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OSSEOINTEGRATION- A CURRENT CONCEPT

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ABSTRACT

Comprehensive changes in the practice of implantology have been made possible through a more exhaustive understanding of the essential requirements of specific case treatment planning, surgical procedures, and the evolution of the design and architecture of the modern day implants. However, the most fundamental process that is the basis to any implant treatment is osseointegration. In the recent times, the concept of osseointegration has undergone a most extensive understanding and research. Osseointegration has been defined as the direct structural and functional connection between ordered, living bone and the surface of a load - carrying implant. Nowadays, an implant is considered as osseointegrated when there is no progressive relative movement between the implant and the bone surface. It has thus been postulated that osseointegration is not the result of an advantageous biological tissue response but rather the lack of a negative tissue response. A thorough knowledge of the mechanism of osseointegration and the various factors influencing it, will go a long way in optimizing the results obtained during implant therapy. This article aims to throw light on the current concept of osseointegration.

KEYWORDS: Bone, Implant -bone interface, implants, Implant surface, Matrix, Osseointegration.

INTRODUCTION

The loss of teeth is an extremely traumatic and upsetting experience for most people. The accompanying feelings of grief and loss are compounded by the inherent inadequacies of complete dentures. It is hardly surprising that many edentulous people and their dentists have searched long and hard for a viable alternative. The search to find a successful attachment mechanism between a denture and the alveolar bone is not new. Since tooth loss from disease and trauma has always been a feature of mankind's existence, it is not surprising that the history of tooth replacement is a long one.[1]

Evidence from ancient civilization showed that attempts were made to replace missing teeth by banding artificial tooth replacements to remaining teeth with metal many centuries ago. For the mechanism of attachment, clinicians have long sought an analog for periodontal ligament. Experiments were conducted to develop a fibrous attachment that could serve the same purpose as the periodontal ligament but all in vain. The periodontal ligament, being a specialized structure which serves not only as an efficient attachment mechanism but also as a shock absorber and sensory organ, is almost impossible to reproduce.

Many surgical procedures have been developed over the years to restore a more favorable anatomy for prosthesis support. However, all these offered short term improvement with no clinically long term success. Implanting artificial materials to aid in denture retention has been used for many years with varying degrees of clinical success. The first scientifically based study on the biocompatibility of implantable materials began in Sweden in 1952. Animal studies, including work with rabbits and dogs, indicated that properly prepared surgical-grade titanium in combination with surgical techniques resulted in a predictable biologic response and a phenomenon that was termed Osseointegration by its progenitor, Professor Per-Ingvar Branemark of Goteborg, Sweden.[2]

Ever since this discovery, Osseointegration has become a realized phenomenon of importance also in the orthopedic and rehabilitation sciences. Osseointegration represents a lifelong process of bone formation, adaptation to function, and repair. The success of dental implants should be defined in terms of the underlying biologic mechanisms affecting the formation, adaptation, and repair of bone. Osseointegration is a process that is measured in clinical terms of implant fixture lifetime and this reflects the significance of lifelong functional maintenance of bone at the implant interface.[3]

Concepts Of Osseointeration[4]
There are two basic theories regarding the bone-implant interface.

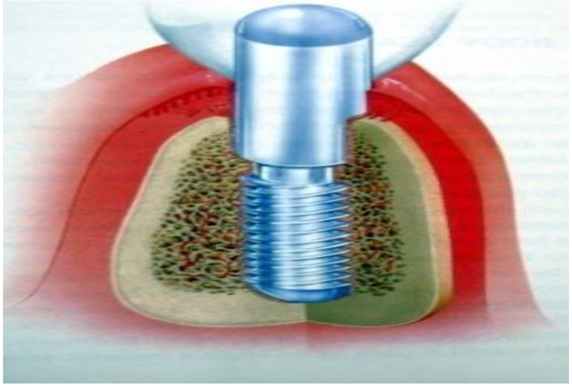
1) **Fibro-osseous integration** (Linkow 1970, James 1975, and Weiss 1986).
2) **Osseointegration** (supported by Branemark, Zarb, and Albrektsson 1985).

