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Implant Stability - Measuring Devices and Randomized Clinical Trial for ISQ Value Change Pattern Measured from Two Different Directions by Magnetic RFA

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1. Introduction

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 (Bränemark, et al. 1977, Sennerby & Roos 1998). 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. 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 (Meredith 1998).

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 (Sennerby & Roos 1998). 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 (Atsumi, et al. 2007).

2. Measuring analyses of implant stability

Presently, various diagnostic analyses have been suggested to define implant stability. Primary implant stability can be measured by either a destructive or a non-destructive method. Histomorphologic research, tensional test, push-out/pull-out test and removal torque test are classified as destructive methods. Non-destructive methods include percussion test, radiography, cutting torque test while placing implants, Periotest® (Siemens AG, Bensheim, Germany), and resonance frequency analysis (RFA) (Meredith 1998).

2.1 Tensional test

The interfacial tensile strength was originally measured by detaching the implant plate from the supporting bone (Kitsugi, et al. 1996). Bränemark later modified this technique by applying the lateral load to the implant fixture (Bränemark, et al. 1998). However, they also addressed the difficulties of translating the test results to any area-independent mechanical properties (Chang, et al. 2010) (Fig. 1a).

2.2 Histomorphometric analysis

Histomorphometric analysis is obtained by calculating the peri-implant bone quantity and bone-implant contact (BIC) from a dyed specimen of the implant and peri-implant bone. Accurate measurement is an advantage, but due to the invasive and destructive procedure, it is not appropriate for long-term studies. It is used in non-clinical studies and experiments.

2.2 Push-out/pull-out test

The 'push-out' or 'pull-out' test is the most commonly used approach to investigate the healing capabilities at the bone implant interface (Brunski, et al. 2000). In the typical push-out or pull-out test, a cylinder-type implant is placed transcortically or intramedullarly in

