

## Implant Stability: Methods and Recent Advances

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### Abstract:

Dental implants represent one of the most successful treatment modalities in dentistry. However, failures do occur in the range from 5 to 8% for routine procedures and up to 20% in major grafting cases after at least 5 years of function . The majority of implant losses may be explained as biomechanically induced failures, since low primary implant stability, low bone density, short implants and overload have been identified as risk factors . Hence, achievement and maintenance of implant stability are pre-conditions for a successful clinical outcome with dental implants. The review focuses on different methods used to assess implant stability and recent advances in this field.

**Key words:** osseointegration, dental implant stability , ISQ,

### I. Introduction

The use of dental implants in the rehabilitation of partially and completely edentulous patients has been significantly increased in dentistry since 1980 [1]. Although high survival rates of implants supporting prosthesis have been reported [2,3,4], failure still happens due to bone loss as a results of primary and secondary implant stability. Primary stability of an implant is the absence of mobility in the bone bed upon insertion of the implant and mostly comes from mechanical interaction with cortical bone. It is also named as “Mechanical Stability” which is the result of compressed bone holding the implant tightly in the bone. Secondary stability, named as “Biological Stability”, happens through bone regeneration and remodelling at the implant/bone interface [5,6]. It is the result of new bone cells forming at the site of the implant and osseointegration. The primary stability is the requirement for successful secondary stability [6]. Secondary stability orders the time of functional loading [7]. Following the placement of an endosseous implant, primary mechanical stability gradually decreases and secondary stability (biologic) gradually increases.

Bone quantity and quality, surgical techniques including the skill of the surgeon, implant (geometry, length, diameter, and surface characteristics) are major factors affecting primary stability [8]. Primary stability, bone modelling and remodelling, and implant surface conditions are the main parameters influencing secondary stability [8].

Osseointegration is an important factor in specifying a series of criteria that identifies success or failure of an implant. Osseointegration is, however, a patient-dependent wound healing process that happens at two different stages: primary stability and secondary stability. [8]

Invasive methods	Noninvasive methods
Surgeon`s perception	Radiographs
Insertion torque	Percussion testing
Seating torque	Impact hammer method
Reverse torque	Periotest and Periotest M
	Pulsed oscillation waveform
	Implant mobility checker
	Resonance frequency analyzer

**Table 1:** Methods to check stability of dental implants

Dental implant stability measurement, an indirect indication of osseointegration, is a measurement of implant`s resistance to movement [9]. Objective measurement of implant stability is a valuable tool for achieving consistently good results first and foremost because implant stability plays such an important role in achieving a successful outcome.[10] The advantages of measuring implant stability are to make more accurate decisions about the time of crown loading or unloading, select the protocol of choice for implant loading, and

increase trust between patient and practitioner.[11] It is, therefore important to be able to quantify implant stability at various times and have in place a long-term prognosis based on implant stability measurement tool. Although various diagnosis analyses have been employed and several research and development projects have been already made in this field, measuring implant stability remains a challenge in dentistry.[12]

Implant stability plays a critical role for successful osseointegration, which has been viewed as a direct structural and functional connection existing between bone and the surface of a load-carrying implant .[8]

Achievement and maintenance of implant stability are prerequisites for successful clinical outcome. Therefore, measuring the implant stability is an important method for evaluating the success of an implant. Implant stability is achieved at two different stages: primary and secondary. Primary stability of an implant comes from mechanical engagement with cortical bone. It is affected by the quantity and quality of bone that the implant is inserted into, surgical procedure, length, diameter, and form of the implant.[3]

Secondary stability is developed from regeneration and remodeling of the bone and tissue around the implant after insertion but is affected by the primary stability, bone formation and remodeling. [2] The time of functional loading is dependent upon the secondary stability. 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 .the measured implant stability .[2,5]

### **Methods currently used to assess implant stability**

The currently available methods to evaluate implant stability are discussed. The methods for studying stability can be categorized as invasive, which interfere with the osseointegration process of the implant, and non-invasive, which do not. Some of the most famous methods in analyzing dental implant stability are histologic analysis, percussion test, radiographs, reverse torque, cutting resistance, and resonance frequency analysis (RFA). Since histologic analysis is not feasible for daily practice it is not discussed in this chapter.[2,13,14,15,16,17,18,19,20] Table 1

