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Biological Considerations Related To Osseointegration

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Abstract: *The innovation by P.I Branemark that bone tissue can adhere permanently to implant surface was a clinical breakthrough in oral rehabilitation. There are several reports by most of the authors which demonstrate the success of implants. The mean age of the implants is increasing in day today life. There are certain factors to be considered in maintaining the success rate of implants through process of osseointegration.This article explains about different biological aspects which are to be considered to increase the rate osseointegration in turn leading to success of implants.*
Key words: *Implants,Osseointegration,Bone.*

I. Introduction

Bone is a special form of connective tissue which makes up the maxilla and mandible. Knowledge about its structure and metabolism is essential in the process of osseointegration.[1]

II. Types Of Bone

1. **Mature**
   (I) Compact
   (II) Cancellous (Trabecular, spongy)
2. **Immature**
3. **Bundle**

Composition
The bone is composed of both organic and inorganic constituents
They are,

Inorganic	- 65%
organic	- 35%
Collagen	- 88% - 89%
Noncollagen	-11%-12%
Glycoprotein's	- 6.5%
Proteoglycans	- 0.8%
Sialoproteins	- 0.35%
Lipids	- 0.4%

Jaw Bones Can Be Classified Into:[1,2]
Alveolar Process
1. Alveolar bone proper
2. Supporting bone
   a. Cortical plates
      (i) Buccal
      (ii) Lingual
   b. Spongy (Cancellous), between cortical plates and alveolar bone proper.

Alveolar process is that part of the jaws which supports and attaches the teeth. [1,2] It consists of two parts.
1. Alveolar bone proper, which forms the socket wall and gives attachment to the PDL.
2. Supporting bone, consisting of buccal and lingual cortical plates and the cancellous bone in between the plates and socket walls.

In many regions only one part of the bone is present. even this plate may be deficient and show perforations. the socket wall is also known as the cribriform plate because of the presence of numerous holes produced by blood vessels. The alveolar process is dependent on the presence of teeth and is formed after the teeth erupt into the oral cavity, it is reabsorbed after the teeth are lost. The presence of basal bone is independent of teeth. [2]

III. The Cortical Plate

The cortical plate of alveolar process is continuous with conical plate of basal bone. These are mature lamellate bone. It consists of dense lamellated, haversian systems. At the crest of the tooth sockets the surface cortical bone is continuous with the alveolar bone proper. The thickness varies in different aspect of the buccal or lingual arch. In general it is thicker in the lingual aspect than labial. The labial aspect of the plates in maxilla shows numerous Volkman's canals for the entry of vessels and nerves. In mandible these canals are large but less frequent. [2]

The Spongiosa

The Cancellous bone lies between the cortical plates and alveolar bone proper. It contains marrow spaces and is continuous with the spongiosa of the body of the jaws. The maxilla has more Cancellous bone than mandible. The spongiosa is more on the lingual aspect than on the buccal. It is frequently absent in the anterior region.

The amount of cancellous bone increase posteriorly. The spongy bone transmits the masticatory forces from alveolar bone proper to cortical plates. These septae transmit blood vessels and the radiolucent lines of these on radiographs are called Hirschfield's canals. The spongy bone of alveolus contains fatty marrows. Red marrow may be seen in maxillary tuberosity and mandibular posterior region. The trabeculae tend to be arranged in a horizontal plane near the alveolar bone and are nearly perpendicular in the interradicular area. By this arrangement it Supports the tooth and resists vertical pressure. [1,2]

The Cribriform Plate

It is that layer of compact bone which forms the bony wall of the tooth socket. It appears radiopaque in radiograph and is called lamina dura.It transmits various blood vessels and nerves and is called cribriform plate. It consists of bundle bone and lamellated bone and gives attachment to Sharpey's fibers. Because of constant mesial and occulsal movement of the teeth this bone is remodeled constantly. These small openings of blood vessels, veins, nerves, lymph vessels, Open through nutrient canals. The interdental and interradicular septae contain perforating canals of Zuckerkandi and Hirschfield (Nutrient Canals).[2,3]

