Introduction to Implant Dentistry and Osseointegration
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Objectives

- To gain an understanding of implant dentistry using osseointegration.
- To understand the factors important for reliable bone anchorage of an oral implant.
- To understand biocompatible materials for osseointegration.
- To understand how physical implant design and surface characteristics play a role in bone tissue integration.
- To develop knowledge of how host bone surgical technique and load consideration affect osseointegration.
Introduction

The primary goal of osseointegration is to create a stable bone anchorage of an oral implanted metal tooth to bone, rather than a soft-tissue anchorage of the same. The latter of the two procedures is known to function poorly over long-term clinical follow-up. This may seem strange since the tooth itself is anchored in soft tissue.

In osseointegration, the tooth is attached with a highly differentiated periodontal ligament or membrane, which is in sharp contrast to the poorly organized soft-tissue attachment of a typical oral implant. Soft-tissue of a scar-like type develops around foreign materials such as metals inserted in the oral cavity. No person or technique has thus far been able to reestablish a “true” ligament or membrane around oral implant placements.

In the past, this type of soft-tissue attachment of oral implants was regarded as unavoidable, thus resulting in the gradual loosening of the inserted biocompatible material. Branemark and his coworkers were the first to suggest the possibility of a direct bone to metal anchorage and they later termed this process as osseointegration.

During the early history of implant dentistry, endosseous and subperiosteal implants were used. In those years, surgeons and restorative dentists were concerned with osseointegration to support prosthetic rehabilitation of sections of the mouth or full arches.

In the development phase of implantology, modifications of the shapes of endosseous screws and prosthetic attachment portions occurred. These alterations enabled multiple prosthetic options to be fabricated for fixed and removable prosthesis. Endosseous titanium screw-shaped implants have been used for over forty years. Since then, implant dentistry has increased in scope. Implants now are placed in more challenging locations and are loaded more quickly while patients are routinely expressing the desire for more esthetic results.

Osseointegration has been widely accepted in oral implantology and has been documented to be excellent over long periods of clinical follow-up. However, attempts to define osseointegration based on histologic criteria have failed, and today the only acceptable definition seems to be based on a confirmed and maintained implant stability as suggested by Zarb and Albrektsson, 1991:

“Osseointegration is a process whereby clinically asymptomatic rigid fixation of alloplastic materials is achieved, and maintained, in bone during functional loading.”
Factors of Importance for Reliable Bone Anchorage of an Implant

In most cases, whenever a biocompatible implant is inserted directly into bone, healing will occur, but is dependent on the following conditions:

- Adequate cells
- Nutrition for these cells
- Adequate stimuli for repair.

However, bone tissue is different from soft-tissue in some aspects. Bone will, at least under ideal conditions, heal without any scar formation due to a condition known as creeping substitution that will gradually replace the bone with formed hard tissue.

Also, even if the repair process is disturbed so that no (or almost no) healing occurs, the dead bone may still be capable of carrying some loads and thereby contribute to function. Such replacements may tolerate the load put upon them by an elderly patient, but not the possible heavy stress common in younger individuals where the results are poorer than with the elderly.

Only the third alternative, a dominant bone resorption, will result in no function whatsoever, if persistent. The ongoing balance between bone formation and bone resorption may be exemplified through the known coupled function between bone cellular elements opposing function such as oseoblasts, or bone forming cells and osteoclasts, or bone resorbing cells. Many researchers in the field claim that the one cell will need the other to be in an active state. This is further exemplified in the previously described “creeping substitution” process.

Although osseointegrated implants have been documented with excellent long-term results, this does not necessarily imply that every implant system claimed to be dependent on osseointegration will result in an acceptable clinical outcome. In fact, there are several reasons for primary, as well as secondary failure of osseointegration. These failures may be attributed to inadequate control of the six different factors known to be important for the establishment of a reliable, long-term osseous anchorage of an implanted device. These factors are:

- Implant biocompatibility;
- Design characteristics;
- Surface characteristics;
- State of the host bed;
- Surgical technique;
- Loading conditions.

