REVIEW ARTICLE

ASSESSING DENTAL IMPLANT STABILITY FOR SUCCESSFUL TREATMENT : A REVIEW OF PREVALENT METHODOLOGIES.

Dr. Abhisek Chowdhury [1], Dr. Seema Rathi [1], Dr. Sanjay Prasad [2], Dr. T.K.Giri [3], Dr. Sugata Mukherjee [4], Dr. Suman Chakraborty [1]

ABSTRACT

Achieving and maintaining implant stability is crucial for implant survival and successful osseointegration. Absence of micro-motions is the most critical factor for successful osseointegration. Implant stability in term of bone to implant contact is determined at two stages – PRIMARY AND SECONDARY. Primary stability comes from mechanical engagement of cortical bone while secondary stability develops following regeneration & remodeling of soft and hard tissue around implant after insertion. So, it is of utmost important to evaluate implant stability at various time points to predict prognosis for successful therapy. The aim of this article is to highlight various methods available to determine implant stability.

KEY WORDS

Implant stability, implant stability quotient, resonance frequency analysis, dental implant, periotest.

ABOUT THE AUTHORS

1. Post graduate trainee, 2.Associate Professor, 3. Professor, 4. Professor and HOD
Dept. of Prosthodontics Crown and Bridge, Dr. R. Ahmed Dental college and Hospital, Kolkata

Corresponding Author
Dr. Seema Rathi
Pg Student, Dept. of Prosthodontics
Dr. R. Ahmed Dental College & Hospital, Kolkata
Mob no. 9812900379
e-mail- seemaratheee@gmail.com

INTRODUCTION

Dental implants are one of the most successful treatment modalities in dentistry and well documented in the literature.[1] There use in rehabilitation of partially & completely edentulous patients has been significantly increased since 1980.[2] Dental implants are permanent prosthesis that enhance the quality of life of these patients.[3] Implant stability is prerequisite for a dental implant to be successful & it plays a vital role for successful osseointegration. Osseointegration is defined as, "The process and resultant apparent direct connection of an exogenous material surface and host bone tissue, without intervening fibrous connective tissue present : the interface between alloplastic materials and bone"- GPT-9.[4]

It is also defined as the capacity of implant to withstand loading in axial, lateral & rotational direction.[5]

Dental implant stability can be divided into primary and secondary components : primary stability is achieved by mechanical engagement of implant within the cortical bone & absence of any micromovement. While secondary stability refers to successful osseointegration of the implant with the surrounding bone.[6] The primary stability is required for successful secondary stability. Following the placement of an endosseous implant, primary mechanical stability decreases & secondary stability gradually increases. So, dental implant stability measurement is an indirect indication of osseointegration.[2]

Historically, the gold standard method used to evaluate the degree of osseointegration was microscopic or histologic analysis. Due to the invasiveness of this method & related ethical issues, several other methods have been proposed- radiographic analysis, percussion test, reverse torque test, tensional test, imaging techniques, cutting torque resistance analysis, periotest and resonance frequency analysis (RFA) device.[8]

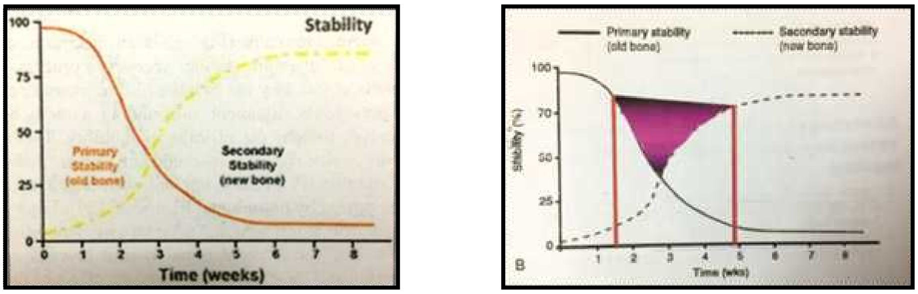

Fig 1.(A & B) The implant's primary and secondary stability curves as well as their transition period when the implant remains at higher risk of micromovent and fails to osseointegrate.[7]

