

The Implant Stability Quotient Whitebook

The relationship between reliable diagnostics
and safe, successful dental implant procedures

1st edition



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Executive summary

This paper will help you understand how reliable diagnostics in the form of objective measurement of implant stability will help surgeons and dentists establish safe and successful dental implant procedures under a wide range of clinical conditions.

It touches upon the history of dental implants and considers relevant trends and developments. It examines factors that influence treatment outcome, and it defines implant stability and looks at its crucial role in determining successful treatment outcome. It explores specific clinical benefits of measuring implant stability. It looks at various methods of measuring implant stability, and it explains why the Resonance Frequency Analysis (RFA) method is the measurement method of choice. It also examines how the Implant Stability Quotient (ISQ) developed by Osstell makes it possible to take full advantage of RFA.

Additional information about ISQ is available at www.implantstability.com.

Foreword

By PROFESSOR LARS SENNERBY, DDS, PHD

Dear Colleague,

The introduction of osseointegrated implants revolutionized dentistry. But the early treatment protocols prescribed by Brånemark in Sweden and Schroeder in Switzerland were rigorous with regard to patient selection and clinical techniques. A healing period was invariably used prior to the prosthetic treatment and loading of the implants. Stringent and sometimes ceremonial protocols were of the utmost importance to strict evaluation of the clinical outcomes of osseointegrated implants and to identifying risk factors.

More than 40 years later, we've seen many improvements in osseointegration technique with regard to implant and prosthetic components as well as clinical and diagnostic techniques. It has been my privilege as a scientist and clinician to personally experience some of the advances over the last 25 years. For example, today, practically any patient can be treated with dental implants, although some may need pretreatment with a bone augmentation procedure. Another major advance is the use of immediate or early loading protocols, which dramatically reduces overall treatment time.

Placement of implants in biologically challenging situations, however, places more demand on the clinician's ability to objectively evaluate the situation and diagnose implant stability. When exactly is an implant safe to load? Can implants at risk for failure be identified after surgery and during premature loading?

Some 15 years ago, I met Dr Neil Meredith at the Eastman Dental Hospital in London. He demonstrated a novel invention for measuring implant stability based on vibration engineering and resonance frequency analysis (RFA). The device involved a transducer that was attached to the implant in question. Based on preliminary in vitro studies, it was quite clear that the technique offered great potential for development into a non-invasive diagnostic method for clinically measuring implant stability and osseointegration.

However, the technique had yet to be evaluated in vivo in animals and patients. Therefore, it was agreed that Dr Meredith would spend a year as part of our department at the University of Gothenburg working on this. Prototypes were evaluated and used in various clinical studies in the Brånemark Clinic in Gothenburg, eventually resulting in Dr Meredith's second PhD thesis, which he defended in 1997.

A grant from the European Commission that same year made it possible to improve the instrument technically and to involve clinicians in the UK, Sweden, Spain and Italy in a multi-center demonstration project. The goal of the project was to develop the RFA prototype device into a commercially available instrument.

Over the years, the RFA method has matured and acquired its own dedicated measurement unit: ISQ – Implant Stability Quotient. Numerous scientific articles have been published and ISQ has become a standard parameter in many investigations. The literature shows clearly that ISQ measurements provide clinically relevant information about implant stability at any point of time during or after implant treatment.

It is my belief that the role of ISQ measurement in implant dentistry is self-evident in much the way that the roles of radiography and other long-used diagnostic techniques are self-evident in conventional dentistry.

Professor Lars Sennerby, DDS, PhD



Dental implants: History, trends and developments

The discovery of osseointegration by a young Swedish scientist more than half a century ago led directly to the invention of the functional dental implant. Since then, lasting functionality, good aesthetics and improved quality-of-life for patients have consistently been associated with this solution. Nevertheless, a strong case can be made that improved diagnostic techniques are necessary to maintain a high level of treatment quality and consistently positive results.