There is a need to control these factors simultaneously in order to achieve the desirable goal of a direct bone anchorage.
Implant Biocompatibility

In regard to metals widely available, pure titanium, niobium and tantalum are known to be the best accepted in human bone tissue. In the case of titanium, there is also documented positive long-term function. The reason for the excellent acceptance of these metals, especially titanium, relates to the fact that they are covered with a very adherent, self-repairing, oxide layer that has excellent resistance to corrosion. Whereas the load-bearing capacity of titanium is sufficiently documented in the case of oral implants, there is less known about the others in this respect.

Other metal alloys such as cobalt-chrome-molybdenum and stainless steel have demonstrated less acceptance in the bone tissue, but it is not certain if this is the case for every possible alloy and if it is a biocompatibility effect alone that is responsible for their poorer integration into bone, when compared with pure titanium. A significantly impaired interfacial bone formation compared to titanium has been found with, for instance, titanium-(6)aluminum-(4)vanadium alloy, and this is probably due to poor biocompatibility of the alloy.

One concern with the metal alloys is that one alloy component may leak out in concentrations high enough to cause local or systemic side effects. However, whether these and other differences between pure titanium, on the one hand, and various alloys on the other, is of a practical, clinical importance is uncertain. This is why the alloys have been placed in the “gray zone” of biocompatible materials.

Other pure metals like copper and silver are known to result in a permanent soft-tissue attachment because of poor biocompatibility and, thus, are not used for oral implants. Ceramics such as calcium phosphate hydroxyapatite (HA) should definitely be considered biocompatible. With respect to HA, the available literature points to at least a short-term (<10 weeks) enhanced interfacial bone formation in comparison to the reference metal, titanium. This represents a potential clinical benefit of HA not found in the various metals described.

Implant Design Characteristics

There is sufficient long-term documentation only on threaded types of oral implants that have been demonstrated to function for many years without clinical problems. However, unthreaded implants may function too, even if there is a lack of positive documentation with respect to bone saucerization, a problem which causes failure of many types of oral implants.

With currently used cylindrical implants, many publications in the literature describe more severe bone loss resorption than would have been expected with certain screw designs. It should be noted that there are many unthreaded implant designs that may give an excellent long-term clinical result, but literature is lacking data to support the unthreaded designs.
Implant Surface Characteristics

With regard to surface structure, there is abundant documentation that most smooth surfaces do not result in acceptable bone cell adhesion, when compared to irregular surfaces. Such implants, therefore, end up being anchored in soft tissue despite the material used and clinical failure may be expected to occur.

Some micro-irregularities seem to be necessary for proper cellular adhesion. With plasma-sprayed titanium surfaces, for instance, more than 1600 ppm titanium has been reported in implant-adjacent bone haversian systems, probably resulting in an impairment of osteogenisis. Another surface parameter is the energy state where high surface energy has been regarded as necessary for implant fixation due possibly to improved cellular attachment.

One practical way of increasing the surface energy is to use glow discharge (plasma cleaning). However, published reports have not been able to confirm the superiority of such artificially enhanced implant energy levels. One reason for this lack of confirmation of the surface energy hypothesis could be that the increased surface energy will disappear immediately when the implant is in contact with the host tissues.

State of the Bone Receiving the Implant

Ideally, when inserting implants, the bone is healthy and adequate in amount. However, in reality, the bone may suffer from a history of previous irradiation, as is the case with head and neck cancer patients, or ridge height resorption and osteoporosis, which present just some of the more commonly found and undesirable states which pose potential problems for oral implantation. A previous history of irradiation may not be a contraindication for the insertion of oral implants. However, it is preferable to allow some time before an implant is inserted into a previously irradiated area of bone.

Additionally, some 10% to 15% of poor clinical results can be anticipated after a therapeutic dose of irradiation. Less satisfactory clinical outcomes found in irradiated bone could be due, at least in part, to vascular damage. One way to increase the healing conditions in previously irradiated bone is by using hyperbaric oxygen (high oxygen tension), as low oxygen tension has negative effects on tissue repair. This is further verified by the finding that heavy smoking, causing a local oral vasoconstriction, is one factor that will lower otherwise good expected outcomes of an implantation procedure.