Bone is a connective tissue derived from the multipotential embryonic mesenchymal cells. It consists of the following. [2,3]

1. Cell: osteoblast, osteocyte and osteoclasts.
2. Intercellular substances

a. Collagen fibrils
b. ground substance (mucopolysaccharide)

Osteoblast (Fig.1)

- Primarily connected with bone formation
- Forms collagen fibrils and ground substance
- Also takes part in calcification
- Produce a homogenous intercellular substance called primary osteoid tissue. [2,3]

Osteocyte

Some osteoblasts become entrapped in osteoid (osseous matrix mineralization) tissue during its formation and are termed osteocytes. They occupy a space called lacunae and anastomose with each other by means of processes contained in Canaliculi. They are essential for the maintenance of bone. The process of osteocytes communicates with each other and with the central canal of a Haversian system. [2,3]

OSTEOCLASTS

Osteoclasts are large multinucleated connective tissue cells, active in bone resorption. They reside in irregular scalloped surface of bone known as Howship lacunae and exert its action with the help of proteolytic enzymes. However other theories state that osteoclasts are foreign body giant cells clearing up the debris after the removal of inorganic salts. They may also appear as clusters of osteocytes after the minerals have been removed. [2,3]

IV. Types Of Bone Tissue

1. Mature Bone
2. Immature Bone
3. Bundle Bone

Mature Bone

Show incremental lines or lamellae and are called lamellated bone

- Can be compact or spongy
- Compact bone is thick and solid. The lamellae are arranged in the form of concentric cylinders surrounding a narrow canal.

Each canal is surrounded by 5-20 lamellae. This whole unit is called Haversian system and the central canal is called a haversian canal. Haversian canals of adjacent units are connected with each other by finer canal called Volkman's canals. Osteocyte, through their Canaliculi also forms a communication with the Haversian canals.[2,3][Fig:2]

Immature Bone

- Contains more osteocyte than lamellated bone
- Cells are arranged haphazardly
- Collagen fibrils are not arranged in orderly fashion and it is not lamellated
- Fibrils are coarser and more in number.
- Contains less ground substance and are less calcified.
- Always arranged in a trabecular pattern. [2,3]

Bundle Bone

- Contains less collagen fibrils
- Sharpey's fibers are embedded in it.
- More ground substance and is more calcified
- This type is restricted to alveolar bone proper.
- Lamellae are less conspicuous because the fibrils are oriented in the same plane perpendicular to the surface function. Jaws are susceptible to metabolic attack when mechanical protection is compromised by an atrophic, mutilated dentition.[4]

Bone physiology is controlled by an interaction of mechanical and metabolic factors. The Biochemical mediators of calcium metabolism (parathyroid, estrogen and vitamin D) predominate in controlling the process. [2,3]

Bone Classification Schemes (Related To Implant Dentistry)

The appreciation of bone density and its relation to oral implantology have existed for more than 25 years. Linkow, in 1970, classified bone density into three categories: [4]

Class I bone structure: This ideal bone type consists of evenly placed trabeculae with small cancellated spaces.

Class II bone structure: The bone has slightly larger cancellated spaces with less uniformity of the osseous pattern.

Class III bone structure: Large marrow – filled spaces exists between bone trabeculae. [4]

MISCH CLASSIFICATION:[Fig:4]

Dl-Dense cortical bone.

D2-Thick dense to porous cortical bone on crest and coarse trabecular bone within.

D3-Thin porous cortical bone on crest and fine trabecular bone within.