#### **- Radiographic analysis**

Radiographic analysis was one of the first methods applied to evaluate the condition of implants after they had been placed. Radiographic evaluation is a non-invasive method that can be performed at any stage of healing process. [18,19,20]Bitewing radiographs are used to measure crestal bone level, defined as the distance from the top of the implant to the position of the bone on the implant surface, because it has been suggested as an indicator for implant success [10]. However, other studies recommended that the resolution of bitewing radiographs cannot be used as the only tool to evaluate either primary or secondary stability [8]. Fig.1 Moreover, crestal bone changes can be only reliably measured if there is no distortion in the radiographic pictures. [17,18]In those pictures, the distortion happens when the central x-ray tube is not positioned parallel to the implant. Furthermore, panoramic view (a dental X-ray scanning of the upper and lower jaw that shows a two-dimensional view of a half circle from ear to ear) does not provide information on a facial bone level, and bone loss.[2] Finally, regular radiographs cannot be used to quantify neither bone quality nor density. They can be used to assess changes in bone mineral only when there are decreases that exceed 40% of the initial mineralization [4,11]. Moreover, because of X-radiation hazards other methods with fewer side effects are preferred.[16,17,19]



**Fig.1;**Implant placement at sites #19 and 20, cover screws were placed and a two-stage protocol was utilized due to low implant stability quotient

#### **-Tensional Test**

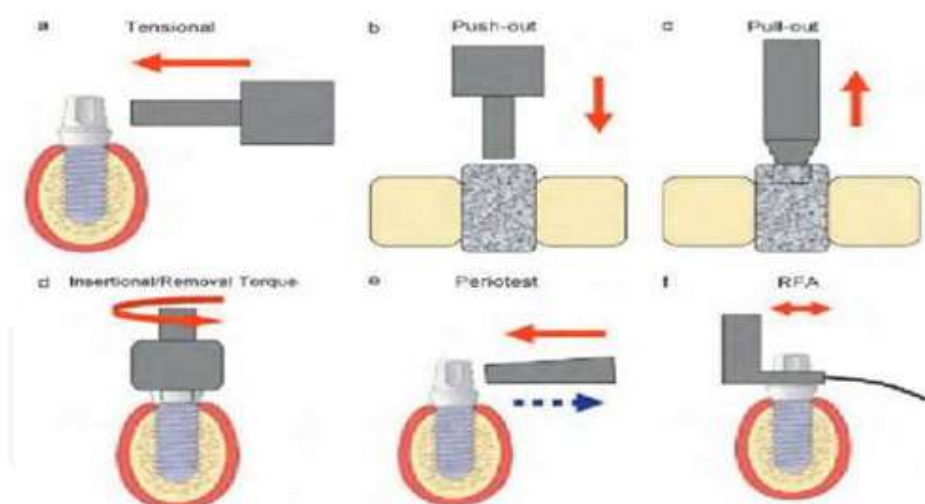
The interfacial tensile strength was originally measured by detaching the implant plate from the supporting bone. Later on it was modified by applying the lateral load to the cylindrical implant fixture. However, there were difficulties in translating the test results to any areaindependent mechanical properties [2,4].

### -Push-out/Pull-out Test

In a typical pushout or pull-out test, a cylinder type implant is placed transcortically or intramedullarily in bone and then removed by applying a force parallel to the interface. The maximum load capability (or failure load) is defined as the maximum force on the force– displacement. However, the push-out and pullout tests are only applicable for non-threaded cylinder type implants, whereas most of clinically available fixtures are of threaded design, and their interfacial failures are solely dependent on shear stress without any consideration for either tensile or compressive stresses [14,16].