Other common clinical host bone problems involve osteoporosis and resorbed alveolar bone ridges. Such clinical states may constitute an induction for ridge augmentation with bone grafts. However, present clinical techniques for bone grafting are in debate and it appears that the 5-year success of oral implants in the 75% range is a realistic outcome after most implant procedures.
This figure is slightly alarming seen against the fact that, at least in the maxilla, 10% to 20% of an average edentulous population may be in need of a bone graft to improve the bone and allow for the insertion of implants. If, however, the bone quality and quantity in the maxilla are controlled, the expected outcome of an oral implantation procedure is similar to that of the mandible.

**Surgical Technique**

If too much surgical trauma is induced, frictional heat will cause a temperature rise in the bone, and the cells that are responsible for bone repair will be destroyed. Bone tissue is now considered more sensitive to heat than previously believed. In the past, the critical temperature was regarded to be in the 56 degree Celsius range, as this temperature will cause denaturation of one of the bone enzymes, alkaline phosphatase.

The critical time/temperature relationship for bone tissue necrosis is considered to be around 47 degrees Celsius, when applied for one minute. At a temperature of 50 degrees Celsius when applied for more than one minute, a critical level where bone repair becomes severely and permanently disturbed, is being approached. This critical temperature should be seen against observed frictional heat at surgical interventions. In the orthopedic field, despite adequate cooling, temperatures of 90 degrees Celsius have been measured.

High temperatures in the dental field are expected when drilling, particularly in the dense mandible. The use of the following have been shown to induce less trauma:

- Well-sharpened drills;
- Slow drill speeds;
- Graded series of drills (avoid making, for instance a 4mm hole in one step);
- Adequate cooling of the surgical site.

It has been demonstrated in clinical studies that, by using a controlled surgical technique, overheating might possibly be avoided. Mechanical injury will remain and is quite sufficient to trigger a proper healing response.

Another surgical parameter of relevance is the power used at implant insertion. Too much power will result in bone tension and a resorption response will be stimulated. This means that the holding power of the implant will fall to dangerous levels after a strong insertion torque. Moderate power at the site of implant placement is therefore recommended. With some implant designs, there may be a need for impaction of the implant at insertion and so other rules may apply.
Loading Conditions

From histological observation and research of animal implants, as well as human, it is known that regardless of control of surgical trauma and other relevant parameters, the oral implant will, in the early remodeling phase, be surrounded by soft tissue. This means that some weeks after implant insertion, the implant will be particularly sensitive to loading, as movement will stimulate more soft-tissue formation, leading eventually to a permanent soft-tissue anchorage.

Basically, the situation is similar to that of a fracture. Loading of an unstabilized fracture will result in soft-tissue healing and poor function, whereas stabilization with metal plates or Plaster of Paris will maintain a satisfying rigidity leading to bone healing of the fracture.

Premature loading of the oral implant will lead to soft-tissue anchorage and poor long-term function, whereas postponing the loading by using two-stage surgery will result in bone healing and positive long-term function. The length of time loading should be avoided is dependent on the implantation site, as well as on the bone bed quality of the recipient.

There may be cases where an almost immediate loading would not disturb the bone healing response, however, in general, loading must be controlled if osseointegration is to occur. Branemark, with his controlled implant system, advocates the use of a 4 month loading delay in the healthy mandible, a 6 to 9 month delay with a sinus lift and a 4 to 6 month delay in the healthy maxilla where bone is, as a rule, more cancellous and less dense in character.

These precise unloaded times are empirically based and are not well-controlled published studies comparing different unloaded periods and relating this to implant success. Furthermore, from a bone biologic point of view, a more suitable design would be to have the implant unloaded and then gradually increase the load. The problem in the case of oral implants is how to properly describe to the patient how a gradual increase of load on bone would and should be controlled. This is a complicated task, since the appropriate loading pattern also depends on individual patient factors.

Immediate Load Approach

A predictable protocol has been developed to transform an arch of highly unsatisfactory teeth to a fixed implant prosthesis utilizing immediately placed, immediately loaded implants. The implant success rate exceeds 97% on the mandible and 92% in the maxilla. The immediate load protocol permits patients who are losing their teeth to be transitioned into implants and remain in fixed dentitions while forgoing multiple surgeries and provisionals.

