Bridge to integration and implant stability: A review.

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Abstract

Objective: This article examines and conducts a critical comparison of various studies regarding the stability modifications and the relationship between primary and secondary stability.

Background: The main factor on which the outcome depends upon is the implant stability. It can be classified into primary and secondary stability, former is a mechanical phenomenon, whereas the latter is a biological phenomenon resulting from osseointegration.

Methods: Invasive and non-invasive techniques are two categories for studying the stability of the implants. Histological analysis, Tensional test, along with Push-out pull-out test, Reverse torque test are invasive methods. Radiographs, Cutting Torque Analysis, Insertion Torque Analysis, Percussion Test, Finite Element Analysis (FEA), Pulsed Oscillation Waveform, periotest, Resonance Frequency Analysis (RFA) are non-invasive methods.

Results: Due to the capacity to measure the stability of the implant more accurately than other methods and provide an early diagnosis of implant failure, insertion torque analysis, periotest and RFA has become a popular choice.

Conclusion: The precision in implant stability refers to the accuracy and consistency of implant placement procedures, while perfection refers to the ideal implant position, orientation and stability.

Application: Implant stability applications are vital for treatment planning, surgical guidance, monitoring healing, predicting success, evaluating treatment effectiveness in implant dentistry.

Keywords: Finite element analysis, implant stability quotient, periotest, resonance frequency analysis.

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Introduction

One of the most effective tooth replacement options in dentistry are dental implants. There is a constant effort to improve implant therapy to achieve a predictable success rate and osseointegration and in order to achieve such outcome, implant stability is a prerequisite. The term osseointegration was coined first by Branemark in 1985 which according to him was "immediately effective and organized communication within the vital bone and its outer surface – enveloping implant".[1] The lack of clinical movement of an implant signifies implant stability. Fibrous encapsulation is seen to occur around the implant with subsequent failure of the implant in presence of any instability.[2] It's crucial to conduct an ongoing, quantitative, and objective evaluation to assess the stability of the implant.[3]

In general, primary stability and secondary stability are two major categories of implant stability. Primary stability is the initial connection or the mechanical interaction between the bone and implant which is attained after immediate placement of the implant. The surrounding bone tightly holds the implant in place due to compression forces thereby creating a secure and stable environment for osseointegration.

Secondary stability is also known as biological stability. In his type of stability bone regeneration takes place by new bone cell proliferation. The surrounding bone then undergoes remodeling which integrates with the implant surface thus establishing a strong and durable bond between the bone and fixture surface.

Implant stability is dependent on the following factors which plays a crucial role in obtaining successful outcomes:

1. Timing of loading depending on operator.
2. Optimal protocol selection based on the needs of each patient.
3. Circumstances where unloading is recommended.

Stability of implant

The density of the bone has an impact on the stability of the implant. The major criteria in the effectiveness of the surgical intervention followed by the stability of the implant achieved post-surgery is the evaluation of quality of bone before surgery. Compared to implant treatments on the mandible, the success rates for implants placed on the upper jawbone are predicted to be lower as the density of the mandible is higher and in anterior regions of jawbone in comparison to posterior region.

Various implant systems, designs, and bone types produce varying levels of stability. Lekhom and Zarb (1985) put forth a method for evaluating the quality of bone that is most widely employed technique in implant dentistry. The evaluation relied on radiographic assessments and also involved the assessment of the cortical bone and trabecular bone quality and the analysis of their resiliency was documented.

During the bone remodeling process after placement of implant, there is a surge in the secondary stability reported with a gradual decline in the primary stability. The period between the two phases of implant stability also known as the implant stability dip is recorded where there is a dip in stability in which inadequate total stability exists (Figure 1). Normally it is seen during 3-4 weeks after placement of implant. The implant stability dip can be reduced by increasing the primary stability.

Factors affecting primary stability of the dental implants:

1. Quantity and quality of residual bone.
2. Surgeons' technique, comprising expertise and capability of operator.
3. Dental implant attributes i.e., geometry of dental implant, dimensions including diameter and length, and quality of outer surface of implants.

Factors affecting secondary stability of the dental implants:

1. Primary implant stability
2. Modelling and remodeling of residual bone
3. Surface features of implant.[4]

Methods currently used to assess implant stability

The techniques for evaluation of stability can be categorized into two types namely invasive and non-invasive methods. Compared to non-invasive techniques, invasive techniques interfere with the implant's osseointegration from taking place.

Invasive/ Destructive methods for assessing implant stability:

1. *Histological and Histomorphometric analysis*

This is an invasive procedure based on a dyed sample of the implant and the bone surrounding the fixture, that estimates the quantity of bone surrounding the implant and bone at the fixture interface. It quantitatively evaluates the area of bone and bone contacting within threads.