Theory of Fibro-osseous integration
Fibrous integration refers to connective tissue made of well organized collagen fibers, present between the bone and implant. In this theory, collagen fibers work similar to sharpey's fibers. They are proposed to affect bone remodeling at areas of tension in a manner similar to periodontal ligament.

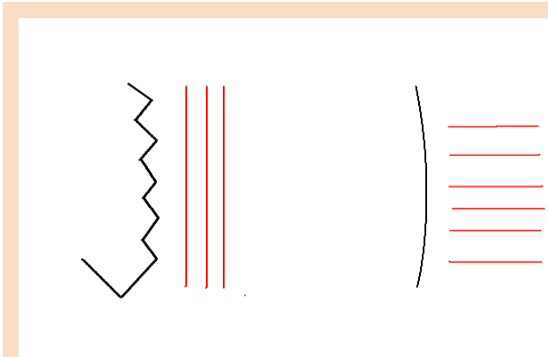
In 1986, the American Academy of Implants Dentistry (AAID) defined fibrous integration as "tissue-to-implant contact with healthy dense collagenous tissue between the implant and bone"

Weiss stated that the presence of collagen fibers at the interface between the implant and bone is a peri-implant membrane with an osteogenic effect. He believed that the collagen fibers invest the implant, originating at the trabeculae of cancellous bone on one side, weaving around the implant, and reinserting into a trabeculae on the other side. When function is applied to the implant, tension is applied to fibers. The fibers closer to the implant interface gets compressed with a corresponding tension on the fibers placed or inserting in to the trabeculae. The difference between compression and tension of the connective tissue components results in a bioelectric current, and this current (a piezoelectric effect) induces differentiation into connective tissue components associated with bone maintenance. Hence, the premise of the fibers being osteogenic.

However there are drawbacks to this theory. Unlike sharpey's fibers, the collagen fibers around implant are arranged irregularly parallel to the implant body. When forces are applied they are not transmitted through the fibers as in natural dentition nor do they bring about bone remodeling as was thought earlier.



Fibro-osseous integration



Implant **Tooth**

Failure of fibro-osseous theory
Conventional implant systems have always had a fibrous capsule or fibrous tissue interface along the surface of the implant, which has been referred to as a pseudo-peri-implant membrane. It was felt that, this membrane gave a cushion effect and acted as similar as periodontal membrane in natural dentition.[5]

However, there was no real evidence to suggest that these fibers functioned in the mode of periodontal ligament. Hence when in function the forces are not transmitted through the fibers as seen in natural dentition. Therefore, remodeling was not expected to occur in fibrous integration. Moreover the forces applied resulted in widening fibrous encapsulation, inflammatory reactions, and gradual bone resorption there by leading to failure.

Theory of Osseointegration
The term "Osseointegration" was coined by Dr Per Ingvar Branemark in 1985. According to him a direct bone to implant attachment is possible (Fig-17) if the implant is allowed to heal undisturbed. Branemark histologically defined osseointegration as "a direct connection between living bone and load carrying endosseous implant at the light microscopic level".

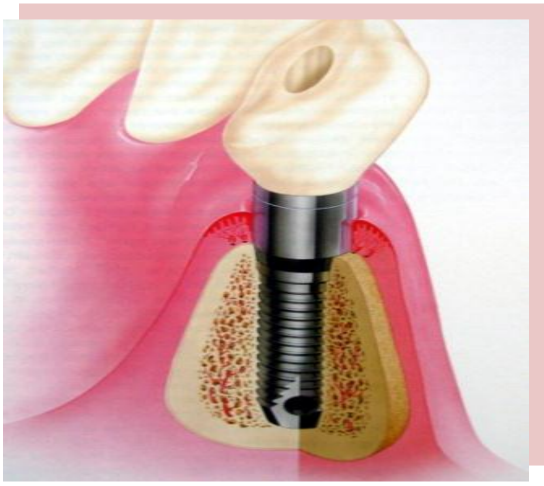
Meffert et al, (1987) redefined and subdivided the term osseointegration into "adaptive osseointegration" and "biointegration". "Adaptive osseointegration" has osseous tissue approximating the surface of implant without apparent soft tissue interface at the light microscopic level.