Progress driven by parallel needs

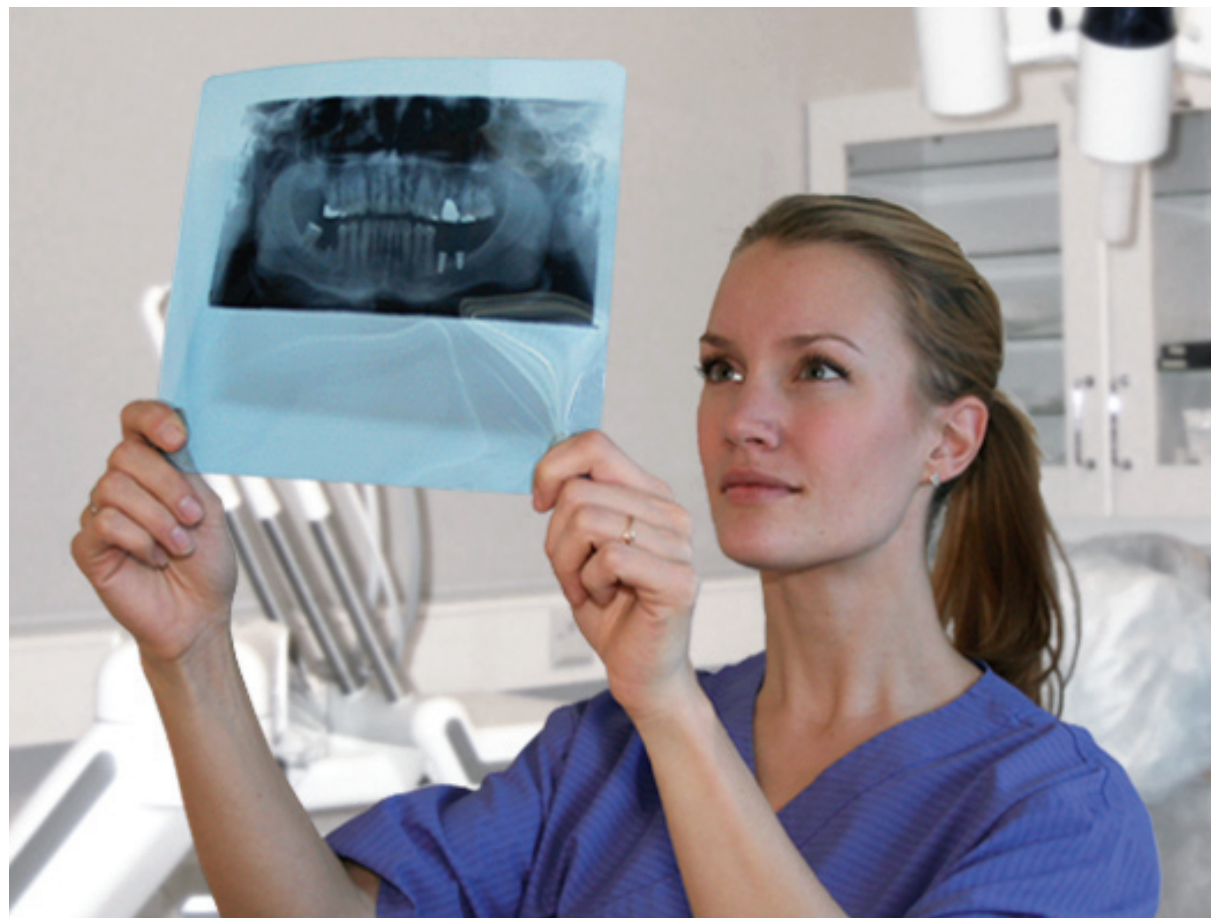
Over the years, there have been many developments in the field of implant dentistry, spearheaded by companies like Astratech, Biomet, Dentsply, Nobel Biocare, Straumann and Zimmer. Examples include implant surfaces that integrate faster, innovative designs that make it easier to achieve high stability and the development of artificial bone material. Together these put implants in reach for more patients. New surgical methods have also been developed, such as sinus-lift surgery, flapless surgery and one-stage protocols. In addition, as implants gain wide acceptance, the number of surgeons offering them continues to increase.

