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# IMPLANT STABILITY: A KEY TO SUCCESSFUL DENTAL IMPLANT-A LITERATURE REVIEW

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## ABSTRACT

At present, thousands of dental implants are being placed everyday all around the world. Therefore, it is imperative for a dental practitioner to have a thorough understanding about the dental implant and also about the factors which ultimately affect its success. Stability of an implant is the most influential criteria for a successful dental implant. This article describes in detail about implant stability, factors which affect implant stability and diagnostic tools which are used to determine implant stability.

## INTRODUCTION

The basis for modern dental implants is a biologic process called osseointegration, in which materials such as titanium form an intimate bond to bone. Osseointegration is a prerequisite for a successful dental implant and is also a measure of implant stability. In 1981, Albrektsson et al demonstrated the six major parameters of osseointegration, the implant material, the implant surface, the implant design, the condition of the bone at the host bed, the surgical technique and the loading conditions.[1]

In the original clinical implant protocols, osseointegration was achieved by long initial healing periods in which implants remained unloaded to assure an undisturbed bone apposition onto the implant surface. The development of new implant surfaces and improved surgical approaches has considerably reduced this healing period, both improving the primary stability at implant insertion and by promoting of early osseointegration.

Primary implant stability plays a fundamental role in successful osseointegration, it is influenced by the shape and design of the implant, the quality and quantity of the bone, the surgical technique and skills of the surgeon, the loading conditions, the presence of parafunctional habits and the healing capacity of the host. Friberg et al reported an implant success rate of only 68% for those implants that showed inadequate initial stability.[2]

The secondary stability is attained by an incremental degree of bone to implant contact. While the secondary stability is getting established the primary stability decreases. During this transition, the risk of micro movements and the potential for impairment of the osseointegration is enhanced. Therefore, it would be desirable to have precise diagnostic tools to determine the minimum implant stability that would enable functional loading without endangering implant outcome.

The methods used to asses implant stability range from those strictly based on clinical criteria, to those that utilize more objective and quantifiable criteria, such as reverse torque measurements or histomorphometry. Non-invasive diagnostic methods have been developed and tested to provide an objective, although indirect evaluation of implant stability and osseointegration. These include the periotest and the resonance frequency analysis.[3]

## OSSEOINTEGRATION

Since the phenomenon of osseointegration was introduced, significant advances have been achieved in implant surface bioreactivity; methods used in diagnosis and treatment planning; enhancement of bone and soft tissues of potential implant sites; and prosthodontic approaches and techniques.

The first definition, and the definition used by most clinicians and researchers today, was coined in the 1960s by the discoverer of the concept, the late Per-Ingvar Branemark, Professor of Anatomy at the University of Gothenburg in Sweden. He demonstrated that direct contact between bone and titanium implant surface was possible, defining osseointegration as “the direct, structural, and functional contact between living bone and the surface of a functionally loaded implant”.[1]

Osseointegration is now regarded as the most favourable implant-bone interface, without which success of the implant cannot be obtained, and great emphasis has been placed on achieving and maintaining osseointegration.

While the absence of Osseointegration can lead to treatment failure, its achievement does not guarantee success. That is dependent on various other factors as well.

**IMPLANT STABILITY**

Successful osseointegration from the clinical standpoint is a measure of implant stability. Two terms, primary and secondary implant stability, are related to implant therapy.[4] Primary stability is associated with the mechanical engagement of an implant with the surrounding bone, whereas bone regeneration and remodelling phenomena determine the secondary stability.

Primary stability is the absence of mobility in the bone bed after the implant has been placed. In the first instance there is an implant fixture mechanical anchorage provided by parent bone walls of the implant bed preparation and the mechanical interlocking with implant threads during insertion. The extent of primary anchorage is related to native bone characteristics, implant design, patient characteristics, and surgical technique.