Factors influencing implant stability

- **Factors affecting primary stability**

Bone quality and quantity
Surgical technique
Implant factors (eg. Geometry, length, diameter, surface characteristics)

- **Factors affecting secondary stability**

Primary stability
Bone formation and remodeling[9]

Bone quality and quantity

Bone quality is often referred to as the amount of cortical and cancelous bone in which the recipient site is drilled. A poor bone quality and quantity have been indicated as the main risk factors for implant failure as it may be associated with excessive bone resorption and impairment in the healing process compared with higher density bone. Some studies have reported dental implants in the mandible D1(>1250 HU) & D2(850-1250 HU) type to have higher survival rates compared to those in the maxilla D3(350-850 HU) & D4(150-350 HU) type. Miyamoto et al. demonstrated that dental implant stability is positively associated with the thickness of cortical bone. CT is the best radiographic method for analyzing the morphology and qualitative analysis of residual bone.

Surgical technique

Surgical technique also influences primary stability. The undersized drilling technique is introduced to locally optimize bone density and subsequently improve primary stability. Insertion torque is also a determinant of primary stability, torque values of 32, 35, or 40 Ncm and higher is chosen as threshold for immediate loading.

Implant factors

Implant design is a vital parameter for attaining primary stability. A threaded implant is designed to increase the bone-implant surface area & to decrease the stresses at the interface during occlusal loading.[3] It also increases the mechanical retention in the bone at the initial implant insertion. Implant surface characteristics and diameter have also been shown to influence primary stability. Rough surfaces present a larger surface area & allow a firmer mechanical link to the surrounding tissues. Rough surface positively influence the healing process by promoting favorable cellular responses and cell surface interactions. Introduction of microthreads or "Retention Grooves" at the neck of the implant may assist in reducing distributing stress & reducing the extent of bone loss following implant installation. Smaller diameter implants provide sufficient implant stability in cases with limited bone volume. Studies have shown long dental implant provide more primary stability than short ones, even in poor quality bone.[22]

Effects of micromotions

Micromotions above 50-150 micrometers may negatively influence osseointegration and bone remodelling by formation of fibrous tissues and inducing bone resorption at the bone-to-implant interface. Therefore, a high initial stability is essential for a successful osseointegration of dental implant.

Objective measurement of implant stability:

1. Helps in making good decisions about when to load
2. Indicates situations in which it is best to unload
3. Allows advantageous protocol choice on a case to case basis
4. Supports good communication and increased trust
5. Provides better case documentation[2]

Helps in making good decisions about when to load

When a surgeon makes a decision about early loading, objective measurement of implant stability can serve as an inclusion criterion for immediate loading.

Indicate situations in which it is best to unload

Implant stability measurement helps in making the right decisions about unloading. Sennerby and Meredith highlight that when replacing an immediately loaded temporary prosthesis with a permanent prosthesis, "low values indicative of overload and ongoing failure." [23] To avoid this type of failure, they suggest that surgeons should consider unloading , perhaps placing additional implants, and wait until implant stability values increase before loading the permanent prosthesis.

Allows advantageous protocol choice on a case to case basis

When implant stability value is low, it indiacte that immediate loading will jeopardize treatment outcome, so in this situation two-step protocol can be applied. When implant stability value is high, then implant could be immediately loaded.

Supports good communication and increased trust

Implant stability measurement helps to improve communication between surgeons and patients. When a surgeon or dentist uses measurable values rather than subjective judgment, helps in making decision & it is easier to explain the treatment choices. The surgeons are more likely to become professional to colleagues alike and to imbibe patient confidence.

Provide better case documentation

Implant stability measurements can be used to document the clinical outcome of implant treatment, which can be helpful at later stages.[10]

Different methods to measure implant stability. They can be divided into invasive and noninvasive methods.