"Biointegration" is a direct biochemical bone surface attachment confirmed at the electron microscopic level
In 1986, American Academy of Implant Dentistry (AAID) defined it as "contact established without interposition of non-bone tissue between normal remodeled bone and an implant entailing a sustained transfer and distribution of load from the implant to and within the bone tissue"

Unlike fibro-osseous integration, osseointegration was able to distribute vertical and slightly inclined loads more equally in to surrounding bone. To obtain a successful osseointegration, Branemark and coworkers proposed numerous factors. According to the proponents the oxide layer should not be contaminated or else inflammatory reaction follows resulting in granulation tissue formation. The temperature during drilling should be controlled by copious irrigation, if not can cause breakdown of alkaline phosphatase which can inhibit alkaline calcium synthesis thereby preventing osseointegration.[6]

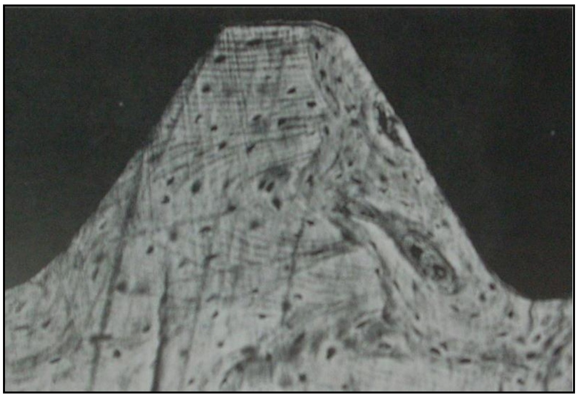
The first month after fixture insertion is the critical time period for initial healing period. When loads are applied to the fixture during this period primary fixation is destroyed. Relative motion of a fixture causes collapse in the balance between bone apposition and resorption, preventing osseointegration. A minimum of three months healing in the mandible and six months in the maxilla is necessary before applying any load to an exposed fixture. Once osseointegration has occurred, there are few limits and masticatory function can approach that of natural dentition with proper occlusal adjustment.[7]

If osseointegration does not occur or osseointegration is lost for some reason, a fibrous connective tissue forms around the implant. The organization process continues against the implant material, possibly resulting from chronic inflammation and granulation tissue formation. In this instance, osseointegration will never occur (Albrektsson et al, 1983).



Osseointegration From A Mechanical And Biologic Viewpoint[5]
Osseointegration represents a direct connection between bone and implant without interposed soft tissue layer. However 100% bone connection to the implant does not occur. It has been suggested that the nature of the osseointegrated bond is related to physical and chemical forces acting over the interface (Albrektsson et al. 1983). The bond is, in all probability, predominantly biomechanical.[8]

Complete bone ingrowth does not occur in spaces much smaller than 100 microns (Albrektsson 1979). However, bone ground substance will adapt to surface irregularities in the 1-100 microns range, explaining why changing the surface topography at this level will result in a profound impact on the holding power of the implant (Wennerberg 1996).



Osseointegration represents a direct bone to implant contact at the resolution level of the light microscope. Retrieved clinical specimen showing a high degree of bone to implant direct contact.

There is no scientific evidence that irregularities even in nm range, will affect the bone response, though this has been suggested by some investigators. Commercially available oral implants have average surface irregularity values (Sa) between 0.5-2.5 microns. In animal experiments there is a scientifically stronger bone.

