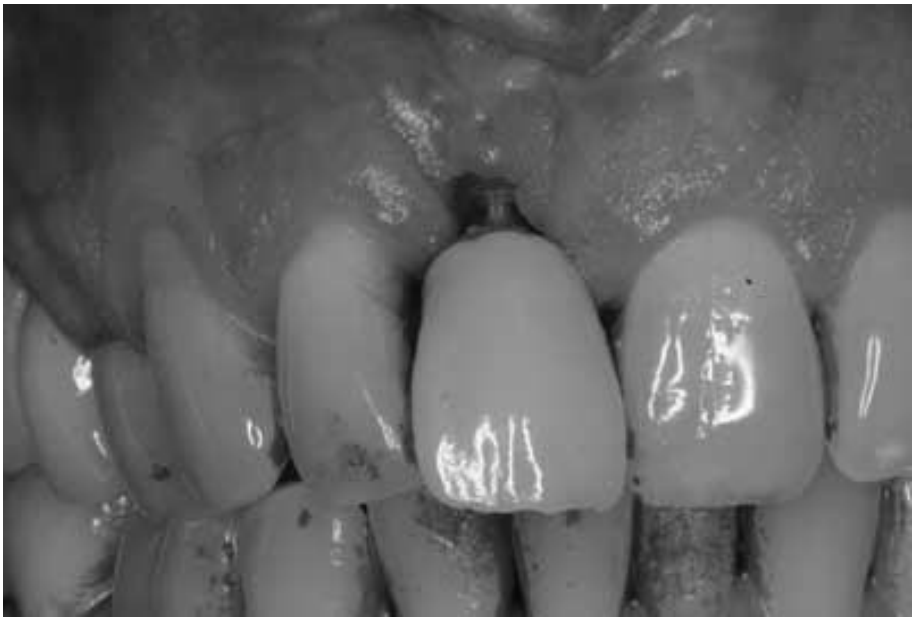
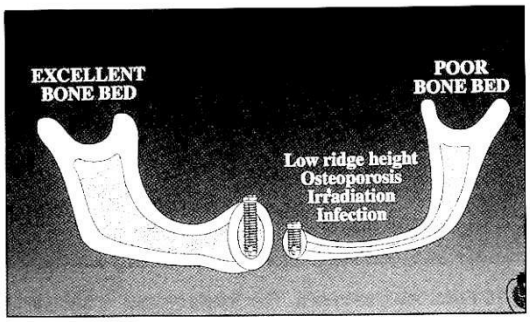


Fig 64. SOFT TISSUE PROBLEMS

HOST FACTORS



State of the host bed. The excellent bone bed is healthy and with an adequate amount and quality of bone. The poor bone bed suffers from low ridge height, osteoporosis, previous irradiation and infection, all conditions that by themselves may represent at least relative contraindications for routine insertion of implants other than in university clinics.

Fig 65.