Invasive methods
Histologic/histomorphologic analysis
Tensional test
Push-out/pull-out test
Removal torque analysis

Noninvasive methods
Clinical perception
Radiographical analysis/imaging technique
Cutting torque resistance
Insertion torque measurement
Seating torque
Periotest
Pulse occillation waveform (POWF)
Invasive methods

Histologic / histomorphologic analysis

This method quantitatively assesses the bone contact and bone area within threads. It requires a light microscope with microvid computers. Mostly performed on the decalcified specimens sectioned for transmission electron microscopy. Due to its invasive and destructive nature, its use has limited to non-clinical and experiments studies.[12]

Tensional test

The interfacial tensile strength was originally measured by detaching the implant plate from the supporting bone. Later on it modified by applying the lateral load to the cylindrical implant fixture. However, there were difficulties in translating the test results to any area independent mechanical properties.[13]

Push-out/pull-out test

This test investigates the healing capabilities at the bone implant interface.[14] It measures interfacial shear strength by applying load parallel to the implant-bone interface. In this test, a cylinder type implant is placed transcortically or intramedullary in bone and then removed by applying force to the interface. However, the pushout/pull-out test is applicable only for nonthreaded cylinder type implants, whereas most of the clinically available fixtures are of threaded type and their interfacial failures are solely dependent on shear stress without any consideration for either tensile or compressive stresses. It is technique sensitive process.

Removal torque analysis

In this technique, stability is tested at second

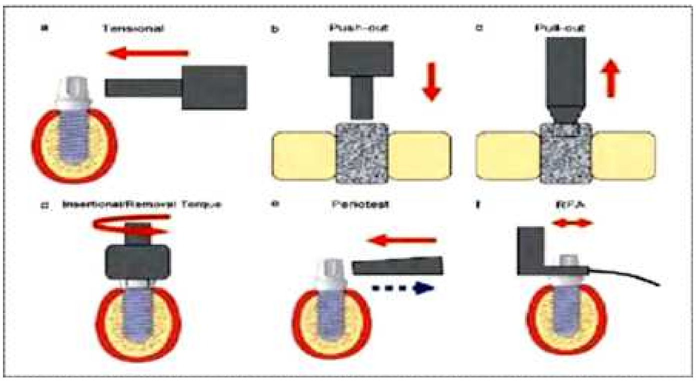

Fig.2 Stability analysis for oral implant osseointegration from clinical oral implants research a-Tensional test, b-Pushout method, c- pull out method, d-Insertional/removal method, e-periotest, f-resonance frequency analysis

stage surgery. A counter clock wise torque is applied to implant upto level of 20Ncm. Torque value of osseointegrated implant ranged from 45 to 48Ncm.[2] osseointegrated implant resist this torque, while failed implant unscrew. This test gives little information about implant bone interface and provides result only by all or none rule i.e osseointegrated or failed, thereby not able to discriminate the degree of bone healing or bone formation around implants.[10]

The clinical use of these methods is limited due to destructive procedure and ethical issues.

Noninvasive methods

Clinical perception

It is based on the mobility as identified by blunt ended instruments. It may also be checked by observing implant cutting resistance during insertion. Perception of 'good stability' can be interpreted incase of sensing an abrupt stop at implant seating. The main disadvantages of this method is its subjective nature.

Radiographical analysis/imaging technique

Various radiographic modalities are used to access both quality and quantity of local bone.[15] It is widely used tool not only for preoperative assessment but also helpful to evaluate health of the implant & estimating crestal bone loss which is a consequence of osseointegration process. However, numerous limitations exists, such as image is two dimensional, resolution is not good and it is difficult to perceive bony changes unless 30-40% bone loss occur.[16] But it is convienent, non-invasive & can be performed at any stage.