### - Insertion torque analysis

Insertion torque analysis, as an invasive method, expresses the amount of force that is applied to the implant as it is inserted. Implant placement insertion torque is initially minimal, and increases quickly until the cortical layer in a jawbone is fully engaged. As the implant is driven into the bone, repeated measurements are taken and a graph is often produced. The maximum value is obtained when the head of the screw makes contact with the cortical plate (the hard, outer shell of alveolar). Insertion torque measurement includes finding the maximum insertion torque value when the screw head contacts the cortical plate. This test has been generally well accepted and has been used for evaluating various implant designs [21]. Insertion torque has been found to correlate with bone density and consequently implant stability [21]. The application of insertion torque has been shown to be limited since estimating the quality of the bone is impossible until the implant insertion is actually started. So, insertion torque measurements cannot be used for the selection of implant sites. This method also cannot be used to follow implant healing and osseointegration procedures.[21] Fig.2



**Fig. 2.** Stability analyses for oral implant osseointegration from Chang, P. C., Lang, N. P. & Giannobile, W. V. (2010). "Evaluation of functional dynamics during osseointegration and regeneration associated with oral implants." *Clinical Oral Implants Research* 21: 1-12. (a) tensional test, (b) push-out test, (c) pull-out test, (d) insertional/removal torque test, (e) Periotest, and (f) resonance frequency analysis

### -Cutting Torque Resistance Analysis (CRA)

This method was originally developed in 1994 by Johansson and Strid [22] and later improved in vitro and in vivo human models. In this method the energy ( ) required in cutting off a unit volume of bone during implant surgery is measured. This energy has been shown to be significantly correlated with bone density, which has been suggested as one factor that significantly influences implant stability [13]. The advantages of this method are detecting bone density and its quality during surgery. The major limitation of CRA is that it does not give any information on bone quality until the osteotomy site (a surgical operation for bone shortening or realignment) is prepared. In addition, this information cannot be used to assess bone quality changes after implant insertion.[2,22]

### -Reverse Torque Test (RTT)

The Reverse Torque Test (RTT), which is proposed in 1984 by Roberts et al. [23], measures the critical torque threshold when bone-implant contact is broken. This indirectly provides information on the degree of bone-implant contact in a given implant. Removal Torque Value (RTV) as an indirect measurement of bone-implant contact was reported to range from 45 to 48 N.cm [15]. The disadvantage of this method is the risk of irreparable plastic deformation within implant bone integration and the implant failure when unnecessary load is

applied to an implant that is still undergoing osseointegration. In addition, applying torque on implants placed in bone of low quality may result in a shearing of bone-to-implant contact and cause implants to irretrievably fail.[23]

#### **- Histological and Histomorphometric Analysis**

Histomorphometric method, quantitatively assesses the bone contact and bone area within threads. This technique generally requires a light microscope with microvid computers.[24]

Ultrastructural studies are mostly performed on the decalcified specimens sectioned for transmission electron microscopy. But due to the invasive and destructive nature of this techniques, its use has only limited to non-clinical and experiments studies.[24]

#### **-Percussion test**

Percussion test is the simplest method for testing implant stability. This test is based upon vibrational acoustic science and impact-response theory. In this method, clinical judgment about osseointegration is made based on the sound heard from the percussion of the implant with a metallic instrument. A “crystal” sound indicates successful osseointegration, while a “dull” sound means weak or failing osseointegration. This method heavily relies on the clinician’s experience level and subjective belief. Therefore, it cannot be used experimentally as a standard testing method.[1,2,4]

#### **-Ultrasonic wave propagation**

An alternative method to assess implant stability is quantitative ultrasound (QUS), as suggested initially by de Almeida et al. [26]. They used the implant as a waveguide and showed a significant correlation between the experimental 1 MHz ultrasonic responses of an aluminum threaded piece and the screwing depth in an aluminum block. They concluded that Ultrasonic waves are sensitive to bone-implant interface properties. In the same study, finite difference numerical simulations depicted an agreement between the 1 MHz ultrasonic response of titanium wave guides and the elastic properties of tissues surrounding the guides. Furthermore, in a recent experimental study by Mathieu et al. [26], a 10 MHz ultrasonic device was validated with implants placed in rabbit bone. The amount of bone surrounding prototype cylindrical titanium implants was shown to be significantly correlated with a quantitative indicator deduced from the ultrasonic response to a 10 MHz excitation.