The secondary stability or biological stability represents enhancement of the stability as a result of peri-implant bone formation through gradual bone remodeling and osteoconduction, with the possibility of new bone formation at the implant-bone interface. It occurs by means of bone apposition to implant, after implant placement. The secondary stability increases with increasing healing time as a result of new bone formation.[4]

**FACTORS AFFECTING IMPLANT STABILITY**

Factors affecting primary stability include bone quantity and quality, surgical technique and implant design. And factors which affect secondary stability include primary stability of the implant, bone remodeling and implant surface conditions.[5]

**IMPLANT CHARACTERISTICS:** Studies have demonstrated that implants of varying designs, placed in different bone qualities, reach various degrees of stability. Also, rough implant surfaces present a larger surface area and allow better mechanical link to the surrounding tissues.[6]

Various implant body designs are available in implant dentistry. They may be categorized as a cylinder type, screw type, press fit, or a combination of features. An implant body may be divided into a crest module, the body, and the apex.

The crest module of an implant body is the transosteal region, which extends from the implant body and often incorporates the anti-rotation components of the abutment implant connection. a larger crest module diameter compared with the implant body increases surface area, which can decrease the stress at the crestal region.

The surface area over which the forces are applied is relevant to bone loss or implant survival and is inversely proportional to the stress observed within the implant system. To reduce risk of biomechanical stress, the force that is applied to the system should decrease or the surface area over which the force is dissipated should increase.[7]

The microscopic features are most important during initial implant healing. The macroscopic implant body design is most important during early loading and mature loading periods. Threaded implants show significantly higher bone implant contact (BIC) compare to cylinder type implants. Although, roughened surface condition shows higher BIC compared to machined surface. the greater the taper of an implant, the greater the component of compressive load delivered to the interface. Hence, implant design may be more important after loading than implant surface condition.

The interfacial interaction between recipient tissues and implanted material are limited to the surface layer of the implant and a few nanometres into the living tissues. The characteristics of synthetic biomaterials used for the construction of dental implants and the associated abutments that contact subepithelial zones of oral tissues are critical to the surface composition, corrosion resistance, cleanliness, surface energy, flexure, and tendency to interact and can play a major role in the successful osseointegration of the dental implant.[8]

**BONE DENSITY:** The density of available bone in an edentulous site is a determining factor in treatment planning, surgical approach, implant design, healing time, and the need for initial progressive bone loading during prosthetic reconstruction. Implant success, arch location, and bone density are often related to each other. The highest implant success rate is seen in the anterior mandible which is followed by the anterior maxilla and the posterior mandible. D1 bone is almost never observed in the maxilla and is rarely observed in most mandibles.[9]

It is rational to wait longer before loading an implant, when the bone density is D3 or D4. Also, when a stress is applied to an implant prosthesis in D1 bone, the titanium–D1 bone interface exhibits very small micro strain difference. In comparison, when the same amount of stress is applied to an implant in D4 bone, the micro strain difference between titanium and D4 bone is greater and may be in the pathologic overload zone.

**SURGICAL TECHNIQUE:** A successful implant surgery should focus on two primary factors, atraumatic surgery and establishing rigid, initial stability. An atraumatic surgical technique is essential to maintain cellular viability thereby preventing the formation of an epithelial connective tissue layer along the bone–implant interface and promote healing.

Although implants have shown results of greater stability in dense bone, the initial stability can decrease remarkably in low-density bone, jeopardizing the osseointegration process and risking failure. The adapted surgical approach by undersizing the implant bed preparation has shown better osseointegration and greater implant stability.

Undersized bone drilling can be performed using smaller drills for placing larger diameter implants. This can potentially enhance the primary stability and achieved optimum levels of initial stability in the low-density bone areas. Previous studies suggest that using undersized bone drilling for implant placement in the maxillary posterior region, where the bone density is relatively low, might be a viable option to increase primary implant stability, which could result in better implant survival rates.