Cutting torque resistance analysis

This was developed by Johansson and Strid.[17] It was later improved by Friberg et al. In this method the energy required in cutting off a unit volume of bone during implant surgery is measured. It determines areas of low density bone and quantifies bone hardness during implant osteotomy at the time of implant placement. Some Clinical studies showed that the highest frequency of implant failures are seen in jaws with advanced resorption and poor bone quality, often seen in the maxilla.[18] Therefore, cutting resistance value may provide useful information in determining an optimal healing period in a given arch location with a certain bone quality.

The major limitation of cutting torque resistance analysis (CRA) is that it does not give any information on bone quality until the osteotomy site is prepared. CRA also cannot identify the lower "critical" limit of cutting torque value (i.e., the value at which the implant would be at risk).

Insertion torque measurement

Insertion torque alone may be used as an independent stability measurement, but it may also act as a variable, affecting implant stability. It is a mechanical parameter generally affected by a surgical procedure, implant design and bone quality at the implant site.[19] However, it cannot assess the secondary stability by new bone formation and remodel around the implant. Furthermore, an increase in insertion torque may signify an increase in primary stability, but maximum insertion torque is produced by the pressure of implant neck on the dense cortical bone of the alveolus. Furthermore, it has been reported that if maximum insertion torque does not signify increased general bone density, it may indicate the insertion torque itself during tapping.

Seating torque test

Like insertion torque, the final seating torque gives some information about the primary stability of the implant when the implant reaches its final apico-occlusal position. It is done after implant placement.

Periotest

It is an electronic device that quantify the mobility of an implant by measuring the reaction of periimplant tissue to a definite impact load. It was originally devised by Schulte to measure tooth mobility. PTV is marked from -8(low mobility) to +50(high mobility).[8]

Table 1: Interpretation of readings in periotest

Reading	Interpretation
−8 to 0	Good osseointegration, implant can be loaded
+1 to +9	Clinical examination is required, in most cases loading is not possible
+10 to +50	Osseointegration is not sufficient, implant cannot be loaded

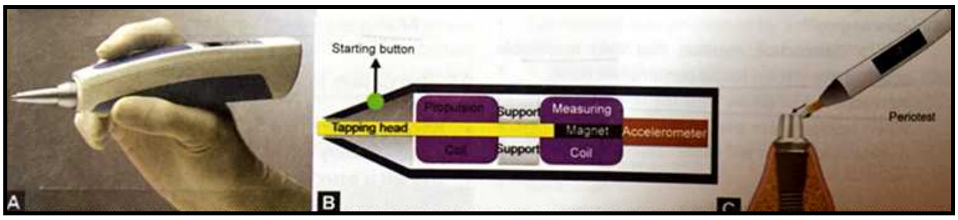

Fig.3 (A) Periotest device, (B) Components of a periotest device, (C) Tapping head hits the implant and the impact is measured by the accelerometer.

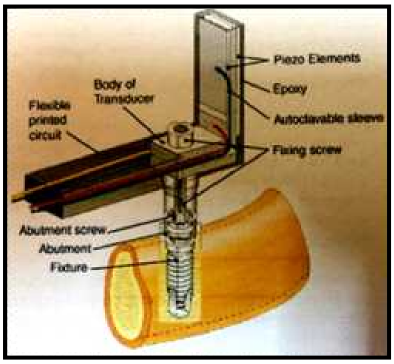

Fig.4 Electrical resonance frequency

Fig.5 magnetic resonance frequency

It can measure implant stability during placement & post surgically .its reliability is questionable due to poor sensitivity & succeptibility to many variables.

Pluse occillation waveform (POWF)

It analyses mechanical vibrational charactersties of implant bone interface using forced excitation of a steady state wave. It consists of acoustoelectric driver (AED), AER pulse generator & ocilloscope. Here, a multifrequency pulse force is applied to the implant. Resonance & vibration generated from bone implant interface are picked up & displayed on ocillocsope screen. Sensitivity of test depends on load direction & position.