Much of the progress has been driven by patient need: people want well-functioning, good-looking teeth, and they want them as soon as they can possibly have them. The implant industry's own desire to create better products that not only improve treatment, but also increase profitability, has been another important driver. New products and methods have made implants a realistic choice for more patients (such as those with poor bone quality or volume).

Progress brings improvement – and new challenges

Change brings improvement, but it has also brought new challenges. Steady replacement of the traditional two-step protocol with a new one-step protocol is an example of a development that offers improved treatment possibilities while simultaneously raising the bar for achieving good results.

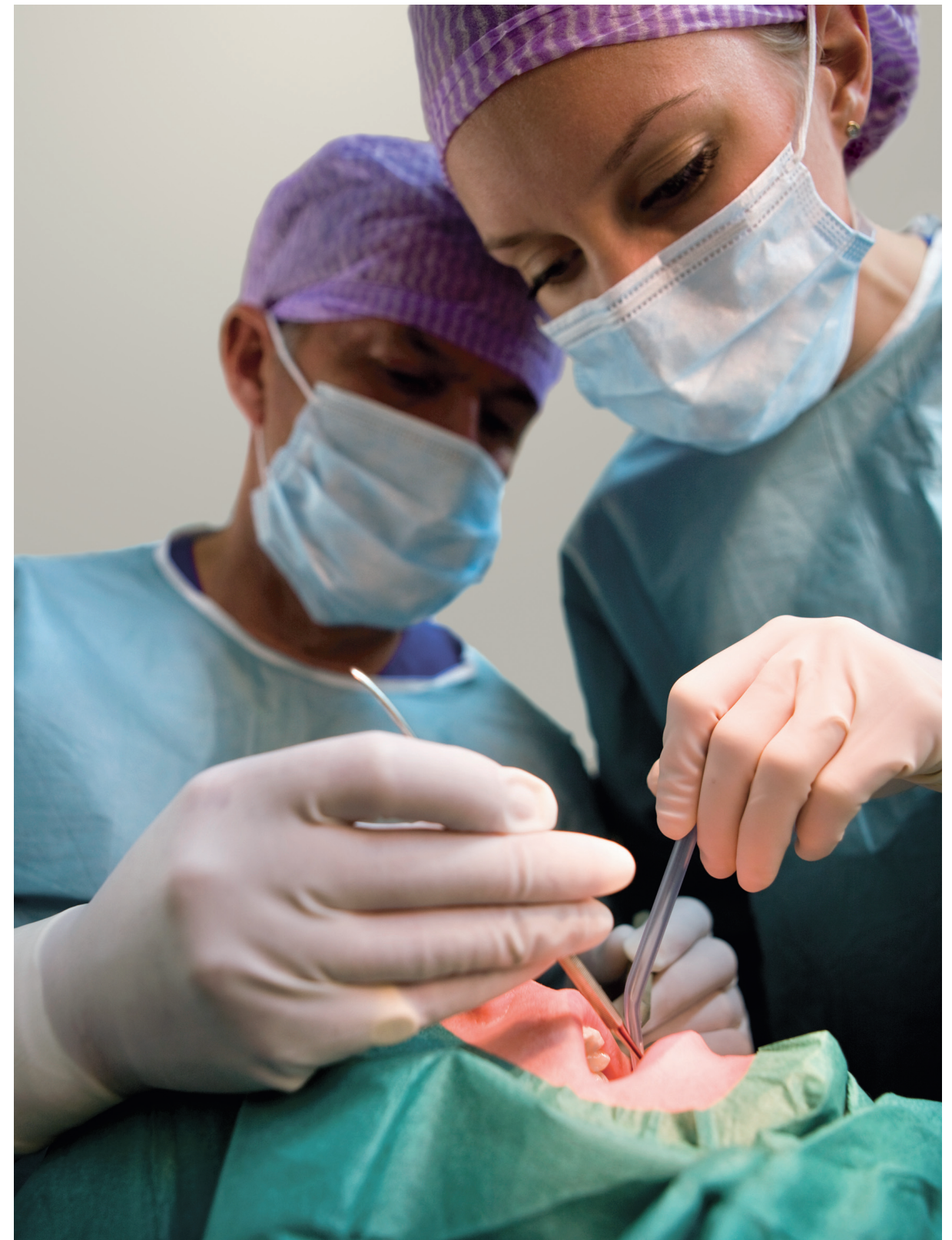
The increasingly common use of artificial bone and bone grafts (for instance) are similar examples. They make it possible to provide the benefits of dental implants to people who may not previously have been candidates for the treatment. At the same time, however, they increase the number of higher-risk patients.