The major cause of implant failure is micro motion. This is created by patient interference (ie, eating a hard diet during the 4 to 6 weeks after implant placement) or a result of an improperly fitted provisional restoration.
Extensive pre-surgical planning is vital to ensure a successful case and prevent sequelae. If one or even two implants fail to integrate, they may be replaced while the patient continues to wear the provisional bridge.

**Peri-Implant Infection**

Both patient and dentist should be aware that infectious complications of dental implants may not only affect function and longevity, but also the systemic health of patients. A known negative outcome of infection is the failure of the implant to integrate with the bone, causing implant loss and possible bone loss. Given the established associations between periodontitis and systemic health, it is possible that infection in and around the implant components may impart risk to the systemic health of patients.

Given the dense and diverse population of oral microbes, it should not be surprising that patients are subjected to periodic episodes of transient bacteremias of oral origins. Even normal everyday activities such as mastication, tooth brushing, and dental flossing have been associated with bacteremias. Thus, many sources of bacteremias are important to estimating overall risk for systemic health complications and a relationship between micro-gap design and bacteremia has not been proven.

Nevertheless, dental implants are increasingly popular options for treating edentulism and they may introduce a possible haven for periodontal bacteria. Thus, consideration must be given to the possible effects of implant placement of long-term local and systemic health of implant patients who develop peri-implantitis. Although most manufactures have focused their implant design modifications on the compatibility of the surface texture or composition to Osseointegration with the bone, future evaluations might well consider the risks involved in placing implants that permit periodontal pathogens to flourish unaffected by hygienic efforts.

**Geriatric Dentistry**

With the population becoming increasingly older worldwide, the general dentist will be confronted with patients who have complex medical and social histories and desire to have tooth replacement therapy.

Dental implant therapy can significantly improve the lives of older people. Through discussions with the patient, the clinician needs to assess the patient’s expectations and desires carefully and balance them with the time and resources needed to accomplish acceptable outcomes. The provision of care should be patient centered. It should best address the rational needs of the patient, while offering an improved quality of life.

The surgical team should evaluate the patient for systemic conditions that may compromise healing and the systemic effects of medication. In general, the survival rates of dental implants in older patients can be affected by certain systemic conditions associated with aging, including long-term smoking, diabetes and post-menopausal estrogen therapy.
As part of a careful informed consent process, the dentist needs to provide the patient, along with his or her family, with an accurate assessment of the procedures, the length of treatment time, and risks to implant treatment.

**Esthetic Requirements for Dental Implants**

Esthetic demands posed by dental implant-supported restorations are increasing in the maxillary anterior region. In this sextant, the natural dentition is surrounded with a scalloped gingival margin and a pyramid-shaped interdental papilla. Gingival architecture is determined mainly by the anatomy of the teeth and the position and the size of the contact surfaces, and all of these features are framed by the lip-line. It is important that the clinician take into account soft-tissue considerations – including the height of the papilla and the presence of attached gingiva – to fulfill the patients esthetic needs.

A preoperative treatment plan for implants in the anterior maxilla requires an evaluation of the hard and soft tissues to determine the type and size of fixture needed. The dentist should visualize the expected restorative outcome by means of a temporary restoration with the desired emergence profile. Both the restorative and dental implant surgeon should use this template and work out all the steps involved in reaching the expected treatment outcomes.

Surgical and restorative concepts related to implant dentistry have been modified tremendously through the years. The ultimate goal of implant-supported restorative therapy is to replace a tooth with a structure that will mimic what is lost functionally and esthetically.

**Conclusion**

The use of poorly controlled surgical techniques in oral implantology exists and the lack of good clinical data to back up many types of oral implants is of great concern. Osseointegration has meant a clinical breakthrough in the science of oral implantology, previously regarded as largely experimental. A scientific approach to any clinical treatment calls not only for well-controlled implantation procedures and surgical techniques, but also for the honest reporting of clinical data.

Any clinical routine usage of untested procedures or oral implant designs should be avoided until sufficient documentation is available and reported, from long term clinical follow-up, to support or deny the procedures or designs stated results.
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