D4 Fine trabecular bone

D5 Immature, nonmineralized bone [4]

These four macroscopic differences of bone may be arranged from the densest to the least dense, as first described by Frost

Dense cortical

Coarse trabecular

Fine trabecular

The macroscopic description of the Branemark bone density classification of Dl bone is primarily dense cortical bone. D2 bone has dense-to-thick porous cortical bone on the crest and within coarse trabecular bone. D3 has a thinner porous cortical crest and fine trabecular bone. D4 bone has almost Porous cortical no crestal cortical bone.[Fig:3] The fine trabecular bone composes almost all of the total volume of bone next to the implant. A very soft bone, with incomplete mineralization, may be addressed as D5 bone. [4]

V. Biologic Parameters For Implant Acceptance

Ten years ago, one of the authors proposed six factors that needed to be more or less simultaneously controlled for osseointegration of an inserted implant to result. The authors' current viewpoints on these six factors, with particular emphasis on recent observations, are summarized here.[5-10]

1. Material Biocompatibility

Comparative investigations have demonstrated a higher degree of bone-to-metal contact with commercially pure (CP) titanium than with stainless steel, cobalt-chromium alloy, and Ti-6AI-4V alloys. Hydroxyapatite is likewise known to be a most biocompatible material, and in short-term followup studies, there is convincing evidence of a more rapid bone response than seen with CP titanium. Gottlander compared several types of HA-coated implants to CP titanium controls and, with respect to long-term observations, found no indications of a stronger bone response to the HA-coated screws. Another advantage claimed for the hydroxyapatite coating - that it will protect against potentially toxic metal ion leakage - was not confirmed by Ducheyne and coworkers, who even reported an in vitro increase in the leakage of aluminum with HA-coated titanium alloy implants. The authors feel that hydroxyapatite-coated implants have been introduced too rapidly as clinical routine products. There has been a relative lack of adequate followup of clinical materials to motivate their present abundant use. [11,12,13]

2. Implant Design

There is no doubt that several different types of implant designs may show primary osseointegration. The question is whether there are stability advantages of screw-type designs compared to cylinders with respect to maintenance of the bony anchorage. [14]

3. Implant Surface

It has been known for some time that a certain implant roughness is advantageous for implant acceptance. However, there have been methodologic problems in identifying the "ideal surface" topography. With a newly developed threedimensional approach, for the first time it has been possible to describe the surface roughness of screw-shaped implants and then insert the same for quantified analyses of the importance of the surface topography for implant incorporation. It seems likely that when the surface is too rough, ion leakage will increase with potential disturbance of the interfacial response. At least one group of investigators has found no less than 1,600 ppm of titanium outside plasma-sprayed titanium implants and even suggested titanium leakage from such surfaces to be a potential drawback. [12]

4. State Of The Host Site

A host site-related parameter is the proportion of cortical and cancellous bone. There is one negative characteristic of the cancellous bone bed: its relatively limited capability of carrying the load. It is known from numerous experiments that the cancellous bone bed is most suitable for implant placement and, provided overload does not occur, it will remodel and become condensed into more compact bone. The load-bearing capability of the host bone must be individually evaluated and, in host sites of an assumed poor stability, a prolonged time between first- and second-stage surgeries is recommended to allow the bone to condense around the implant. [16]

5. Surgical Technique

Previous investigations have demonstrated the importance of controlling surgical trauma by not overheating or overstressing the bone. [17]

6. Loading Conditions

This topics is, of course, of a particular interest to the prosthodontist. More research is needed on the specific loading conditions that exist around an osseointegrated oral implant. The issue may be viewed from biologic as well as a biomechanical standpoint. For the biologist it is evident that the same mother cell may differentiate into a bone forming osteoblast or soft tissue-forming fibroblast, depending on environmental influences, premature loading leads to implant movements that in turn will shift the ehaling response to predominant soft tissue repair. The two stage implantation procedure has been recommended to allow incorporation of the implant under relatively stable conditions whereafter loading is allowed. It has been advocated that it is clinically advantageous to allow no extension of a maxillary fixed prosthesis during the first few months of loading to await proper bone remodeling and condensation in accordance with Wolff's law. [22]