Better diagnostics for reliable quality and safety

New developments clearly fulfil demand for faster, less disruptive treatment options for more patients. In the vast majority of cases, they have been proven safe and effective. They also allow more dentists to treat more patients and to increase per-patient earnings. However, questions remain about how to achieve reliable quality and safety in a one-step protocol, in more complicated treatment cases and for less-experienced surgeons.

This paper explores how better diagnostics in the form of objective measurement of implant-stability levels can help clinicians to provide safe and predictable implant procedures for all patients.



Factors that influence treatment outcome

It has been clinically demonstrated that implant stability plays a significant role in determining treatment outcome. ^{i,ii} Implants show high success rates if certain preconditions are fulfilled. ⁱⁱⁱ

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.

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.

Patient parameters

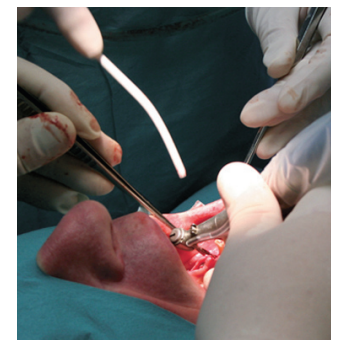
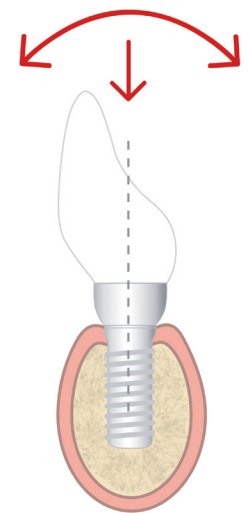
The single most significant patient parameter is bone quality. Risk factors associated with bone quality include the presence of transplanted bone, irradiated bone and soft bone. All of these conditions are increasingly common as more patients are given the option of being treated with dental implants.

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.

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.



What is 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.
2. Biological stability, which is the result of new bone cells forming at the site of the implant and osseointegration.

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.

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).

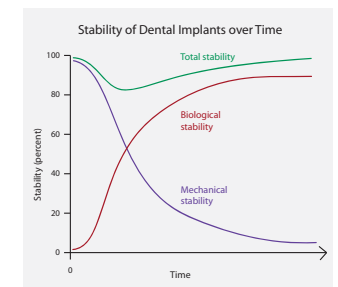
In other words, as a result of osseointegration, initial mechanical stability is supplemented and/or replaced by biological stability, and the final stability level for an implant is the sum of the two. Stability does not generally remain constant after implant placement. For example, there is likely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

Stability and various types of mobility

While implant stability is sometimes described as the “absence of clinical mobility,”^{iv} 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.

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.

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.



Graph showing implant stability over time

Why measure implant stability?

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.^{vii}

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).

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.

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.^{viii}

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.”^{ix}

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.

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.

Provides better case documentation

Finally, objective implant stability measurements can be used to document the clinical outcome of implant treatments, which can be useful at a later stage if a problem should occur.

How is implant stability measured?