#### **-Finite Element Analysis (FEA)**

Finite Element Method (FEM) is a numerical technique, which facilitates the RF analysis by providing an interface where a 3D model of an object and its support can be developed and studied. FEM approximates the real structure with a finite number of elements and assigns mechanical properties of objects such as Young’s Modulus, the Poisson ratio and density. This method can simulate complex geometric shapes, material properties, and generate various boundary conditions of the real situation, which are difficult to produce in the laboratory. FEM simulation method has the advantage of allowing independent control of each parameter in the Finite Element (FE) models.[1,2,7]

The first person who used modal analysis, the study of the dynamic properties of structures (will be explained in more details in chapter 2) together with Finite Element Method in analysis of implant stability was Williams & Williams [27]. Since then, FEM has gradually become an important tool in biomedical research. Wang et al. [28] used FEM for calculating RFA to determine the identifiable stiffness range of interfacial tissue (a thin layer surrounding the implant) of dental implants. They found that when the Young’s modulus of the interfacial tissue is less than 15 MPa, the resonance frequencies are significantly affected by the interfacial tissue and the influence of other parameters such as geometry, boundary constraint, and material property of the bone are negligible. One limitation of finite element modelling is that it is a numerical approach based on many assumptions, which might not necessarily realistic to simulate real cases.[27,28]



**Fig. 3;** Periostest

### **-Periotest**

Periotest®, Siemens AG, Bensheim, Germany (Fig. 2) is an electronic device which quantitatively measures the damping characteristics or dynamic tissue recovery process after loading, to assess osseointegration. Periotest® was originally devised by Dr. Schulte [29] to measure tooth mobility was designed to assess damping characteristics of periodontal ligament surrounding a tooth by calculating contact time between the test subject and percussion rod, thereby establishing its mobility. This instrument has been widely used to measure implant stability. Periotest value (PTV) is marked from -8 (low mobility) to +50 (high mobility). PTV of -8 to -6 is considered good stability. A healthy implant surrounded by bone will exhibit stiffness characteristics as compared to a tooth supported by periodontal ligament [29]. Fig.3

In periotest an electronically controlled rod weighting 8 g taps implant 4 times/sec at a constant speed for 4 seconds at a velocity of 0.2 m/s. The rod is decelerated when it touches the implant. The greater the implant solidity, the higher the deceleration and thus higher the damping effect of the surrounding tissues. After tapping the spot, rod recoils, a faster recoil indicates increased damping [19].

Periotest can measure all surfaces such as the abutment or prosthesis, but the rod must make contact at a correct angle and distance. Meredith [3,5] demonstrated that number of important variables, including angulation, striking point and abutment length, may influence the accuracy of this technique. If the perpendicular contact angle is larger than 20 degrees, or if the parallel contact angle is larger than 4 degrees, the measured value is invalid. Also, the rod and the test surface must maintain 0.6-2.0 mm distance and if the distance is over 5 mm, the measured value may be insignificant [20].

Periotest has a limited use as a clinical diagnostic aid, since there is lack of resolution, poor sensitivity and more over results may be influenced by to position and direction of percussion rod. The most failing point of this method is that the percussing force on the implant may deteriorate the stability in poor initial stability implants [3].

### **-Resonance Frequency Analysis (RFA)**

In resonance frequency analysis, implants are forced to oscillate and the frequency at which they oscillate at maximum amplitude is registered as their resonance frequency. Similar to all distributed system, an implant can have many resonance frequencies, each called a harmonic. The resonance frequencies are dependent on the material, length and the quality of the supporting mechanism. Since the material and length of the implant are constants, variations of the resonance frequency highly correlate to the quality of the support (osseointegration). [30]



**Fig. 4;** Osstell ISQ from Osstell AB, Sweden

RFA, as a method of monitoring implant/tissue integration, was first introduced for dental applications in 1996 [31]. It is a non-invasive and objective method for short and long-term monitoring of changes in implant stability [1,26,27]. RFA has been applied for implant stability measurement in both humans [28-30] and animals [31-33] (in vivo) and in vitro [25,34,32]. RFA, as a technique for measuring dental implant stability, has attracted considerable scientific interest in recent years and an increasing number of prominent journal papers are published about it since its first introduction. [31]

The RFA of an implant, as it was briefly mentioned in this section, can be influenced by some factors including implant length, implant diameter, implant geometry, implant surface characteristic and placement

position, as well as bone quality, bone quantity, damping effect of marginal mucosa, bone implant contact, effective implant length and connection to transducer.