2. *Tensional test*

The tensile strength at the interface was determined by disengaging the implant from the underlying bone which was modified by Bränemark by delivering the force to the cylinder-shaped fixture laterally. (Figure 2)

3. *Push-out/pull-out test*

In this technique, a force is applied along the junction in a parallel direction and is used to remove the implant after it has been inserted transcortically or intramedullarily into bone (Figure 3). On a force-displacement graph, the greatest force is known as the maximum load proficiency (or failure load). Interfacial failures in threaded designs are due to shear stress.

4. *Reverse torque test*

Reverse torque test utilizes a torque wrench, which determines the essential torque threshold that must be reached before bone-implant contact is lost. It is an indirect evaluation of the interaction between the fixture and surrounding bone. According to reports, the Removal Torque Value (RTV) was estimated to be between 45 and 48 N.cm (Figure 4). The potential risk of this method is the irrevocable plastic deformation observed at the fixture bone interface. Excessive stress on an implant result in its failure that is yet to complete osseointegration.

Non-invasive / Non-destructive methods for assessing implant stability:

1. *Radiographic Analysis*

Radiographic analysis can be performed at any phase of healing due to its non-invasive nature. Radiographs specially the bitewing radiographs are considered to be an indicator for implant success and are used to measure crestal bone level. However, only when there is no aberration in radiographic images, the changes in the crestal bone levels can be measured accurately. Bone mineralization changes in the radiographs cannot be detected until 40% of demineralization has taken place. Crestal bone level changes evaluated by computer assisted techniques such as CBCT may provide reliable radiographic data.

2. *Cutting Torque Resistance Analysis*

It is the evaluation of a unit of quantity of residual bone lost due to an electrically driven machine and is calculated by manually adjusting the pressure thereby reducing the interoperator differences while drilling at a very low speed.[3] This method can help detect bone density and can also assess the quality of bone. The drawback is that until the osteotomy site is prepared, information regarding the quality of bone is unavailable.[3] Additionally, the cutting torque value's lower limit, or the critical point at which the it would be in danger cannot be precisely determined.[5] This technique can measure implant stability exclusively during implant placement period.[6]

3. Insertion Torque Analysis

The force applied to the fixture during its insertion into the jaw bone is determined by insertion torque analysis. Initial implant insertion torque is negligible but the value when the top of the screw engages with the cortical plate is at its maximum. Furthermore, the osseointegration and healing processes for implants cannot be monitored using this method. [7] The primary stability increases as the insertion torque rises.

4. Seating Torque Test

The final seating torque is analogous to the insertion torque analysis because when the ultimate apico-occlusal position is attained by the implant, the details about the primary stability of it is disclosed. It happens following implant insertion.[8]

5. Percussion Test

Percussion test is checked by a blunt sided instrument. In addition to impact response theory the assessment relies on vibrational-acoustic science also. A “crystal” ringing sound if observed it indicates a proper osseointegration in contrast to a “dull” sound means poor osseointegration.

6. Finite Element Analysis (FEA)

FEA is a mathematical approach offering an interface for creating and analysing 3D models of objects and the supports that hold them thereby makes it easier to conduct radiofrequency analysis. With a limited number of elements, FEM simulates the true structure and allocates mechanical properties to things like Young's modulus, the Poisson ratio, and density.[9] In order to calculate RFA and identify the range of recognisable stiffness of interfacial tissue, Wang et al. employed FEM. Finite element modelling has a number of fundamental drawbacks, including the fact that it relies heavily on mathematical approaches that may not always be realistic to represent real-world situations. [10]

7. Pulsed Oscillation Waveform

By forcing a steady-state wave to oscillate, a pulsed oscillation waveform was employed to study the mechanical vibrational features of the implant-bone interface.[11] It revolves around the estimation of vibrational frequency and amplitude which is brought produced by a brief burst of multifrequency force at a frequency of roughly 1KHz. Oscilloscope, pulse generator are used in addition to acoustoelectric driver (AED), and acoustoelectric receiver (AER) to examine the waveform.

8. Periotest

Periotest is an electronic device devised by Dr. Schulte, which quantitatively measures the periodontal ligament that surround a tooth’s shock absorbing capability to a distinct impact load thus assessing the mobility of natural tooth. Periotest value (PTV) spanning from -8 (low mobility) to +50 (high mobility) with PTV of -8 to -6 is considered to be of good stability (Figure 5). Reading values (−8 to 0) indicate greater osseointegration and followed by easy loading of an implant, while implants are not usually loaded in values ranging from (+1 to +9), and finally values ranging from (+10 to + 50) indicates poor osseointegration that is inadequate for implant loading. Periotest's drawbacks include limited sensitivity along with a deficit of resolution, and the possibility that the exact location and trajectory of the percussion rod could affect the results.

