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MEASURING IMPLANTS STABILITY—A REVIEW

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ABSTRACT

Achieving and maintaining implant stability are prerequisites for a dental implant to be successful. Implant stability can be defined as the absence of clinical mobility, which is also the suggested definition of osseointegration. Primary implant stability at placement is a mechanical phenomenon that is related to the local bone quality and quantity, the type of implant, and placement technique used. Secondary implant stability is the increase in instability attributable to bone formation and remodeling at the implant–tissue interface and in the surrounding bone. There are many ways in which the implant stability can be evaluated such as clinical measurement of cutting resistance during implant placement, reverse torque test, and the periotest. This article aims to throw light on the various methods to determine implant stability.

Keywords: implant stability, implant stability quotient, periotest, resonance frequency analysis

INTRODUCTION

Successful osseointegration is a prerequisite for functional dental implants, and primary implant stability is a prerequisite for successful osseointegration. Implant stability can be defined as absence of clinical mobility. Implant instability could result in fibrous encapsulation with resultant failure. The establishment and maintenance of osseointegration, is defined as "a direct structural and functional connection between ordered, living bone and a surface of a load-bearing implant" are requirements for long term implant success.[1]

IMPLANT STABILITY

Implant stability can be defined as the absences of clinical mobility, which is also the suggested definition of osseo-integration. Achieving and maintaining implant stability are prerequisites for successful clinical outcome with dental implants. Nonetheless, a clinically stable implant also exhibits mobility on the microscale when loaded. For instance, if applying a lateral load (bending) to a bone-integrated implant, the implant will be displaced but will return to its original position as soon the load is removed. Thus, a stable implant can display a varying degree of stability (i.e., different degrees of displacement or resistance to load), depending on factors relating to the bone, the surgical technique and the implant design. During clinical function, loading is applied in axial, lateral, and rotational directions. Furthermore, axial loads can be in intrusive or extrusive directions. Lateral loads can principally occur from any 360° direction around the implant. Rotational loading can be either clockwise or counterclockwise. Thus, the outcome of an implant stability analysis is highly dependent on the type of test used and the direction and type of the applied force.

PRIMARY IMPLANT STABILITY

Primary implant stability has been acknowledged as an essential criterion for later achievement of osseointegration. Dental implant stability is a measure of the anchorage quality of an implant in the

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alveolar bone and is considered to be the consequential parameter in implant dentistry. Implant stability can occur at two different stages: primary and secondary. It has been established to affect the process of osseointegration, the pattern of implant loading, and, finally, the success of an implant. Primary stability of an implant mostly comes from mechanical engagement with cortical bone.[1] It thus prevents the formation of a connective tissue layer between implant and bone, consequently ensuring bone healing. Therefore, primary stability of an implant is a prerequisite to undisturbed peri-implant bone healing.

Atsumi et al[2] proposed the following factors that affect the primary stability:

1) Bone quantity and quality
2) Surgical technique, including the skill of the surgeon
3) Implant (e.g., geometry, length, diameter, and surface characteristics).

Turkyilmaz and Aksoy[3] in a study mentioned that the factors affecting the primary implant stability can be divided into:

1) Patient-related (i.e., bone volume and quality)
2) Procedure-dependent parameters: (i) type of implant (drill size–implant size, pretapped or self-tapped implant) and (ii) type of surgical procedure. An insufficient primary stability causes poor healing related to the early loss of the implant.

The two main factors affecting implant stability are the location and the stiffness of the implant in the surrounding tissue. The stiffness can be considered in three ways: (1) the stiffness of the implant components themselves associated with the geometry and material composition, (2) the stiffness of the implant–bone interface, and (3) the stiffness of the bone itself associated with the trabecular/cortical bone ratio and bone density.

Maintenance of low implant micromovement, especially in early healing periods, presents importance in promotion of direct bone ingrowth to implant surface. Thus, when the implant is stable in the bony bed during placement and during healing, new bone will predictably fill the bone–implant interface and most of the implant surface will come in direct contact with living bone.

BONE QUANTITY AND QUALITY AFFECTING THE PRIMARY STABILITY

Typically, implant stability is anticipated to decrease during the early weeks of healing; this is followed by an increase in stability. This is related to the biologic reaction of the bone to surgical trauma. During the initial bone remodeling phase, bone and necrotic materials are resorbed by osteoclastic activity, which is reflected by a reduction in the implant stability quotient (ISQ) value.