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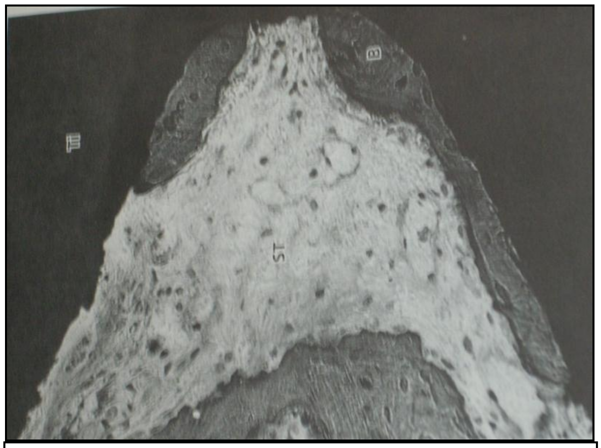
Commercially available oral implants have average surface irregularity values (Sa) between 0.5-2.5 microns. In animal experiments there is a scientifically stronger bone response to surfaces with values of 1.0-1.5 microns. Surface irregularities in the two microns range or greater will show a diminished bone response, possibly because of increasing ionic leakage from the relatively rough surfaces.

Osseointegration is a time related phenomenon. (Fig 8) and Albrektsson in 1987 demonstrated that during the first few weeks after implant insertion there were no signs of proper osseointegration. Three months after implant insertion there was a relatively high proportion of bone to implant direct contact and a clearly increased resistance to torque removal. The amount of bone and resistance to torque further increased, in the rabbit model used, at 6 and 12 months of follow-up.[9]



A few weeks after implant insertion there is very sparse bone to implant contact. The bone tissue (B) contact with the implant (Ti) increases with time. ST = soft tissue.

Previous attempts to measure implant stability and thereby its degree of osseointegration have included the Periotest measurements (Schulte and Lukas 1993). Meredith and co-workers (1994, 1996) have described a different approach to assess bone formation around an implant, measuring the resonance frequency of a smaller transducer attached to an implant fixture. Resonance frequency of an implant / transducer system was found to be related to the height of the implant not surrounded by bone and the stability of the implant / tissue interface.

Once established the osseointegrated interface is relatively resistant but certainly not immune to various types of stimuli. Whereas the healing bed around the implant is highly sensitive to irradiation or heat injuries, once osseointegration has occurred, the same trauma levels will seemingly not affect the bond (Eriksson 1984, Jacobsson 1985). However, prolonged adverse conditions may result in breakage of osseointegration and subsequent implant failure. A good example is implant overload. Overload is detrimental to osseointegration during the first few months after implant insertion, because interfacial movements will simulate soft tissue formation in the interface but once osseointegrated; the interface is capable of carrying occasional strong loads. Continuous dynamic overloading of osseointegrated implants, however, will lead to micromovements and subsequent bone resorption.[10] If the condition were not altered in time (precise time / load relations are unknown), continuing bone resorption will result in increasing micromovements, eventually leading to implant failure. This sequence of events is typical for cylindrical implants without any macroscopic retention elements in the form of threads (Albrektsson 1993).

Osseointegration Vs Biointegration

As a result of recent research, the terminology used to further define the retention means of dental implants has been altered to Osseointegration Vs Biointegration. In 1985, deputter et al. observed that there are two ways of implant anchorage or retention: mechanical and bioactive.[13]

Mechanical retention basically refers to the metallic substrate systems such as titanium or titanium alloys. The retention is based on undercut forms such as vents, slots, dimples screws and so forth and involves direct contact between the dioxide layer on the base metal and bone with no chemical bonding.[11]

Bioactive retention is achieved with bioactive materials such as hydroxyapatite (HA), which bonds directly to bone, similar to ankylosis of natural teeth. Bone matrix is deposited on the HA layer as a result of some type of physiochemical interaction between the collagen of bone and the HA crystals of the implant.