7. Fixture Site Positions

The most important principle is to achieve good initial stability and full coverage of the fixtures in well-vascularized, highly osteogenic bone. Bicortical initial stabilization should be the goal. If this is not possible, one must resort to at least monocortical fixation. The additional stability that can be achieved by engaging the lingual cortical plate of the mandible should be used whenever possible. [17]

For adequate load distribution to the bone and the fixtures themselves, the latter should be spread well apart and placed along a curve or any arrangement other than a straight line. The center and the ends of the tentative superstructure should be well supported. However, the final design and extension should await the experience of bone quality from fixture and abutment surgeries. No figure for any optimal interfixture distance can be given because this depends on the vitality and mechanical capacity of both the fixture sites and the interfixture bone and may vary from one area to another. A clinical rule of thumb is, however, that the interfixture distance should not be less than one fixture diameter. This approach also facilitates later hygiene efforts between abutments.[11]

The anterior loop of the mandibular canal and the nasopalatine duct should be avoided so as not to interfere with nerve function and osseointegration.[11]

8. Number Of Fixture Sites

The available bone volume in different areas can be reasonably well assessed preoperatively by palpation and, especially, by tomographic radiographs. The same is not true for bone quality, which can be adequately determined only after some drilling has been performed. One may find, for example, that areas planned as fixture sites are totally unsuitable due to the presence of empty or fatty marrow compartments. Consequently, the number and position of fixtures cannot be finally decided upon until the preoperative period. Within the jaws it is generally advisable to start drilling for fixture sites close to the midline and then prepare the next ones as far posteriorly as possible, because the central and posterior sites strongly influence the outcome of the entire treatment. Only then can decisions be made on any interpositional fixtures to be placed. [19,20]

In the totally edentulous mandible, placement of fixtures from one molar area to the other (if the position of the mandibular canal allows) is not a recommended procedure. The mandible flexes somewhat during chewing, and rigid connection of such fixtures to a stiff bridge may cause micro fractures in the perifixtural bone during mandibular flexing.

For oral purposes, one fixture can carry one crown only, two fixtures provide minimal support for a bridge in partial edentulism, and four fixtures are the minimum for a full-arch bridge, provided they are spaced well apart along a curve. Unpublished data from the Goteborg team showed no significant differences in 5- to 12-year survival rates for maxillary and mandibular bridges supported by four or six fixtures.

9. Inclination Of Fixture Sites

The inclinations of the fixture sites depend on; [9]

1. Local bone anatomy:The dominant principle is still that the fixtures should be totally embedded in bone. This may call for lingual or buccal positioning or a tilting of a fixture site to avoid concavities in the bone. If no bone grafts are placed into the floor of the maxillary sinus, distal tilting of the marginal parts of fixture sites may also be needed in the first premolar region to avoid penetration into the maxillary sinus. Moreover, such an inclination frequently allows advantage to be taken of the canine eminence.
2. Jaw relationships: Unless orthognathic surgery is performed before or possibly in combination with bone grafting at fixture installation, pseudoprognathism due to resorption generally calls for buccal inclination of maxillary and lingual tilting of mandibular fixture sites in total edentulism.
3. Design of the suprastructure: With proper inclination of fixture sites, penetration of bridge screw canals through buccal facings can be avoided. An overly palatal inclination may, on the other hand, result in a bulky bridge that interferes with phonation.
4. Desire for parallelism: If parallel fixture sites are prepared, the construction of the suprastructure may be facilitated.[9]

10. Lengths Of Fixtures

The lengths of the fixtures should be determined only after all "high-speed" drilling has been finished. In particular, marginal countersinking may reduce the depth of a fixture site, and then fixtures shorter than originally anticipated must be chosen. The depth of a fixture site should be measured with a graded (ball-point) explorer to the lowest marginal bone edge. [20,21]