The osteotome technique was proposed by Robert Summers in 1994. He used a special set of matched and tapered osteotomes, as a method for inserting implants in the posterior maxilla. Using his custom osteotomes, Summers proposed that his osteotomes would compact the osseous layer around the osteotomy, which will form a denser bone interface with the implant.[10]

Piezosurgery is a technique that enables accurate and safe osteotomy lines through micrometric and selective bone cutting, based on the generation of ultrasonic vibrations. The properties and design of the cutting device, the drilling speed and pressure, osteotomy shape and procedure pattern, and finally, the use of supplemental irrigation can significantly reduce bone tissue damage. The ultrasonic technique is effective in performing implant preparation, with a significant decrease of postoperative pain and swelling. The only disadvantage being a significant increase in operating time.

Osseodensification is a new method of biomechanical bone preparation performed for dental implant placement. The procedure is characterized by low plastic deformation of bone that is created by rolling and sliding contact using a densifying bur that is fluted such that it densifies the bone with minimal heat elevation. This technique was developed by Salah Huwais in 2013, and is done using specially designed burs that help densify bone as they prepare an osteotomy.

While Standard drills excavate bone during implant osteotomy, the osseodensification burs allow for bone preservation and condensation through compaction autografting during osteotomy preparation, thereby increasing the bone density in the peri‑implant areas and improving the implant mechanical stability. Use of these specialized burs in this method led to the formation of undersized osteotomy when compared to conventional drills. It helped improve bone density and also increased bone‑to‑implant contact, thereby improving implant stability.

**LOADING PROTOCOL:** Implant loading protocols have been differentiated by the duration of the healing period following implant placement prior to the initial delivery of a provisional or definitive implant restoration. Different implant loading protocols have been clinically applied, these include (a) immediate loading, (b) early loading and (c) conventional loading.[11]

Conventional loading is based on the initial clinical experience of Branemark, he suggested that requisite for successful osseointegration is an extended submerged healing phase. Which was establishes as a healing period of 3 to 6 months. Early loading of dental implants is between 1 week and 2 months after implant placement. The development of this early loading protocol was because clinical and experimental research on implant systems directly challenged the conventional loading with convincing outcomes. The time period suggested for insertion of the prosthesis was between 2 days to 3 months after surgery. Immediate loading implies that implants would be exposed to the oral environment and subjected to functional loads. Recent evidences show that functional forces are key triggers to a series of biological reactions that not only accelerate the initial healing process but also the structural changes of peri-implant bone.

Finally, the progressive bone loading aims at increasing the density of bone, decreasing the risk of implant–bone failure, and decreasing crestal bone loss. As bone responds to physiologic forces, a gradual increase in loads during prosthetic fabrication stimulates an increase in density.

## METHODS TO ASSESS IMPLANT STABILITY

With objective measurement of implant stability, surgeons can make well-informed decisions about protocol choices on a case-by-case basis.

**INVASIVE METHODS:** These methods are mostly used only in pre-clinical applications and may be of value as research techniques. Their clinical usage is limited due to ethical concerns associated with the invasive nature of these methods.

Histomorphometry is broadly defined as the measurement of the shape or form of a tissue. Quantitative analysis of bone architecture can be achieved using bone histomorphometry which provides valuable information on the amount of bone and its cellular activity. Structural parameters evaluating the quantity of cancellous bone and osteoid are measured using static histomorphometry. To study the changes in cellular activity over time, the bone is measured using dynamic histomorphometry.[12]

Push-out/pull-out test investigates the healing capabilities at the bone implant interface. It measures interfacial shear strength by applying load parallel to the implant-bone interface. In a typical push-out or pull-out test a cylinder-type implant is placed transcortically or intramedullarly in bone structures and then removed by applying a force parallel to the interface. This test is assessed during the healing period.

Removal torque measurement tests are commonly performed to evaluate osseointegration of the bone-to-implant interface and the stability of the installed dental implant. In this technique, osseointegration is tested at second stage surgery. During the test, a counter clock wise (reverse) torque is applied to implant. up to level of 20 Ncm as removal torque value of clinically osseointegrated implant ranged from 45 to 48 Ncm. Therefore, Osseointegrated implants resist this torque, while failed implants unscrew. The measurements are performed by a manually operated removal torque tester.