Plasma-spraying and the ion-sputter coatings are two techniques used to coat metallic implants with HA. Plasma-spraying involves heating the HA by a plasma flame at a temperature of approximately 15,000^{0}C to 20,000^{0}C. The HA is then propelled onto the implant body in an inert environment (usually Argon) to a thickness of 50-100*u*m. Ion-sputter coating is a process by which a thin, dense layer of HA can be coated onto an implant substrate. This technique involves directing and ion beam at a solid-phase HA block, vaporizing it to create a plasma, and then recondensing this plasma on the implant.[12]

Various authors have reported bone formation and maturation occurring at a faster rate and at earlier periods on HA coated implants than on non-coated implant; and the HA – coated system developing an average of 5-8 times the mean interfacial strength of an uncoated, grit surfaced titanium system in 10-32 week studies.

Research in animals has shown that not only is there the possibility of bone growing in a coronal direction on the surface of a material such a s HA, but there is also the possibility of development of a supra alveolar connective tissue apparatus with new gingival fibers inserting into the osteoid.[13]

Structural Aspects of the Interface between Tissue and Titanium Implants

The tissue-titanium-implant interface may be divided into three main zones.[10]

A. The bone – implant interface
B. The implant – connective tissue interface
C. The implant – epithelium interface

The Bone – Implant Interface

The interaction between bone and the titanium surface must firstly be recognized as a zone rather than a distinct, well defined structure. The zone is a composite entity of numerous cells, proteins and molecules in close apposition to a polycrystalline surface of titanium (Albrektsson et al. 1983, Sennerby et al. 1991).

On observing the implant and bone interface at the light microscopic level (100X) it shows that close adaptation of the regularly organized bone next to the Ti implants.

Scanning electron microscopic study of the interface shows that parallel alignment of the lamellae of haversian system of the bone next to the Ti implants. No connective tissue or dead space was observed at the interface.[14]

Ultra microscopic study of the interface (500 to 1000X) shows that presence of amorphous coat of glycoproteins on the implants to which the collagen fibers are arranged at right angles and are partly embedded into the glycoprotein layer.

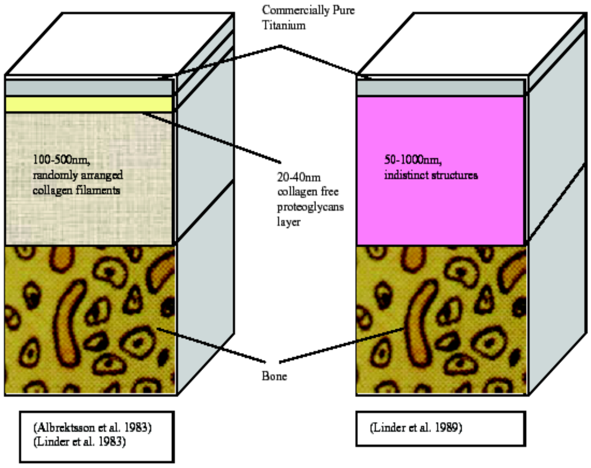
Mechanism of attachment

As a general rule, cells do not bind directly to the foreign materials. The cell binds to each other or any other foreign materials by a layer of extracellular macro molecules (glycoproteins).

The glycoprotein layer in between the cells or in between the tissues will be of a thickness of 10 to 20 nm (100 to 200 A^0).

At the interface, the glycoprotein layer of normal thickness (10-20 nm) is adsorbed on the implant surface within the help of adhesive macromolecules like Fibronectin, Laminin, Epibiolin, Epinectin, Vitronectin (serum spreading factor), Osteopontin, thrombospodin and others. At the molecular level the macromolecules contains Tri-peptides made up of Arginin-glycine-Aspartic acid (RGD). The cells like fibroblasts and other connective tissue cells contain binding elements called as "integrins". The integrins recognizes the RGDs and bind to them.[15]