Currently, there are two commercially available devices used to evaluate the resonance frequency of implants placed into the bone, Implomates (Bio Tech One) and Osstell (Integration Diagnostics). Their main difference is in the way they excite implants. Fig.4

The Implomates device (Taipei, Taiwan) has been studied extensively by Huang et al. [32]. This device utilizes an impact force to excite an implant. There is a small electrically driven rod inside the device that produces impact force. The received time response signal is then transferred in frequency spectrum for analysis (range 2 to 20 KHz). The first peak in the frequency spectrum (distinguishable from the noise) indicates the primary resonance frequency of implant. Higher frequency for the primary resonance and the sharpness of that peak indicates a more stable implant.

Osstell measures RF by attaching a metal rod to an implant with screw connection and exciting the rod doing a frequency sweep. The rod is excited by a small magnet that is attached to its top that can be stimulated by magnetic pulses from a handled electronic device. The rod can vibrate in two directions (perpendicular to each other) and thus it has two fundamental resonance frequencies. Implant Stability Quotient (ISQ) is a scale developed by Osstell for implant stability. It converts the resonance frequency values ranging from 3,500 to 8,500 Hz into an ISQ of 0 to 100. A high value indicates greater stability, while a low value indicates instability. Values greater than 65 are recommended as successful implant stability. Even though Osstell is clinically used but there are not much convincing data on the relation between bone-implant interface and ISQ values [3,32]. Although for clinical applications, Osstell has a better performance than the Periotest, both RFA devices still have some uncertainties. Further research is needed to establish higher reliability of these diagnostic devices.[33]

#### **Factors that influence treatment outcome**

It has been clinically demonstrated that implant stability plays a significant role in determining treatment outcome. Implants show high success rates if certain preconditions are fulfilled.[1]

Because they determine the level of implant stability (primary and secondary), clinical parameters (including both patient and surgical parameters), and treatment protocol are important factors in determining treatment outcome. [2] Fig.5

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 satisfactory treatment outcome. [34]

#### **Patient parameters**

The single most significant patient parameter is bone quality. Risk factors associated with bone quality include the presence of transplanted bone, irradiated bone and soft bone. All of these conditions are increasingly common as more patients are given the option of being treated with dental implants.[1,34]

#### **Surgical parameters**

Surgical technique plays a role in determining implant stability and thus treatment outcome as well. Risk factors here primarily involve instances of traumatic surgical technique that cause injury to the bone. It can be argued that this too is becoming increasingly common as more and more surgeons venture into the field of implant dentistry. [1]

#### **Treatment protocol**

The original two-step protocol for implant surgery provided an initial healing period before loading, in which stability was enhanced by new bone formation and osseointegration. Today, a newer one-step protocol is becoming more common. In many cases, initial mechanical stability is sufficient to justify immediate loading. However, the lack of a pre-loading healing period arguably increases the risk of insufficient stability at the time of loading.[1,10,12,14,15,16]

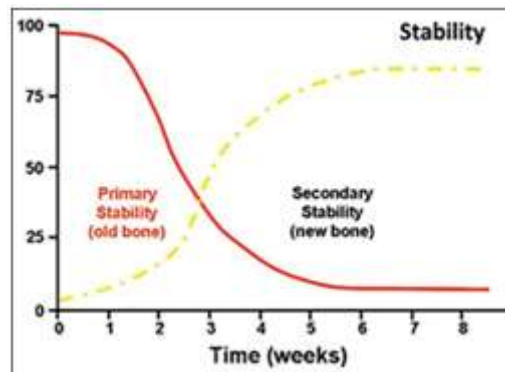


Fig .5: primary stability comes with old bone. secondary stability comes with new bone

### Why measure implant stability?

Implant stability can be seen as a combination of:

1. Mechanical stability, which is the result of compressed bone holding the implant tightly in place.[1,2]
2. Biological stability, which is the result of new bone cells forming at the site of the implant and osseointegration. [1,2]

Mechanical stability is generally high immediately after implant placement (primary stability). This is due to mechanical compression of the bone when the implant is placed, and it decreases with time. [2]

Biological stability, on the other hand, is non-existent immediately after placement. It becomes apparent only as new bone cells form at the implant site, and it increases with time (secondary stability). [3]

In other words, as a result of osseointegration, initial mechanical stability is supplemented and/or replaced by biological stability, and the final stability level for an implant is the sum of the two. Stability does not generally remain constant after implant placement. For example, there is likely to be an initial decrease in stability followed by a subsequent increase as the implant becomes biologically stable.[35]