Resonance frequency analysis:

RFA, as a method of monitoring implant/tissue integration, was first introduced for dental applications in 1996.[2] It is non invasive diagnostic method that measure implant stability and bone density at various time points using vibration and structural principle analysis. In this technique implants are forced to oscillate and frequency at which they oscillate at maximum amplitude is register as their resonance frequency. This technique uses an L- shaped transducer that is screwed to an implant and excited over a range of frequencies. A piezoelectrical crystal on the vertical portion of the L beam is used to stimulate the implant/transducer complex; second piezoelectric crystal on the opposite side of the beam is used as a receiving element to detect the response of the beam.[8]

Four generations of RFA are there. The first generation is based on a measuring element transducer placed on implant/ abutment and then connected to a measuring unit with a wire. The second generation device analyses frequency response utilizing the magnetic technology. The third generation device is provided with a small battery driven system, which enables quick and simple measurements & chair side interpretation.[6]

The first commercially available RFA equipment is Osstelltm, Osstell AB, then Osstell Mentor & the most recent version of RFA is Osstell ISQ . This new magnetic RFA device has a transducer, a metallic rod with a magnet on top, which is screwed onto an implant. the magnet is excited by a magnetic pulse from a wireless probe. The pulse duration is about 1ms. After excitation, the peg vibrates freely, and the magnet induces an electric voltage in the probe coil. That voltage is the measurement signal sampled by the resonance frequency analyser.

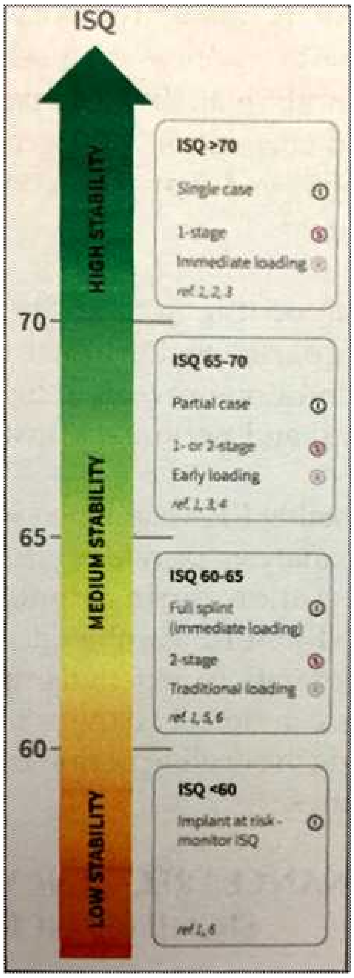

Fig.6 Implant stability quotient scale

Implant stability quotient (ISQ) is the measurement unit used. Resonance frequency of 3.5 kHz and 8.5 kHz formed by magnetic field is converted into ISQ values. Classically, the ISQ has been found to vary between 40 & 80, higher the ISQ, the higher the implant stability.

RECENT ADVANCEMENT

Implatest conventional impulse testing

It utilizes joining an accelerometer with associated wire and connector to the implant, striking it to calibrated hammer and subsequently recording and interpreting data[24].

Electromechanical impedance method

This method uses electro mechanical impedance of piezoelectric materials which is directly related to mechanical impedance of the host structure. It consists of bonding or embedding one or more piezoelectric transducer (PZTs) to the host structure. When subjected to electrical field, the transducer induces low to high frequency structural excitations, which affects transducers electrical admittance[25]. The measurement of the PZTs electrical conductance and succeptance can be exploited to access health of host elements.

Micro motion detecting devices

These are customizing loading devices that consists of digital micrometer and a digital force gauge to determine implant micro motion. Here, forces are generated by turning a dial and applied to abutment via a lever. The digital micrometer are placed tangent to crown of abutment and detected the displacement after load application.[20]

CONCLUSION

Ability to monitor implant stability is a valuable diagnostic and clinical tool to evaluate treatment outcome. Although various advanced tests and equipment are available, no single definite method has been established with fair amount of reliability. Hence, further researches are needed to devise more precious instrument with higher amount of accuracy.

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