9. Radiofrequency Analysis (RFA)

It is a diagnostic method that is non-invasive in nature. evaluates the stiffness and stability at implant bone junction and bone density using vibration and a structural analysis method at various time intervals. RFA is dependent on material, length of implant and osseointegration achieved. Variations in resonance frequency are a strong indicator of how well the osseointegration has been achieved. The resonance frequency has a strong relationship with the osseointegration, because the material and dimensions of the implants are constants.[12] It is based on ISQ index also known as implant stability quotient. ISQ varies from 0-100. Greater the ISQ values better is the implant stability. ISQ values greater than 65 indicate successful implant stability whereas values less than 60 indicate risk of implant failure. Studies have confirmed an ISQ of 70 or above is recommended for a prothesis than can be loaded immediately, however values between 65 to 70 is necessary for early loading, and values ranging from 60 to 65 for traditional loading is required. (Figure 6)

RFA can be of two types namely-

1. **Electronic Technology Resonance Frequency Analysis**: The device consists of the transducer, along with computerized analyser and an excitation source (Figure 7). It converts the 3,500–8,500 Hz resonant frequency values into an ISQ ranging between 0 to100.

2. **Magnetic Technology Resonance Frequency Analysis:** It comprises of a magnetic peg attached to the transducer that can be affixed to not only on the implant but also on the abutment (Figure 8). The complex vibrates on activation and elicits electric volt which are monitored by the analyser. ISQ values are on a scale from 0 to 100.

Newer methods under research and development

1. **Electro-Mechanical Impedance Method:** It makes use of piezoelectric materials' electro-mechanical impedance, which is closely linked to the host structure's mechanical impedance. The Piezoelectric Zirconate Titanate (PZT) starts vibrating when a 1V voltage is applied in the range of kHz. Any transition in structural parameters, such as rigidity, damping effect, or mass allocation, would affect the electrical admittance reading of PZT as determined by the analyser.[3]

2. **Micro-Motion Detecting Device:** It is a unique loading apparatus customizable in nature. A digital micrometer and a digital force gauge were used to ascertain implant micromotion.

Conclusion

The significance of achieving greater primary implant stability and its relevance for osseointegration of dental implant is highlighted in the present review of literature. The precision in implant stability refers to the accuracy and consistency of implant placement procedures, while perfection refers to the ideal implant position, orientation and stability. So, by combining precision with a commitment to perfection, dental professionals can achieve proper osseointegration and optimal implant stability. There is no particular method that has been established to evaluate the implant stability definitely till date. Due to its capacity to measure implant stability more accurately than various other methods, analyse the impact of early and delayed loading, and provide an early diagnosis of implant failure, RFA has become a popular choice. Hence, the present indications from this review of literature is that many diagnostic techniques that support long-term implant stability should be studied further to gain additional knowledge and expertise and ensure the best possible treatment outcome for the patients.

