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Assessment of Implant Stability- A Critical Review

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ABSTRACT

Successful osseointegration is a prerequisite for functional dental implants, and primary implant stability is a prerequisite for successful osseointegration. Continuous monitoring in an objective and qualitative manner is important to determine the status of implant stability. It is, therefore, of an utmost importance to be able to access implant stability at various time points and to project a long term prognosis for successful therapy. Various methods have been proposed: Radiographs, surgeon's perception, Insertion torque (cutting torque analysis), seating torque, reverse torque testing, percussion testing, impact hammer method, pulsed oscillation waveform, implant mobility checker, Periotest, resonance frequency analysis. Therefore this review focuses on the currently available methods for evaluation of implant stability.

Key Words: Implant stability, periotest, cutting resonance analysis, resonance frequency analysis.

INTRODUCTION

Achievement and maintenance of implant stability are prerequisites for successful clinical outcome(Sennerby & Meredith 2008). Therefore, measuring the implant stability is an important method for evaluating the success of an implant. Clinical assessment is based on mechanical rather than histological criteria of stability,[1] considering primary and secondary stability. Primary stability mostly comes from mechanical engagement with cortical bone and the absence of mobility in the bone bed upon insertion of the implant and depends on the quantity and quality of bone, surgical technique and implant design. Secondary stability depends on bone formation and remodeling at the implant-bone interface and is influenced by the implant surface and the wound healing time.

The former is a requirement for successful secondary stability. The latter, however, dictates the time of functional loading.[2] It can also be postulated that because implant stability is crucial to satisfactory treatment outcome, being able to objectively determine levels of implant stability at various stages of treatment will increase the satisfactory treatment outcome which will project long-term prognosis of implant placement. At present, various diagnostic analysis have been suggested to define implant stability which include: standerized radiographs, surgeon's perception, cutting torque analysis, reverse torque testing (RTT),percussion testing, impact hammer method, Periotest, resonance frequency analysis (RFA). Therefore, the purpose of this paper is to review methods currently used to evaluate implant stability.[Table1]

Surgeon's Perception

The clinical perception of primary implant stability is frequently based on the mobility detected by blunt ended instruments. It's a very unreliable and nonobjective method. It can also be checked by the cutting resistance of the implant during its insertion. The feeling of "good" stability may be accentuated if there is the sense of an abrupt stop at the seating of the implant. Root forms of tapered implants often have a geometry that will provide a firm stop and perhaps a false perception of high stability.[3]

Table 1: Methods to check stability of dental implants

Invasive methods	Non invasive methods
• Surgeon's Perception • Histlogic sections • Histomorhometry-Fr. Ground Section • Ultrastructural Studies-Tem • Insertion torque Test • Seating torque Test • Cutting Torque Resistance Analysis • Reverse Torque	• Percussion • Radiographs • Periotest • Resonance Frequency analysis(Meredith et al) • Dyanamic Model Testing • Reverse removal test • GCF Evaluation-Presence of (AST)

Radiograph

Radiographic evaluation is a non-invasive method that can be perfomed at any stage of healing. Bitewing view is used to measure crestal bone level. It has been reported that 1.5mm of radiographic crestal bone loss can be expected in the first year of loading in a stable implant, with 0.1mm of subsequent annual bone loss. However, numerous limitations exist with the use of a conventional radiograph alone in making an accurate assessment: 1.5 mm is a mean value, due to a low incidence of implant failure, changes in radiographic bone level alone cannot precisely predict implant stability, it is impractical to detect radiographic bone loss at 0.1 mm resolution, conventional periapical or panoramic views do not provide information on a facial bone level, and bone loss at this level precedes mesiodistal bone loss, neither bone quality nor density can be quantified.

Insertion Torque Test

Measuring the insertion torque while installing the implant is an attempt to quantify the surgeon's tactile perception. A disadvantage of this method is that the insertion torque varies
depending on the cutting properties of the implant and the presence of fluid in the preparation. However, insertion torque measurements can only be used when the implant is inserted and are not possible at later stages of the treatment process.

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. However, seating torque measurements can only be used when the implant is inserted and are not possible at later stages of the treatment process.

Cutting Resistance Analysis (CRA)

It was originally developed by Johansson and Strid [4], and later improved by Friberg et al[5-6]. The energy (J/mm3) required for a current fed electric motor in cutting off a unit volume of bone during implant surgery is measured. CRA gives a far more objective assessment of bone density than clinician- dependent evaluation of bone quality. Therefore, CRA value may provide useful information in determining an optimal healing period in a given arch location with a certain bone quality. The energy correlates to bone density, which is one of the factors determining implant
stability. However, the lower limit value has not been established, which can denote potential failure of the implant. Moreover, it can only be used during the surgery and not as a diagnostic aid, and it cannot assess the secondary stability by new bone formation and remodeling around the implant.[9]

Reverse torque test

Application of a reverse or unscrewing torque has also been proposed for the assessment of implant stability at the time of abutment connection.[10]. It measures the torque threshold where bone — Implant contact was destroyed. However, the applied torque may in itself be responsible for the failure (Sullivan et al., 1996). Finally, measurement of lateral mobility is more useful than measurement of rotational mobility as an indicator of a successful treatment outcome. A rotationally mobile implant can be laterally stable, and RTT fails to measured lateral mobility. This method has been criticized as being destructive. [11] Researchers have cautioned about the risk of plastic deformation within the peri implant bone and of implant failure if the unnecessary load was applied to an implant that was still undergoing osseointegration. Furthermore, reverse torque value can only provide information as to all or none outcome (osseointegrated or failed); it cannot quantify the degree of osseointegration. Hence, RTT is mainly used in experiments.