This process is followed by new bone apposition initiated by osteoblastic activity, that is, adaptive bone remodeling around the implant. An accelerated formation of bone-to-implant contact contributes to a faster increase in secondary stability. This biologic process eliminates the decrease in primary stability and ensures consistency of stability over time (without the drop during the healing period).[4] The long-term success of dental implants in various clinical situations depends to a large extent on the quality of the implant and bone bond. Because of a higher ratio of compact to trabecular bone in the mandible, implants inserted into the anterior mandible have higher survival rates than implants placed in the posterior maxilla. Initial implant stability is mainly determined by the bone quantity and quality (trabecular/cancellous to cortical bone ratio). A positive correlation was found between primary stability and cortical thickness of the artificial bone (**Table 1**).

Primary stability at implant installation is achieved by the physical congruence between the surgically created bone bed and the implant, which is dependent on the macroscopic implant design, the surgical technique, and the bone density.[5]

SECONDARY IMPLANT STABILITY

Bone Formation/Remodeling

Secondary implant stability is the increase in stability due to bone formation and remodeling at the implant–tissue interface and in the surrounding bone. Secondary stability offers biological stability through bone regeneration and remodeling. Secondary

Table 1: Factors affecting primary stability

Factors influence on primary stability
Bone quality and quantity
Cortical bone > trabecular bone Favorable
Increased cortical bone thickness Favorable
Bone in posterior mandible > bone in posterior maxilla Favorable
Cortical bone in males More favorable
Cortical bone in females Less favorable
Implant characteristics
Wide diameter implants Favorable
Threaded implants > custom made implants Favorable
Tapered wide implants > nontapered implants Favorable
Long implants More favorable
Short implants Less favorable
Acid etched implants > machined surface implants Favorable
Non-self-tapping implant> self-tapping implant Favorable
Surgical Techniques
Osteotome technique Less favorable
Conventional technique More favorable
Bicortical anchorage Favorable

stability, which is seen after the healing period, is primary stability with a further gain in stability because of bone formation around the implant.[6] Degree of implant stability may also depend on the condition of the surrounding tissues. It is, therefore, of an utmost importance to be able to quantify implant stability at various time points and to project a long-term prognosis based on measured implant stability. A secure primary stability leads to a predictable secondary stability. Secondary stability has been shown to begin to increase at 4 weeks after implant placement. At this time point, the lowest implant stability is expected. Therefore, the original Branemark protocol suggested a 3- to 6-month nonloaded healing period to achieve adequate stability before functional loading.[7]

Loading Protocol

Under defined circumstances, early and immediate loading protocols have now been recognized to be viable alternatives to the classical 1- or 2-stage delayed loading approaches. Subsequently, the clinician needs reliable and supportive objective guidelines to determine on an individual basis the prognosis of a given implant, if immediately loaded, early loaded within 6 to 8 weeks, or left classically to heal for a 3 to 6 months period.[8]

Evaluation of Secondary Implant Stability

Historically, the gold standard method used to evaluate the degree of osseointegration was microscopic or histologic analysis. However, due to the invasiveness of this method and related ethical issues, various other methods of analysis have been proposed: clinically checking for mobility with the help of blunt ended instruments, radiographs, cutting torque resistance, reverse torque, and resonance frequency analysis (RFA).[9]

Measuring implant stability supports making good decisions about when to load, allows advantageous protocol choice on a patient-to-patient basis, indicates situations in which it is best to unload, supports good communication and increased trust, and provides better case documentation.

METHODS TO MEASURE IMPLANT STABILITY

The methods to determine implant stability clinically are clinical perception, percussion test, reverse torque test, cutting torque resistance analysis, and periotest RFA.

1. Clinical Preception

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.[10]

2. Percussion Test

The percussion test may involve the tapping of a mirror handle against the implant carrier and is designed to elicit a ringing sound from the implant as an indication of good stability or osseointegration. Percussion tests probably provide more information about the metallic property of the tapping instrument,

and will at best only yield poor qualitative information. This is the main disadvantage of the percussion tests.

3. 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. Implants that rotate under the applied torque are considered failures and are then removed. However, the implant surface in the process of osseointegrating, albeit slowly, may fracture under the applied torque stress. Moreover, as animal experiments have demonstrated the reintegration of loosened and rotationally mobile implants, the reverse torque testing has fallen into disrepute. So, the disadvantage of this method is that while applying reverse torque to osseointegrated implants may sometimes destabilize the implant and can affect long-term prognosis of the implant.[10]

4. Cutting Torque Resistance Analysis

The energy required for a current-fed electric motor in cutting off a unit volume of bone during implant surgery is measured. The energy correlates to bone density, which is one of the factors for 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 during prosthetic phase, and it cannot assess the secondary stability by new bone formation and remodeling around the implant (**Figure 1**).