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FIGURES

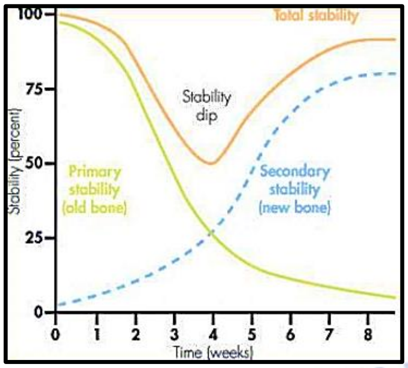

Figure 1

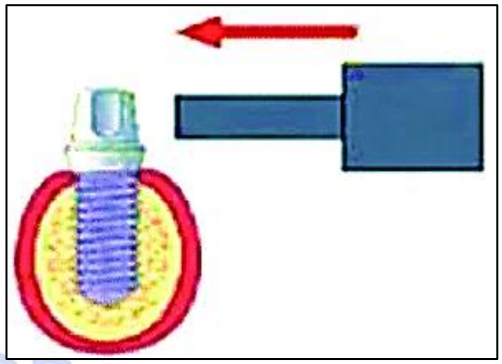

Figure 2

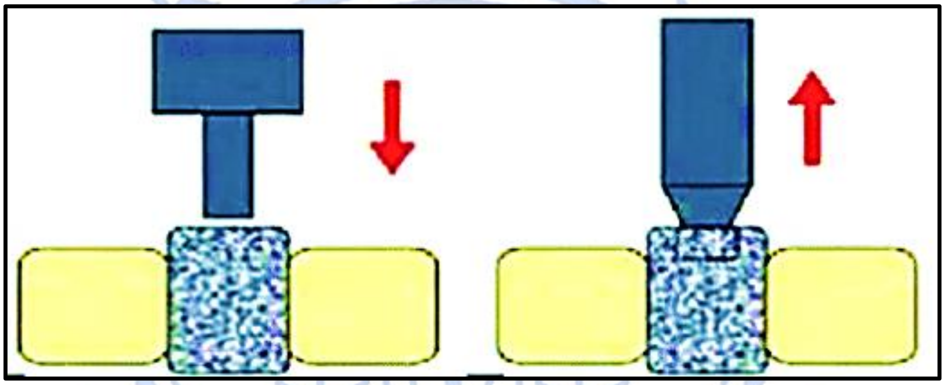

Figure 3

Figure 4

Figure 5

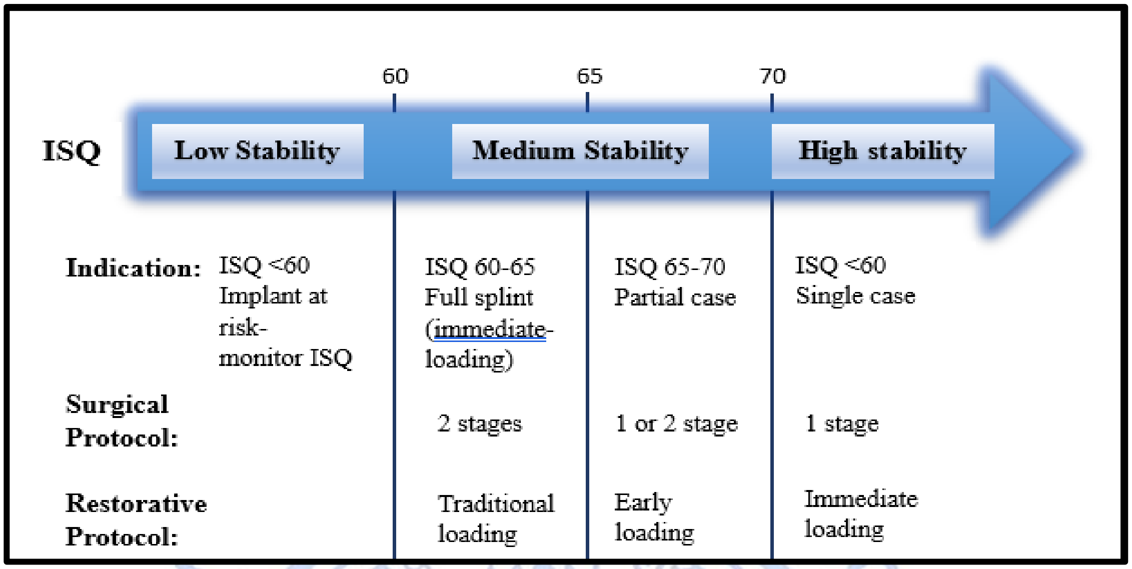

Figure 6

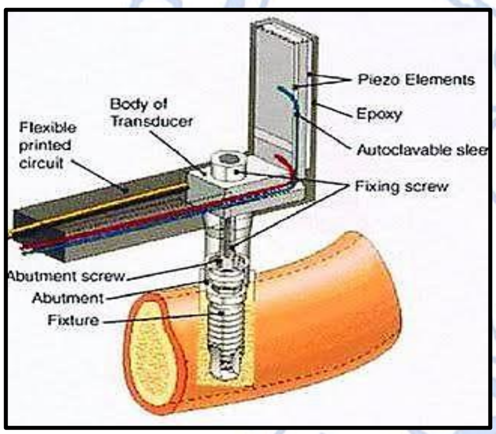

Figure 7

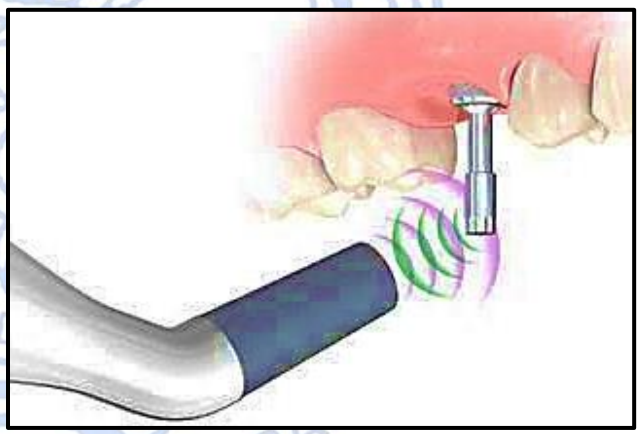

Figure 8