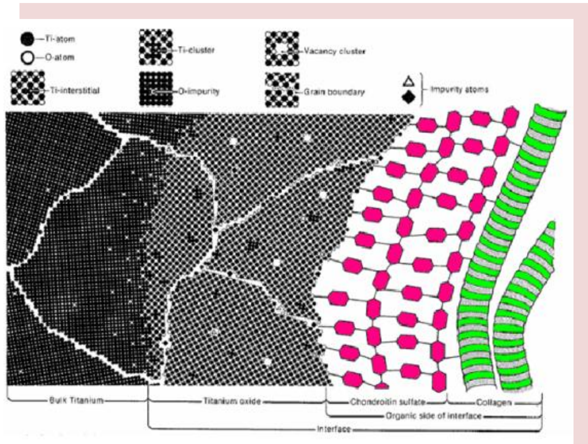
The macromolecules are adherent more firmly to the metallic oxide layer on the Ti implants. The mode of attachment between the oxide layer and the macromolecules may be of covalent bonds, ionic bonds or van-der-walls bonding.



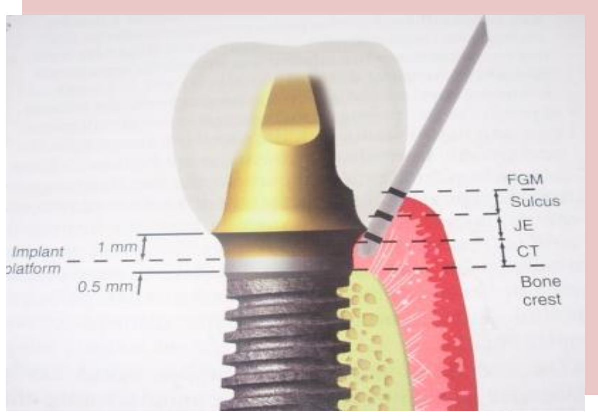
Diagrammatic representation of the bone implant interphase as represented by cited authors (adapted from albrektsson et. Al 1994).

Implant Connective Tissue Interface

The connective tissue above the bone attaches to the implant surface in the similar manner as that of the implant bone interface. The supra crestal connective tissue fibers will be arranged parallel to the surface of the implant. Because of this type of the attachment the interface between the connective tissue and implant is not as strong as that of the connective tissue and tooth interface. But the implant connective tissue interface is strong enough to withstand the occlusal forces and microbial invasions.[16]



Connective Tissue Interface with Titanium Implant (adapted from Albrektsson et. al 1983).



Implant epithelial interface

The implant epithelial interface is considered as Biologic seal by many authors. At this interface, the glycoprotein layer is adherent to the implant surface to which hemidesomosomes are attached. The hemidesmosomes connect the interface to the plasma membrane of the epithelial cells. Because of this attachment the implant epithelial interface is almost similar to the junctional epithelium. For the endosseous implants the sulcus depth varies from 3 to 4mm.

Soft Tissue-Implant Interface

In contrast to the natural tooth, macroscopic evaluations suggest that implants display no periodontal ligament or gingival sulcus (Schroeder et al. 1981). The epithelium has been observed to have a tight adaptation to the collar of the implant with little inflammation, presumably in the absence of dental plaque (Schroeder et al. 1981). The junctional epithelium is often quite difficult to discern, but has been identified to remain coronal to the crestal alveolar bone (Listgarten et al. 1992).[17]

An intervening dense connective tissue layer is observed between the alveolar bone and epithelium. This layer generally contains connective tissue fibers which are oriented parallel to the implant surface and tends to be less vascularized on approaching the implant surface (Listgarten et al. 1992).

On an ultrastructural level, the epithelial cells seen adjacent to the implants display no alteration in morphology. Though often found very close to the titanium surface, a small residual gap would always be present, filled with an amorphous granular substance (Schroeder et al. 1981). No direct contact with cell membrane and titanium surface has been observed in this coronal area. Due to limitations in specimen preparation, the nature of the interface between the junctional epithelium and implant has not been evaluated successfully (Albrektsson et al. 1983, Listgarten et al. 1992).[18-20]

CONCLUSION

Osseointegration represents a direct connection between bone and implant without interposed soft tissue layers. However, 100% bone connection to the implant does not occur. Problems in identifying the exact degree of bone attachment for the implant to be termed osseointegrated has led to a definition of osseointegration based on stability instead of on histologic criteria: " A process whereby clinically asymptomatic rigid fixation of alloplastic materials is achieved, and maintained, in bone during functional loading" (Zarb & Albrektsson 1991).