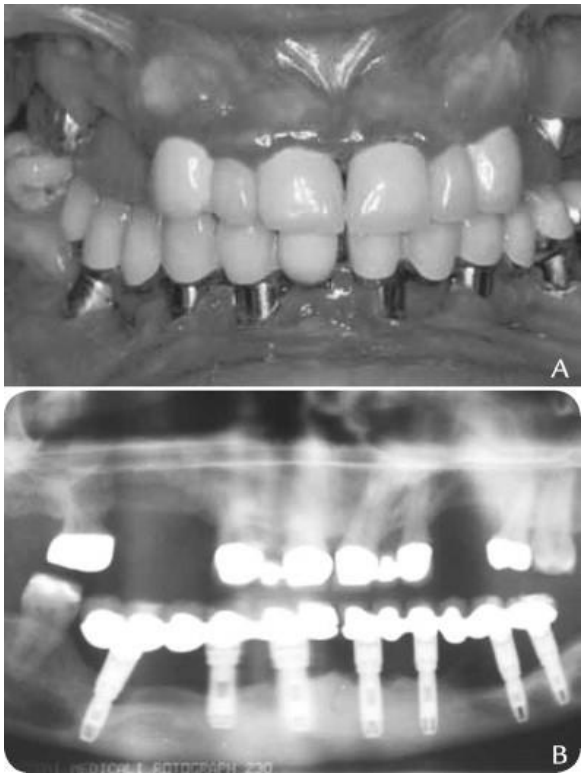


Fig 66. HOST FACTORS

Host factor a great unknown in dental implant failure. All patients have multitude of systemic and social factors that may play a role in implant success. Medical conditions, such as osteoporosis, diabetes, and others, may affect bone repair and the solidarity of the integration. Such medical conditions may also affect the sensitivity of the bone-implant interface to adverse post restorative influences. Medications, such as oral contraceptives, corticosteroids, or antineoplastic drugs, can also alter tissue metabolism, the repair response, and the resistance to irritants.

Pinpointing a single cause of dental implant failure is difficult. Most often, combinations of these various factors come into play. A marginal medical history, improper surgical technique, inadequate zone of keratinized gingival, poor prosthesis design, inadequate oral hygiene, heavy occlusal forces, and lack of follow-up care by the patient create a negative environment and compromise the short-term and long-term prognosis for dental implants.

TREATMENT OF FAILING IMPLANT

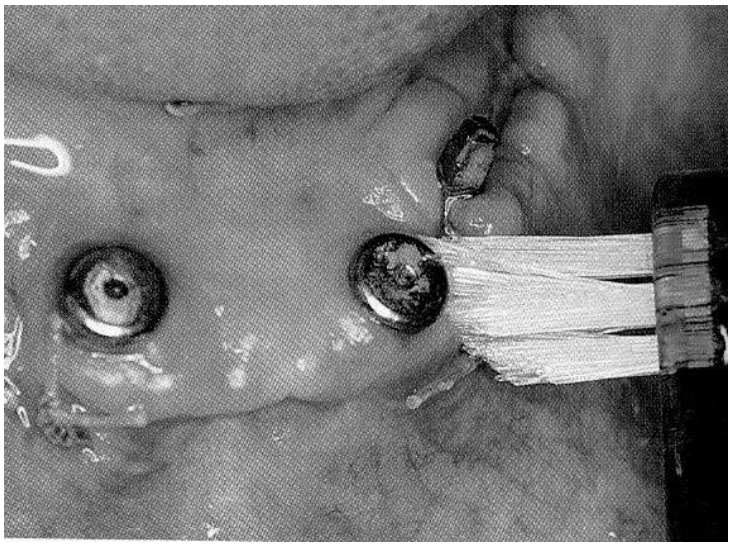


Fig 67. TREATMENT OF FAILING IMPLANT

Clinical and radiographic evidence that peri-implant conditions are not stable and that continuing advancing bone loss is occurring indicates the need for intervention. Clinical testing of the individual implants must show immobility of the implant despite the clinical bone loss. Mobility is tested manually as is done for natural teeth or with an instrument such as the PerioTest mobility device. Before any corrective treatment, the cause(s) should be identified and reduced or eliminated.

If the problems are mainly of the suprabony type (horizontal regular bone loss without vertical defects), management can focus on correction of the soft tissue portion of the peri-implant "pocket". Standard techniques, such as gingivectomy or apically positioned flaps, are used in these situations to reduce the pocket and improve access for oral hygiene. Regeneration of bone is not a goal of corrective treatment in these situations, and care must be taken not to reduce or eliminate surgically the zone of keratinized gingiva. When the bone loss around the dental implants is irregular with localized dehiscences and vertical defects, regenerative therapy may be indicated. Protocols for these types of rescue treatments are still under development.

Patients with failing dental implants should be placed on a regimen of systemic antibiotics. Antibiotics of choice include Doxicycycline, 100mg twice a day; Clindamycine, 150 mg thrice a day; or Amoxycillin/augmentin, 500 mg four times a day—all started 2 days before surgical treatment and continued for 10 days afterward.