5. Periotest

The periotest offers a more reliable method of diagnosing implant status by measuring levels of subclinical mobility in a reproducible manner (**Figure 2**). It is a device which is an electrically driven and electronically monitored tapping head that percusses the implant a total of 16 times.[11] The entire measuring procedure takes ~4 seconds. The instrument includes a tapping rod that impacts the abutment/implant assembly. The rod is drawn by a propulsion coil toward the impacting surface and essentially moves at a constant velocity from the moment it leaves the hand piece until it impacts the surface. This means that over a certain distance (~4 mm), the tapping rod is moving at the same velocity and is designed to impact the surface at any time during this constant velocity travel. The end of the rod inside the hand piece is rigidly connected to an accelerometer, which produces an output proportional to its acceleration (**Figure 3**). The readings are from −8 to +50 and are interpreted (**Table 2**).

Figure 1: Reverse torque test.

Figure 2: Periotest.

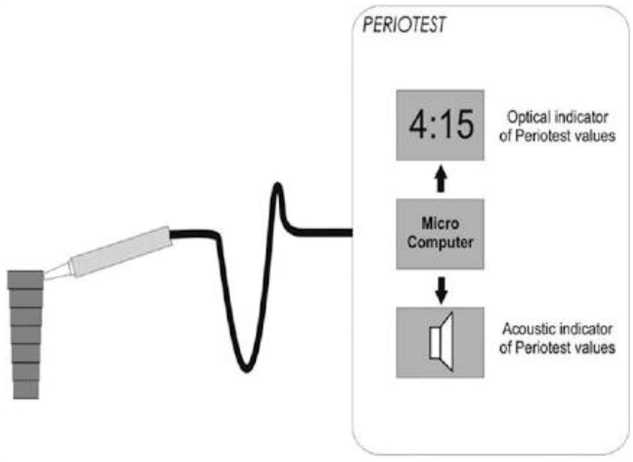

Figure 3: Diagrammatic representation of periotest.

Table 2: Periotest interpretation

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

The factors that influence the periotest value are the quality of the hard tissue in the region of the implant, so that no specific values can be deemed as appropriate for higher or lower degrees of integration. It is a function of the distance from the implant flange to the point at which the rod impacts the abutment. These variations suggest that for implants, there is no absolute value that can be regarded as acceptable; rather, variations that occur over time may be more meaningful.

In vitro evaluations revealed that no statistically significant difference existed in measuring periotest values from the operator to operator, as well as high level of repeatability between different periotest units. Successfully integrated dental implants have yielded a wide range of stability readings with the periotest. This range in values is believed to reflect bone density at the implant interface, which is related to implant location.[12]

The measurements are significantly affected by excitation conditions such as direction and position. The measurements must be made in the mid buccal region and be perpendicular to the implant axes (**Figure 4**). Considering the intra oral environment, it is considerably easy to make measurements on anterior implants whereas it is not possible for molars owing to the buccal mucosa.[13] The periotest cannot diagnose a "borderline" case or "an implant in the process of osseointegration." It does not reflect the level of peri-implant bone and therefore cannot be substituted for radiography.[14]

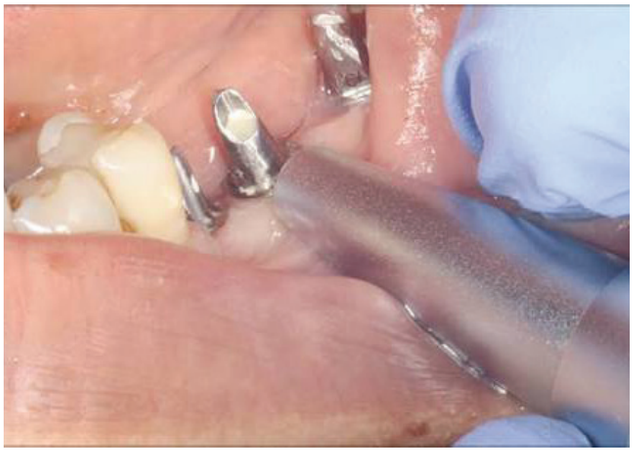

Figure 4: Application of periotest.

6. Resonance Frequency Anaylsis

It is a noninvasive diagnostic method that measures implant stability and bone density at various time points using vibration and structural principle analysis. Two commercially devices have been developed to assess implant stability. The original (electrical) method uses a direct connection (wire) between the transducer and the resonance frequency analyzer.[15] The second method uses magnetic frequencies between transducer and resonance frequency analyzer. In the electronic device, the transducer is L-shaped cantilever beam which connects to the implant via a screw attachment. 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 (**Figure 5**).