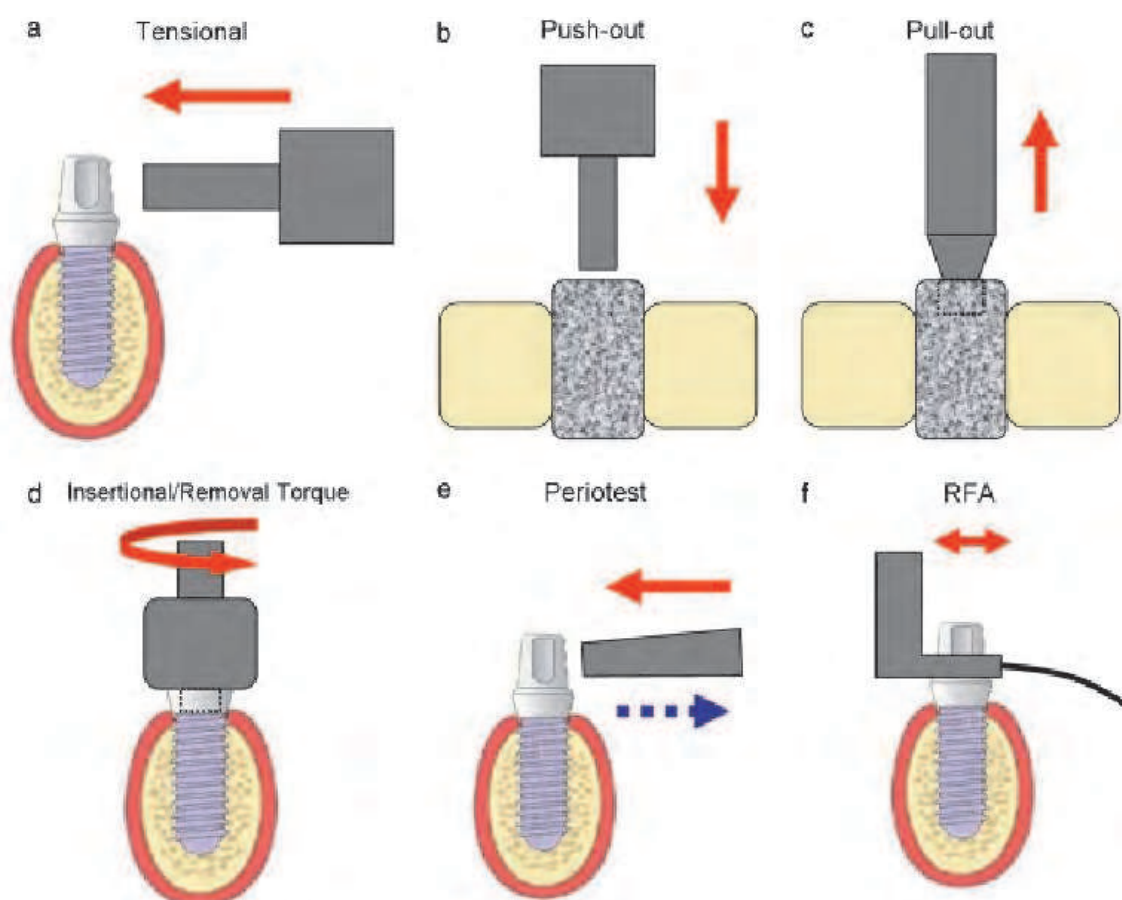


Fig. 1. Stability analyses for oral implant osseointegration from Chang, P. C., Lang, N. P. & Giannobile, W. V. (2010). "Evaluation of functional dynamics during osseointegration and regeneration associated with oral implants." *Clinical Oral Implants Research* 21: 1-12. (a) tensional test, (b) push-out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

bone structures 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 plot, and the interfacial stiffness is visualized as the slope of a tangent approximately at the linear region of the force-displacement curve before breakpoint (Brunski, et al. 2000, Lutolf, et al. 2003). Therefore, the general loading capacity of the interface (or interfacial shear strength) can be measured by dividing the maximum force by the area of implant in contact with the host bone (Berzins, et al. 1997). However, the push-out and pull-out 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 (Brunski, et al. 2000, Chang, et al. 2010) (Fig. 1b-c).

2.3 Removal torque analysis

Application of a reverse or unscrewing torque has also been proposed for the assessment of implant stability at the time of abutment connection (Sullivan, et al. 1996), however, implant surface in the process of osseointegration may fracture under the applied torque stress (Ivanoff, et al. 1997) (Fig. 1d).

2.4 Percussion test

The test is carried out by a simple percussion with the handle of a dental instrument on the implant abutment and listening to the resulting sound. However, this method may be subjective according to the examiner and give inaccurate measurements for implants because of the high rigidity of implants and the lack of periodontal ligaments.

2.5 Insertion torque measurement

Insertion torque values have been used to measure the bone quality in various parts of the jaw during implant placement (O'Sullivan, et al. 2004). Insertion torque alone may be used as an independent stability measurement, but it may also act as a variable, affecting implant stability. In a different light, insertion torque is a mechanical parameter generally affected by surgical procedure, implant design and bone quality at implant site (Beer, et al. 2003). However, it cannot assess the secondary stability by new bone formation and remodeling around the implant. So it cannot collect longitudinal data to assess implant stability change after placement. Also, an increase in insertion torque may signify an increase in primary stability, but maximum insertion torque is produced by the pressure of implant neck on the dense cortical bone of the alveolus. Furthermore, it has been reported that if maximum insertion torque doesn't signify increased general bone density, it may indicate the insertion torque itself during tapping (Calandriello, et al. 2003) (Fig. 1d).

2.6 Radiography

Radiography provides useful information for evaluating the quantity and quality of bone in the area for an implant before placing the fixture. It is also helpful in predicting implant stability by observing the process of osseointegration or peri-implant lesions. However, there is a limitation in image resolution and standardized X-rays are difficult to achieve due to the distortion of images, making quantitative measurements more challenging. In addition, it is difficult to perceive changes in the bone structures and morphology of the implant-bone interface unless over 30% bone loss occurs. Although the accuracy of the

diagnosis is low, radiography is the major method used clinically to evaluate osseointegration and implant stability because of its convenience. (Albrektsson, et al. 1986).

2.7 Periotest®

Periotest® (Siemens AG, Bensheim, Germany) was originally devised by Dr. Schulte to measure tooth mobility (Fig.2). Teerlinck, et al.(1991) used this method to overcome destructive methods in measuring the implant stability. Periotest® evaluates the damping capacity of the periodontium. It is designed to identify the damping capacity and the stiffness of the natural tooth or implant by measuring the contact time of an electronically driven and electronically monitored rod after percussing the test surface. Periotest value (PTV) is marked from -8 (low mobility) to +50 (high mobility). PTV of -8 to -6 is considered good stability.

Periotest® can measure all surfaces such as the abutment or prosthesis, but the rod must make contact at a correct angle and distance. 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 0.6-2.0mm distance and if the distance is over 5mm, the measured value may be insignificant. (Ito, et al. 2008, Schulte 1988). Periotest® has limited clinical use since it cannot measure the mesiodistal mobility and the position and angle of the rod affects the measured value. Also, it cannot detect the small changes in the implant-bone surface. The most failing point of this method is that the percussing force on the implant may deteriorate the stability in poor initial stability implants.



Fig. 2. Periotest® (Siemens AG, Bensheim, Germany) measures tooth mobility and implant stability by periotest value (PTV). (a) Periotest®, (b) Periotest®M.

2.8 Resonance Frequency Analysis (RFA)

In 1998, Meredith suggested a non-invasive method of analyzing peri-implant bone by connecting an adapter to an implant in an animal study. The experimented resonance frequency analysis system was commercially produced as Osstell™ (Osstell AB, Göteborg, Sweden).