Whenever possible, the suprastructures should be removed and a healing cover screw/cap placed on the head of the implants. Access to the problem area is achieved by means of a full-thickness flap to expose the dental implant and the adjacent bone.

Flap reflection must be extensive enough to gain clear appraisal of the exposed pathologically involved implant surface. As part of flap development, the granulomatous tissue next to the implant and in the adjacent bone defects must be removed with hand curets, files, or hoes. Neither ultrasonic instruments nor lasers should be used during these procedures.

Once the dental implant has been uncovered, the clinically exposed surfaces must be cleansed and decontaminated. The Cavi-jet/Prophy-jet provides mechanical cleansing of the implant surface by means of a baking soda "sandblasting" effect. Care should be used not to damage, ditch, or remove too much of the implant surface but rather simply to clean the surface mechanically.

If the implant has a hydroxyapatite (HA) coating, the sodium bicarbonate sandblasting action removes some or all of the HA coating in areas where excess time of application and high pressure from the air/powder spray are directed onto a small area of implant.

Chemical detoxification is then carried out by applying hydrogen peroxide intermittently with sequential soaked pellets for 5 minutes. This is followed by a similar application of tetracycline paste (250 mg capsule of tetracycline dissolved in 5 ml of sterile saline) for 5 minutes with similar sequential 1-minuite applications. The use of tetracycline in this manner is particularly effective when an HA coating is present because tetracycline binds and is slowly released in active form from HA, thereby providing a reservoir of antibacterial activity.

If a dehiscence on only one surface or a true infrabony defect is present, placement of a grafting material seems to beneficial. Bioactive material such as demineralized freeze-dried bone allograft particles or filler materials such as HA, HTR polymer, or BIOCORAL particles can be used.

Research has shown the advantage in certain applications of using guided tissue regeneration barrier materials to "seal" the surgical site. If at all possible, the flaps should be coronally positioned or laterally positioned to cover the dental implant and the repair area. This often requires submucosal releasing dissections to gain enough release of the tissues for primary coverage of surgical area. Such total coverage is also possible

only if the prostheses and abutment heads are retrievable, so a healing screw can be placed as at the time of original dental implant placement. Because of the tension present in the flaps, the swallowing of the vestibule, and the need for long-term closure, atraumatic, nonirritating, nonrecordable sutures should be used.

Follow-up care, including non-leaded healing, proceeds as with the initial implant placement. Repair and reintegration are allowed to proceed for 4 to 6 months, at which time re-uncovering and reattachment of the prostheses can occur. The uncovering is usually performed with a flap approach to reclaim the vestibular depth and secure a good zone of keratinized gingiva. Before prostheses replacement, however, any etiologic factors contributing to the treated problems around the implants must be corrected.

The combination of recognition of problems as they arise, appropriate intervention, correction of etiologic factors, and good follow-up care can “rescue” ailing/failing dental implants and preserve the patient’s investment in the implants themselves and the attached prostheses.

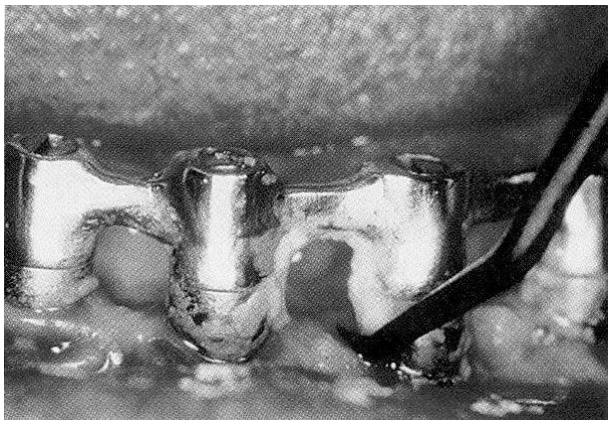
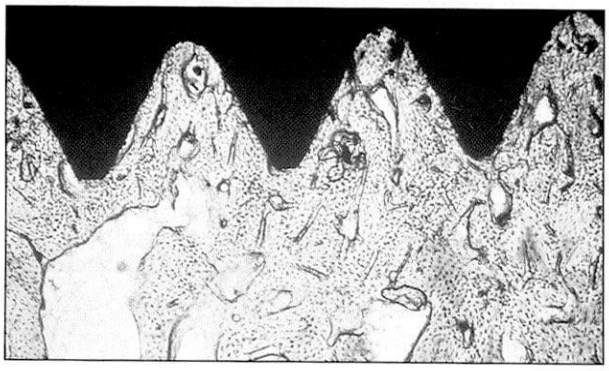