### Stability and various types of mobility

While implant stability is sometimes described as the “absence of clinical mobility,” in practice, a clinically mobile implant would be so obviously unstable that no responsible surgeon or dentist would consider loading it. Therefore, the absence of clinical mobility is not a useful definition for determining treatment outcome or for the purposes of this paper. [34]

In addition, an implant that is stable enough to be loaded will nevertheless not be 100% immobile. It can be rotationally mobile due to the fact that when an implant is newly placed, bone has yet to be formed and interlocked with the implant surface. With time, bone formation will lead to increased interlocking with the implant surface and a stronger implant/bone interface. [36]

An implant will also always exhibit some amount of lateral micro mobility. It is the amount of lateral micro mobility at various stages of treatment that seem to have a decisive effect on treatment outcome. Therefore when discussing the potentially positive effects of precisely determining implant-mobility levels, we refer to levels of lateral micro mobility.[36]

Objective measurement of implant stability is a valuable tool for achieving consistently good results first and foremost because implant stability plays such a significant role in achieving a successful outcome. Objective measurement of 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
- Provides better case documentation

### Supports making good decisions about when to load

When a surgeon makes a decision about early loading, objective measurement of implant stability can be invaluable: A specified degree of implant stability can serve as an inclusion criterion for immediate loading. This supposition is born out, for example, by a study by Östman, et al in which low failure rates were reported when a minimum stability level was used as an inclusion criterion for immediate loading in totally edentulous

maxillae and in posterior mandibles. vi In another study, Sjöström, et al found lower primary stability for 17 implants that failed within the first year compared to 195 implants that were successful. [37]

**Allows advantageous protocol choice on a patient-to-patient basis**

A one-step treatment protocol offers certain clear advantages for both patients and professionals alike: Fewer procedures are required and the patient will have well-functioning and attractive new teeth more quickly. However, because a two-step protocol is sometimes a better choice in higher risk situations, surgeons may avoid using a one-step protocol in all higher-risk cases (such as cases where artificial bone or bone grafts have been used). [38]

With objective measurement of implant stability, surgeons can instead make well-informed decisions about protocol choices on a case-by-case basis. In other words, when low implant stability measurements indicate that immediate loading will jeopardize treatment outcome, a two-step protocol can be applied. In cases where high implant stability measurements indicate that this is not the case, higher-risk patients will be able to enjoy the benefits of the faster, less disruptive one-step protocol. [2,3]

**Indicates situations in which it is best to unload**

Objective measurement of implant stability also supports making the right decisions about unloading. Sennerby and Meredith point out that when replacing an immediately loaded temporary prosthesis with a permanent prosthesis, “low (secondary) values may be indicative of overload and ongoing failure.” To avoid failure, they suggest that in such cases surgeons should consider unloading, perhaps placing additional implants and waiting until stability values increase before loading the permanent prosthesis. [38]

Furthermore, in a study by Glauser, et al in which all implants in a sample group were loaded, those that failed showed significantly lower stability after one month than those that were successful. The authors conclude that, “this information may be used to avoid implant failure in the future by unloading implants with decreasing degree of stability with time. [39]

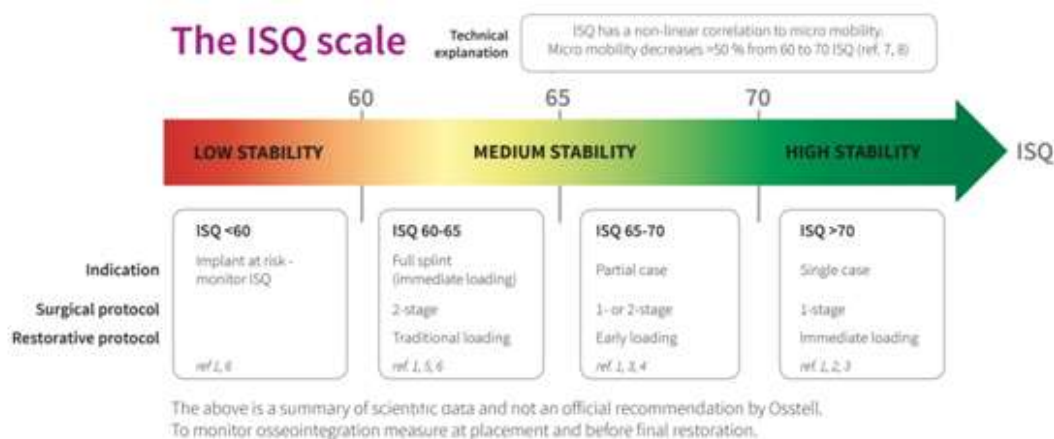


Fig.6; The ISQ Scale

**Supports good communication and increased trust**

Implant-stability measurements can also help improve communication between surgeons and referring dentists and between surgeons and patients and between dentists and patients, which in turn can increase trust in the clinicians.