**NON-INVASIVE METHODS:** One method of trying to evaluate primary stability is quite simply the perception of the surgeon. This is often based on the cutting resistance and seating torque of the implant during insertion. An experienced surgeon's perception is of course invaluable and should under no circumstances be discounted.

Periapical radiology provides with high-resolution images of a limited region of the mandibular or maxillary alveolus. Digital radiology is an imaging process wherein the film is replaced by a sensor that collects the data. The resultant image can be modified in various ways, such as gray scale, brightness, contrast, and inversion.

Cone-beam computed tomography scanners use a rotating x-ray source that generates a conical-shaped beam that can be modified to acquire a desired area of interest. For pre-implant evaluation, the assessment of the edentulous area in question for bone quantity and quality can be done. After the quantity and quality of bone are evaluated, special software programs allow the dentist to actively place implants in areas of interest. This imaging technique enables the evaluation of proposed implant sites and provides diagnostic information that other imaging or combinations of imaging techniques cannot provide. The density of structures within the image is absolute and quantitative and can be used to differentiate tissues in the region and characterize bone quality.

Reverse torque testing is a common mechanical test that has been used for many years to investigate the nature and strength of the bone-implant interface of endosteal implants. The reverse torque test proposed by Roberts et al. in 1984, and developed by Johansson and Albrektsson in 1987 is considered as a special advantage in stage 2 surgery, because it represents a definitive clinical verification of initial integration of the dental implant with the bone surface. The level of applied torque ranges from 10 to 20 Ncm. This method is an objective diagnostic tool, easy to apply, cheap, non-invasive, and capable of discriminating between a stable and a mobile implant. The implants which fail in this test are presumed to be fibrous encapsulated, are likely to become late failures, and therefore are not recommended for use as support for prosthesis abutments.

Periotest is an electronic device which quantitatively measures the damping characteristics or dynamic tissue recovery process after loading, to assess osseointegration. Periotest value (PTV) is marked from -8 (low mobility) to +50(high mobility). PTV of -8 to -6 is considered good stability. This device can measure values even when an abutment or crown is attached to the implant, which enables monitoring of the stability of the implant even after loading and over time.[13] The clinical value of one single value might be questionable, since factors such as bone density, implant position (upper or lower jaw), abutment length, and supracrestal implant length do play an influence.

The resonance frequency analysis technique has been extensively used in experimental and clinical research for many years. Resonance frequency analysis stability measurements essentially apply a bending load, which mimics the clinical load and direction and provides information about the stiffness of the implant–bone junction.[14] The result of a measurement is presented as a dedicated parameter the implant stability quotient (ISQ). The implant stability quotient unit is based on the underlying resonance frequency and ranges from 1 (lowest stability) to 100 (highest stability). Transducers are available for different implant systems making all resonance frequency analysis measurements comparable, irrespective of the type of implant or abutment. The most recent version of resonance frequency analysis is wireless device, where a metal rod (a peg) is connected to the implant by means of a screw connection (Osstell Mentor). The peg has a small magnet attached to its top, which is excited by magnetic pulses from a handheld computer. The peg vibrates in two directions, which are approximately perpendicular to each other. The vibration takes place in the direction that gives the highest resonance frequency (first mode) and in the direction that gives the lowest resonance frequency (second mode). Thus, two implant stability quotient values are provided, one high and one low. The resonance frequency analysis technique has the potential to provide clinically relevant information about the state of the implant–bone interface at any stage of the treatment.

## CONCLUSION

Implant stability is a key factor for a successful dental implant. Primary implant stability is a mechanical phenomenon that is related to local bone quality and quantity and to the type of implant and placement technique used. It measures the threshold of the bone-implant interface to withstand the micromovements at implant placement, thereby facilitating undisturbed healing leading to the achievement of secondary stability. It is important to understand the factors which affect the stability of an implant as it can help the surgeon in coming up with the ideal treatment plan for each patient. And finally, Objective measurement of implant stability aids in making decisions about when to load, allows making treatment protocol choice on a patient-to-patient basis, indicates situations in which it is best to unload, supports good communication and increased trust between doctor and patient.

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