Fig 69. **rescue**



In the biologic reality there is no evidence of a complete bone to implant contact, but there is more or less soft tissue. Nevertheless, at the light microscopic level of resolution there is adequate evidence for osseointegration, even if there is no consensus to a histologically based definition of the term.

Fig 70.

The goal of modern dentistry is to return patients to oral health and in a predictable fashion. The partial and complete edentulous patient may be unable to recover normal function, aesthetics, comfort, or speech with a traditional removable prosthesis.

The patient's function when wearing a denture may be reduced to 60% compared with that formerly experienced with natural dentition; however, and implant prosthesis may return the function to near limits. The aesthetics of the edentulous patient are also affected as a result of bone atrophy. Continued resorption leads to irreversible facials changes. And implant stimulates the bone and maintains its dimension in a manner similar to healthy natural teeth. As a result, the facial features are not compromised by lack of support. In

addition, implant supported restoration are positioned in relation to aesthetics, function and speech, not in neutral zones of soft tissue support. The soft tissues of the edentulous patient are tender from the effects of thinning mucosa, decreased salivary flow and unstable or unretentive prosthesis. The implant retained restorations does not require soft tissue support and improves oral comfort. Speech and function are compromised with prostheses from supporting structures during use. The tongue and per oral musculature may be a compromise in order to limit the movement of mandibular prosthesis. The implant prosthesis is stable and retentive without the efforts of the musculature.

Implant prosthesis can offer a more predictable treatment course than traditional restorations. The discovery of osseointegration by Brånemark has revolutionized prosthetic treatment modality. The understanding of biologic entities and their functions in osseointegration has helped in many ways to the clinician, the manufacturers and not the least, the patients. The success and survival rates of Osseo integrated implants have heightened the expectations of the fraternity who can confidently take up the challenges of poor foundation dentistry. Statistics on the use of dental implants beer this out, about 1 lakh to 3 lakhs dental implants are placed per here approximates and the replacement of hip and knee joints placed per year. Implants are currently used to replace missing teeth, rebuild the craniofacial skeleton, provide anchorage during orthodontic treatment, and he went to help form a new bone in the process of distraction osteogenesis.

Research in biomaterials and biomechanics has fuelled a large part of the significant revolution associated with Osseo integrated implants. Focus has also shifted on other key areas like guided tissue regeneration, growth factors and tissue engineering.

Many advances have been made in the understanding of events at the interface between bone and implants and in developing methods for controlling these events. However, in the midst of the excitement born out of this activity, it is necessary to remember that the needs of the patient must remain paramount. It is also worth noting another as yet unsatisfied need. What all of the new developments, continuing education of clinicians in the expert use of all the advances is needed? A worthwhile in task for the future is to find ways to more effectively deliver products of research into the hands of clinicians.

CONCLUSION

Osseointegration forms the foundation of successful implant therapy and remains one of the most important concepts in modern dentistry. The long-term success of dental implants depends on multiple factors including implant design, surgical protocol, bone quality, patient-related factors, and biomaterial properties. Advancements in implant surface technologies and diagnostic methods have improved the predictability and success rates of implant treatment. A thorough understanding of the biological principles of osseointegration is essential for achieving optimal clinical outcomes and long-term implant stability.

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