When a surgeon or dentist can refer to measurable values rather than subjective judgements as the basis for decision-making, it is easier to explain treatment choices. The surgeon or dentist is also likely to appear more professional to patients and colleagues alike and to inspire more confidence. [2]

Furthermore, it would be beneficial for colleagues cooperating during the treatment process to be able to refer to objective and accurate measurements, for example, when judging when an implant is stable enough to receive a prosthesis. [3]

**Implant Stability Quotient**

The Implant Stability Quotient (ISQ) is a scale of measurement developed by Osstell for use with the Resonance Frequency Analysis (RFA) method of measuring implant stability. It is an objective standard with great potential to enhance treatment and reassure patients and professionals alike. [40]



In order to understand the promise offered by the RFA method when used with the ISQ scale, let us first take a closer look at how RFA works.

### **RFA – how does it work?**

The RFA technique is essentially a bending test of the bone-implant system in which an extremely small bending force is applied by stimulating a transducer. It is equivalent in terms of direction and type to applying a fixed lateral force to the implant and measuring the displacement of the implant. This effectively mimics clinical loading conditions, although on a much reduced scale. The RFA method can potentially provide clinically relevant information about the state of the implant-bone interface at any stage of treatment. [2,3]

Early RFA transducers were designed, based on basic principles of physics, as a simple cantilevered bar that could be screwed to an implant fixture or abutment. The bar was stimulated over a range of frequencies and the first flexural resonance of the resulting system was measured in Hz.xiv

The most recent version of RFA is wireless. 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 pulses 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 vibration is in the direction where the implant is least stable. Thus, two ISQs are provided, one higher and one lower. For example, an implant with buccally exposed threads may show one low value, reflecting the lack of bone in the buccal-lingual direction, and one high value, reflecting good bone support in the mesial-distal direction.[40,41]

### **The concept of ISQ**

The Implant Stability Quotient is a nearly linear mapping from resonance frequency measured in kHz to the more clinically useful scale of 1-100 ISQ. The higher the ISQ, the more stable the implant. Fig.6

ISQ was originally defined by a set of calibration blocks with varying degrees of stability. Today, different implants require different transducers (Smartpegs), but all Smartpegs show comparable ISQ values for the same degree of stability, even when implants from different systems are measured. This is achieved by fine-tuning the geometric design of each new Smartpeg type by comparing its ISQ with already existing Smartpegs.

### **The importance of ISQ**

The development of ISQ makes it possible to determine a standard clinical range within which stability values should fall to achieve a successful treatment outcome. The studies mentioned in Chapter 4 of this paper (Sennerby and Meredith; Östman, et al; Sjöström, et al and Glauser, et al) were based on measurements made with RFA and ISQ. These and other studies provide good indications that the acceptable stability range lies between 55 and 85 ISQ, with an average ISQ level of 70.

ISQ also makes it possible to attach specific values to the graph from making it a useful tool for determining if an implant is sufficiently stable at any stage of the treatment process.[40,41,42]

### **ISQ used with RFA:**

- Supports making good decision about when to load[9,10]
- Allows advantageous protocol choice on a patient-to-patient basis.[12,14,15]
- Indicates situations in which it is best to unload[16]
- Supports good communication and increased trust[9,10,16]
- Provides better case documentation[15]

## **II. Conclusion**

To date no definite method has been established to measure implant stability accurately with fair amount of reliability. Though, clinical measurement of implant stability can be evaluated with resonance frequency analysis with fair amount of predictability. The theoretical basis of resonance frequency analysis is based on sound foundation; still there are uncertain issues such as critical value that can suggest success or failure of a particular implant system. Hence, further research is needed to establish higher reliability of the currently discussed methods.

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