The clinical procedure of osseointegration has an ultimate aim to provide the edentulous patient with occlusal rehabilitation. Long term clinical experience has clearly indicated that osseointegrated reconstructions rely for their prognosis on persistent precision in the surgical procedures involved in installing the titanium fixtures.

The range of application of osseointegration has been extended from the initial application in the field of dental implants to replace missing teeth to assist in orthodontic tooth movement in the present era. Even a cursory review of the wide range of applications of osseointegration reveals how many patients have derived enormous benefit from the discovery of this biologic phenomenon. Patients and clinicians alike owe a great debt to those who discovered osseointegration and those who worked patiently and persistently to refine its applications.

REFERENCE

1. David. M. Davis. The shift in the therapeutic paradigm: Osseointegration. J Prosthet Dent, 1998; 79: 37-42.
2. Sumiya Hobo, Eiji Ichida, Lily T. Garcia. Osseointegration and Occlusal Rehabititation, Introduction, 3-7.
3. Lyndon F. Cooper. Biologic determinants of bone formation for osseointegration: clues for future clinical improvements. J Prosthet Dent, 1998; 80: 439-49.
4. Glossary of prosthodontic terminologies, July 2005; 94.
5. Jan Lindhe, Thorkid Karring, Niklaus P. Lang. Clinical Periodontology and Implant Dentistry, Osseointegration: Historic Background and Current Concepts, Fourth Edition, 809-820.
6. Per-Ingvar Branemark Osseointegration and its experimental background. J Prosthet Dent, 1983; 50: 399-410.
7. Tomas Albbrektsson, Ann Wennerberg. The impact of oral implants: Past and Future. J Can Dent Assoc, 2005; 71: 327.
8. Sumiya Hobo, Eiji Ichida, Lily T. Garcia. Osseointegration and Occlusal Rehabititation, Biological considerations for osseointegration, 33-54.
9. J.E. Davies. Mechanisms of endoosseous integration. Int J Prosthodont, 1998; 11: 391-401.
10. H-A. Hansson, T. Albrektsson, P-I Branemark. Sturctural aspects of the interface between tissue and titanium implants. J Prosthet Dent, 1983; 50: 108-113.
11. Timothy G Donley. Titanium endosseous implant-soft tissue interface: A literature review.J Periodontol, 1991; 62: 153-160.
12. K.H.Lee, M.F.J.Maiden, A.C.R. Tanner, H.P.Weber. Mirobiota of successful osseointegrated dental implants. J Periodontol, 1999; 70: 131-138.
13. T. Albrektsson, George A. Zarb. The branemark osseointegrated implant, Biological, microbiological and clinical aspects of the peri-implant mucosa, 39-78.
14. Carl Misch. Contemporary implant dentistry, 242-248.
15. Tomas Albrektsson. Direct bone anchorage of dental implants J Prosthet Dent, 1983; 50: 255-261.

16. Carl J. Drago. Rates of osseointegration of dental implants with regard to anatomical location. J Prosthod, 1992; 01: 29-31.
17. Murat Cehreli, Saime Sahin, Kiwanc Akca. Role of mechanical environment and implant design on bone tissue differentiation: current knowledge and future contexts. Journal of dentistry, 2004; 32: 123-132.
18. Jingade R.R.K., Rudraprasad, Sangur R. Biomechanics of dental implants. JIPS, 2005; 5: 18-22.
19. Sumiya Hobo, Eiji Ichida, Lily T. Garcia. Osseointegration and Occlusal Rehabititation, Biomechanical considerations on osseointegrated implants, 265-280.
20. U. Lekholm. Clinical procedures for treatment with osseointegrated dental implants. J Prosthet Dent, 1983; 50: 116-120.