While objective measurement of implant stability clearly offers important advantages, the answer to the question of how to best obtain such measurements has perhaps been less obvious. Over the years a number of methods have been used to measure implant stability with varying degrees of success:

The surgeon's perception

One method of trying to evaluate primary stability is quite simply the perception of the surgeon. This is often based on the cutting resistance and seating torque of the implant during insertion. A perception of "good" stability may be heightened by the sensation of an abrupt stop when the implant is seated. The geometry of an implant with a fixed collar creates just such a firm stop and thus lends itself to a perception of high stability.^x

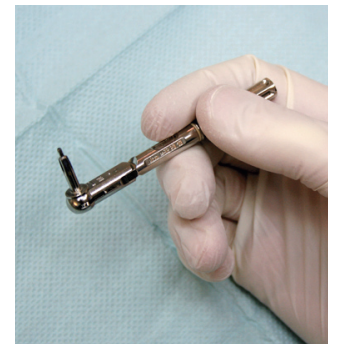
An experienced surgeon's perception is of course invaluable and should under no circumstances be discounted. However, perception is obviously not possible to quantify, to consistently and effectively teach to others or to use as a basis for future comparison. Particularly in higher-risk cases, relying on perception is often not sufficient to ensure a positive treatment outcome. In addition, one's personal perception is difficult to communicate to others. But most importantly, this type of measurement can only be made when the implant is inserted – it cannot be used later, for example, before loading the implant.

Insertion torque

Measuring insertion torque when 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, the method does yield some information about the energy used when installing the implant. Its main disadvantage is that, like the surgeon's perception, 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

Like insertion torque, the final seating torque gives some information about the primary stability of the implant. The main disadvantage is that it cannot be repeated at a later stage, and thus it cannot serve as a reference for the next treatment



A torque wrench in a clinician's hand

stage. Seating torque can also be misleading in a case of high final torque caused by the top or the apical part of the implant hitting cortical bone.

Percussion testing

Percussion testing is a tool-based method for testing implant stability. This method involves tapping the implant carrier with a tool, such as a mirror handle, and listening for a (“good”) ringing tone. There are also electronic devices for this purpose, such as Periotest or the Dental Mobility Checker. This type of test is highly subjective and has largely been discredited. As pointed out by Sennerby and Meredith, percussion testing: “... probably provides more information about the tapping instrument and at best yields only poor qualitative information.”^{xi} The disadvantages of the electronic percussion tests are that they are rather insensitive to changes in implant stability and the results are user-dependent.

Reverse torque testing

Application of reverse torque has been used to assess secondary implant stability at the abutment connection. Implants that rotate when reverse torque is applied are removed. However, this method has fallen into disrepute for a number of reasons: As demonstrated in one study, the stress of the applied torque may in itself be responsible for the failure.^{xii} In addition, work with animals has demonstrated reintegration of loosened and rotationally mobile implants.^{xiii}

Finally, as we point out in Chapter 5 of this paper, 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 reverse torque testing fails to measure – or take into account – lateral mobility.

Radiographs

Radiographic evaluation is a semi-invasive method that can be performed at any stage of healing. Radiographs can yield other information such as implant position, but neither implant stability, bone quality or bone quantity can be determined with this method. Even changes in bone mineral cannot be radiographically detected until several months have passed and until 40% of demineralisation occurs.



The torque wrench in use

Resonance frequency analysis

Resonance Frequency Analysis is a testing method that provides objective and reliable measurements of lateral micro-mobility at various stages of the implant process. The method analyzes the first resonance frequency of a small transducer attached to an implant fixture or abutment. The measurement unit is ISQ. While potentially both objective, accurate and useful, this method has nevertheless traditionally suffered from some drawbacks.

One early drawback with the transducer was that it was sensitive to the stability of the implant, in the direction it was mounted. Since the transducer could be mounted in any direction if there is enough space for it and since the stability was different in different directions, the result could vary if the transducer was mounted in a different direction. The original transducer has now been replaced by a multidirectional version. Other recent developments have mitigated the other drawbacks.

In the following chapter, we will describe exactly how ISQ works and examine its usefulness as a diagnostic tool.



What is the 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.

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. (Fig 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.

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.



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.