Major extra bony protrusions of the apical parts of fixtures (e.g., into the maxillary sinus or the nasal cavities) are not justified. Experience with surgical displacement of the inferior alveolar nerve to gain bicortical fixation in mandibular molar areas is thus far limited.[20,21]

11. Load-Bearing Capacity

The net effect of all the considerations discussed above governs what dynamic load the fixtures are able to bear. It is the quality of all perifixtural bone and the total interface surface of all fixtures that determine the load-bearing capacity. Consequently, four 15-mm-long fixtures may be capable of carrying the same load as six 10-mm-long ones, provided all are strategically well placed. [14,15]

The long-term fixture survival rate is slightly smaller for the maxillae than for the mandible. These results are likely to reflect, differences in the load-bearing capacity between the jaws. Such difference could theoretically require a greater fixture/bone interface in the maxillae for adequate load distribution, that is, more or possibly longer fixtures than in the mandible.[14.15]

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Fig.1: High Resolution Scanning Electron Micrograph of an Osteoblast

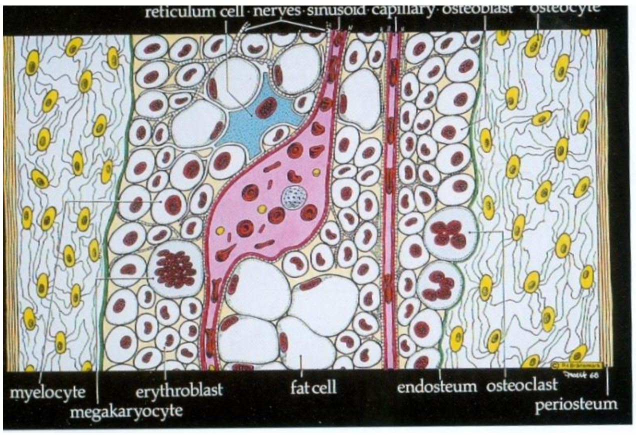

Fig.2: Tissue components of bone marrow

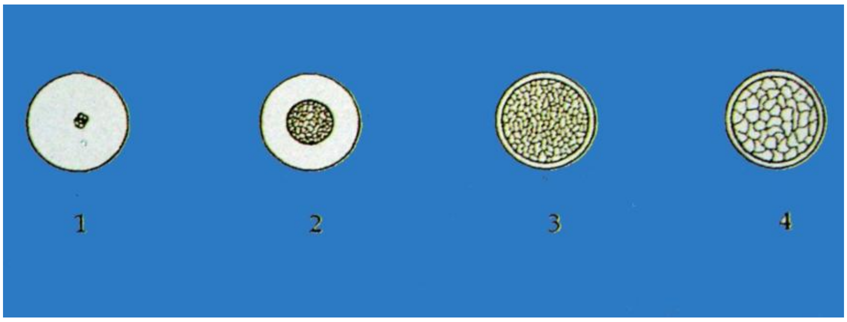

Fig.3: Bone quality as categorized by Branemark

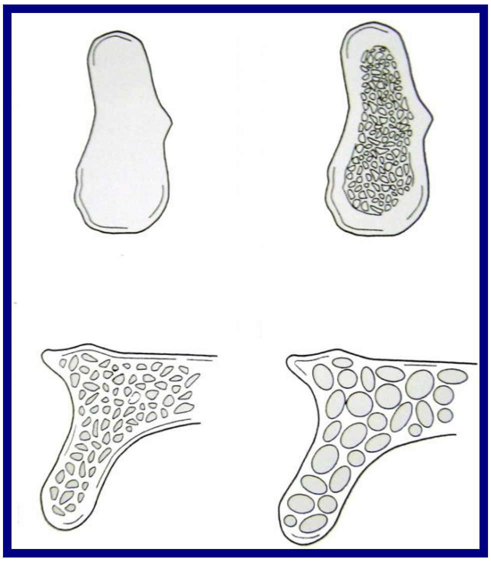

Fig.4: Macroscopic description of the four Misch densities