Percussion Test

It is based upon vibrational acoustic science and impact-response theory. A clinical judgment on osseointegration is made based on the sound heard upon percussion with a metallic instrument. A clearly ringing "crystal" sound indicates successful osseointegration, whereas a "dull" sound may indicate no osseointegration. However, this method heavily relies on the clinician's experience level and subjective belief. Therefore, it cannot be used in experimentally as a standardized testing method.

Impact hammer Test

It is an improved version of the percussion test except that sound generated from a contact between a hammer, and an object is processed through fast Fourier transform (FFT) for analysis of transfer characteristics. Periotest and Dental Mobility Checker are currently available mobility testers designed according to the impact hammer method.

Dental mobility checker

The DMC, which was originally developed by Aoki [12] and Hirakawa,[13] measures tooth mobility with an impact hammer method using transient impact force. It detected the level of tooth mobility by converting the integration (i.e., rigidity) of the tooth and alveolar bone into acoustic signals. A microphone is used as a receiver. The response signal transferred from the microphone is processed by FFT for conversion for analysis in the time axis. DMC uses a small impact hammer, hence can be easily used even in molar regions. There are some problems, however, such as the difficulties of double-tapping and difficulty in attaining constant excitation. The application of a small force to an implant immediately after placement may jeopardize the process of osseointegration.[14]

Periotest

Quantifies the mobility of an implant by measuring the reaction of the peri-implant tissues to a defined impact load. The Periotest was introduced by Schulte to perform measurements of the damping characteristics of the periodontal ligament, thus assessing the mobility of natural tooth.[17,18] Periotest uses an electro-magnetically driven and electronically controlled tapping metallic rod in a handpiece. Periotest value range from −8 (low mobility) to +50 (high mobility).

Interpretation of readings in the patient.

- -8 to 0 – Good osseointegration, implant can be loaded
- +1 to +9 – Clinical examination is required, in most cases implant loading is not yet possible.
- +10 to +50 – Osseointegration is insufficient, the implant must not be loaded.

Despite some positive claims for Periotest,[15,16] the prognostic accuracy of PTV for implant stability has been criticized for a lack of resolution, poor sensitivity, and susceptibility to operator variables.

Periotest M

The Periotest is the instrument most commonly used for measuring osseointegration in dental implants. It is also available as a hand-held mobile device, known as the Periotest M. Its wireless design, allows it to be used for a maximum freedom of movement. It is a simple and quick method of gaining an objective statement as to whether the implants have become well osseointegrated and can be loaded. Moreover, the Periotest can be employed at all stages of implantlogical treatment — From primary stability testing, through the healing period, and right up to the finished prosthetic. It is this ability to measure the finished crown that is of particular value. According to reports, every tenth implant is susceptible to peri implantitis 15 years at the latest following its original insertion. By conducting continuous tests with the Periotest, it is possible to detect and treat this condition at an early stage. It is therefore recommended that implants are measured routinely using the Periotest. Doing so will serve to build a sense of security and trust, both for the dentist and for the patient.

Resonance frequency analysis

It was suggested by Meredith in 1998.[19] It is a noninvasive diagnostic method that measures implant stability and bone density at various time points using vibration and a principle of structural analysis. RFA utilizes a small L-shaped transducer that is tightened to the implant or abutment by a screw. The transducer comprises of two ceramic elements, one of which is vibrated by a sinusoidal signal (5–15 kHz) while the other serves as a receptor. The transducer is screwed directly to the implant body and shakes the implant at a constant input and amplitude, starting at a low frequency and increasing in pitch until the implant resonates. High frequency resonance indicates stronger bone-implant interface. It also provides baseline reading for future comparison and postsurgical placement ofthe implant.

RFA has been widely used for clinically assessing osseointegration, as well as for prognostic evaluation. However, the latter aspect still has to be questioned. The most recent version of RFA is a wireless gadget. A metal rod is attached to the implant with a screw connection. The rod has a small magnet attached to its top that is stimulated by magnetic impulses from a handheld electronic device. The rod mounted on the implant has two fundamental resonance frequencies; it vibrates in two directions, perpendicular to each other. One of the vibrations is in the direction where the implant is most stable and the other is in the direction where the implant is least stable. With this method, implant stability is measured either by determining the resonance frequency of the implant-bone complex or by reading an ISQ value.

Classically, the ISQ has been found to vary between 40 and 80, the higher the ISQ, the higher the implant stability.[20] Implant stability can be determined for implants with an ISQ of 47. All implants with an ISQ more than 49 osseointegrated when left to heal for 3 months.All implants with an ISQ more than 54 osseointegrated when immediately loaded. For implants with low ISQ values, a decrease in implant stability should alert the practitioner to submit these implants to a tighter follow-up schedule and to take additional precautionary measurements in terms of unloading until implant stability is regained or if nonloaded to check for mechanical trauma and/or infection.

The drawbacks with this technology are that the transducer is limited to a set of 60 measurements, thus making the method rather expensive. In order to perform the RFA, a transducer is fixed to the implant. This excludes monitoring all implants that support a cemented restoration.

CONCLUSION

To date, no definite method to evaluate implant stability has been established. Although RFA has attracted considerable scientific interest in recent years; it can also be used to evaluate the effect of early and delayed loading, assess stability over a period of time and early diagnosis of implant failure. However, more research is required to devise an accurate instrument which will help gauge the implant stability.

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