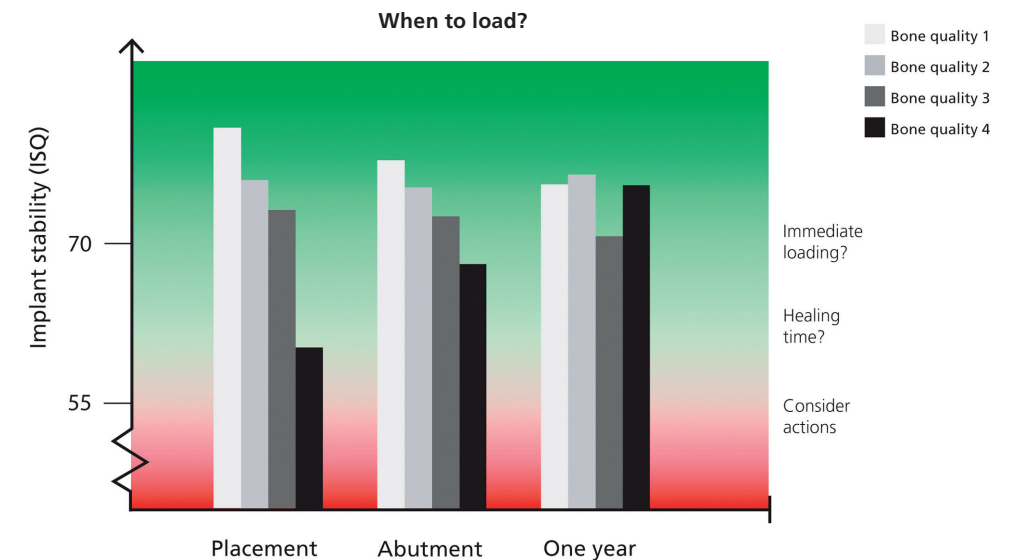
The importance of ISQ

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 Chapter 3, making it a useful tool for determining if an implant is sufficiently stable at any stage of the treatment process.

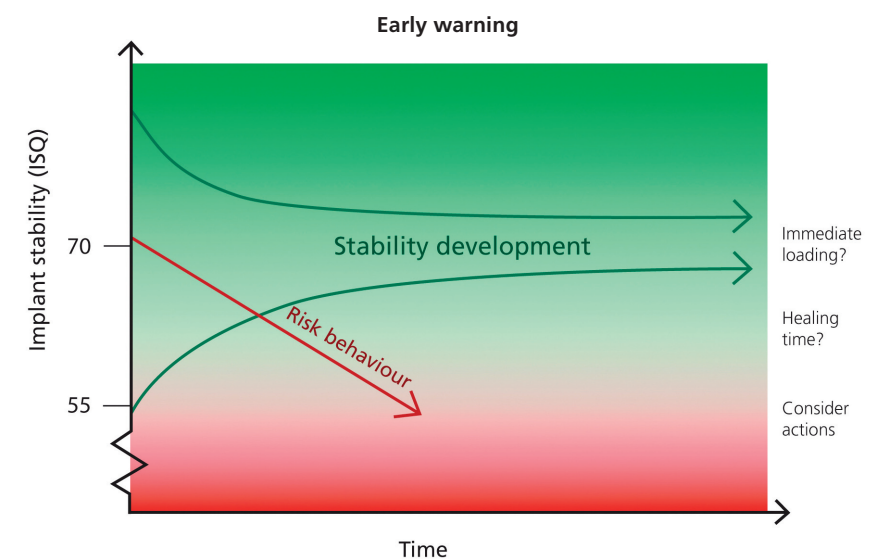
ISQ used with RFA:

- Supports making good decision about when to load
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*High initial stability (ISQ values of 70 and above) tends not to increase over time despite the fact that the initial high mechanical stability decreases and is replaced by increased biological stability. Lower initial stability normally increases with time because the lower mechanical stability is increased by the bone remodeling process (osseointegration). Values of ISQ 55 or lower should be taken as a warning sign and actions to improve the stability should be considered (larger implant diameter, longer healing time, etc.)**

** Implant stability measurements using Resonance Frequency Analysis. Biological and biomechanical aspects and clinical implications. Periodontology 2000, 2008. Sennerby & Meredith*



The overall average value of all implants over time is approximately 70 ISQ. If the initial ISQ value is high, a small drop in stability normally levels out with time. A big drop in stability or a continuing decrease should be taken as a warning sign. Lower values are expected to be higher after the healing period. The opposite could be a sign of an unsuccessful implant and actions should be considered.

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