The new magnetic RFA device has a transducer, a metallic rod with a magnet on top, which is screwed onto an implant or abutment. The magnet is excited by a magnetic pulse from a wireless probe. The pulse duration is ~1 minute. 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 analyzer (**Figure 6**). The electronic device and the magnetic device are capable of measuring similar changes; however, the magnetic device results in higher ISQ value when measuring the stability of nonsubmerged dental implant.[16]

With this method, implant stability is measured either by determining the resonance frequency of the implant-bone complex or by reading an ISQ value given by the Osstell apparatus. Classically, the ISQ has been found to vary between 40 and 80, the higher the ISQ, the higher the implant stability. A substantial increase or decrease in implant stability could be detected with this method that otherwise could not be clinically perceived. The factors affecting the readings

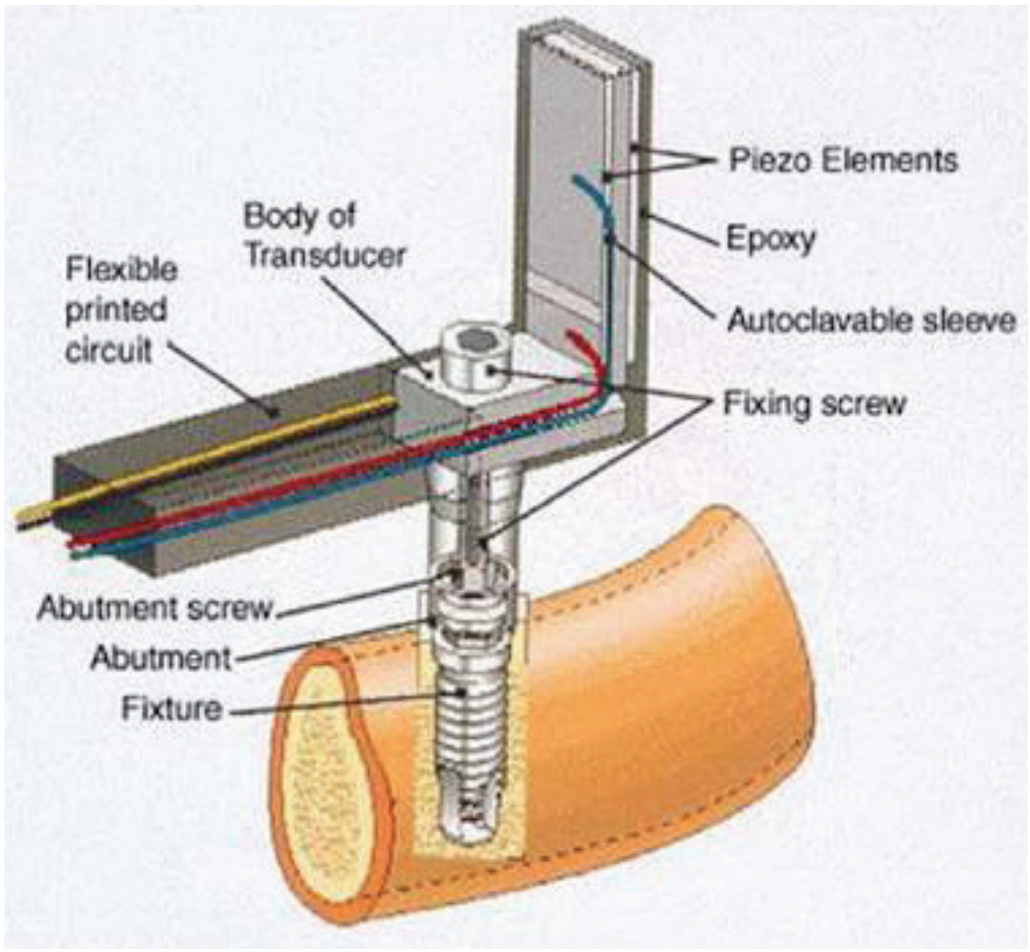

Figure 5: Electronic resonance frequency analyzer.

Figure 6: Magnetic resonance frequency analyzer.

are effective implant length, bone quality and quantity, implant length, diameter, and shape. Effective implant length is the length of the exposed threads and abutment height. It is inversely proportional to the resonance frequency.

A study was conducted in which 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. For implants with high ISQ values, reduction implant stability during the first 12 weeks of healing should be considered as a common event that should not require alteration of routine follow-up.

The drawbacks with this technology are that the transducer is limited to a set of 60 measurements, thus making the method rather expensive. To perform the RFA, a transducer is fixed to the implant. This excludes monitoring all implants that support a cemented restoration.[17]

CONCLUSION

Although there are various methods which help to determine implant stability, the number of variables affecting the results makes it difficult to come to a critical value which can determine the success, failure, or long-term prognosis of an implant.

Source of Support

Nil.

Conflict of Interest

None.

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