A measurement of Osstell™ is displayed as implant stability quotient (ISQ) from 1 to 100, where 100 signifies the highest implant stability. Osstell™ was later followed by Osstell™ Mentor, and Osstell™ ISQ.

3. RFA principle and application

3.1 Introduction

Meredith et al.(1996) reported the use of resonance frequency analyzer to evaluate implant stability by applying architectural engineering, and proved in early in vitro test the ability of the device in evaluating the stiffness change of the surface. RFA uses the principle of when a frequency of audibility range is repeatedly vibrated onto an implant, the stronger the bone-implant surface, resonance occurs in a higher frequency. The first commercial product of the resonance frequency analyzer(RFA) was Osstell™(Osstell AB, Göteborg, Sweden)(Fig.3), followed by Osstell™ Mentor and recently Osstell™ ISQ was introduced. Osstell™ uses electronic technology and other devices(Osstell™ Mentor, Osstell™ ISQ) use magnetic technology (Fig.5).

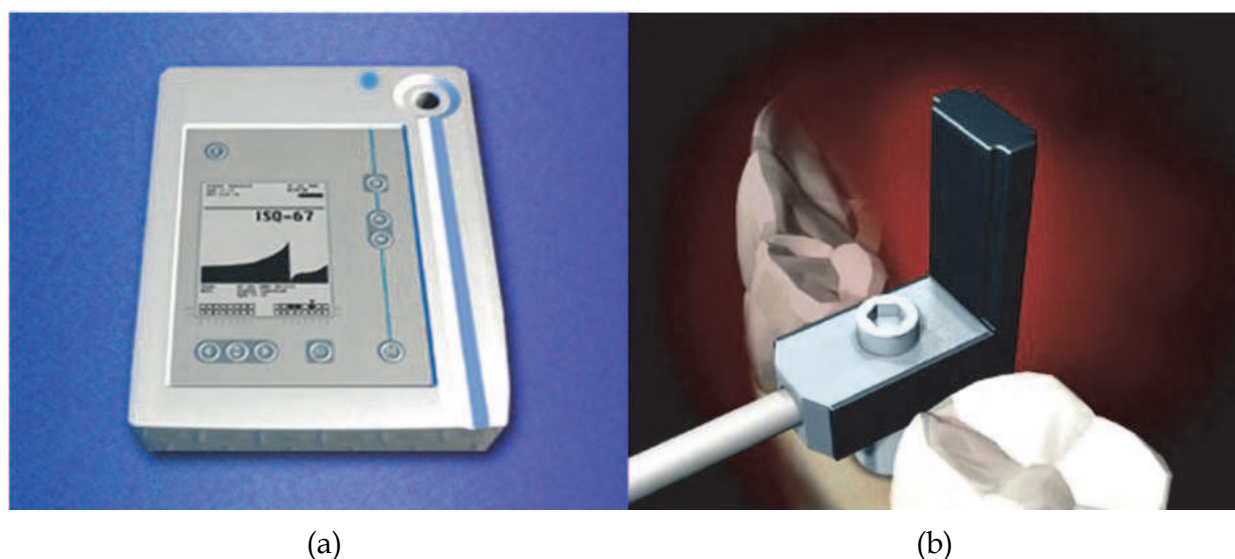


Fig. 3. Pictures showing the first commercial products of resonance frequency analyzer. (a) the Osstell™ and (b) the application of the Osstell™ electronic transducer to the implant.(The figure and illustration are cited with permission from Osstell website, www.osstell.com, April, 2011)

3.2 Electronic technology resonance frequency analyzer(Osstell™)

The primary model Osstell™ produces alternating sine waves in a specific frequency range by uniform amplitude and makes the transducer connected to the implant or abutment vibrate under 1mm like an electronic tuning fork. A cantilever small beam is connected to the transducer and on this beam, 2 piezo-ceramic elements are attached. (Fig.3,4). One of them receives the signal and vibrates the transducer, and the other passes this vibration to the resonance frequency analyzer. Values on the monitor are displayed from 0-100 so that it can be conveniently used clinically. The value of 100 signify the highest stability state. Generally ISQ values for successfully integrated implants are reported from 57 to 82. These values can be displayed by graphs on the computer monitor or be expressed by values between 4500-8500Hz. The obtained output can be calculated by the equation below.

$$fn = \alpha \sqrt{\frac{EI}{\rho l^4}}$$

fn is the RF of the beam, l is the effective vibration length of the beam, E is the Young's modulus, I is the moment of inertia, ρ is the mass, α the constant that increases as peri-implant bone density increases. Therefore, when osseointegration is achieved, RF increases since α value increases. 'l' signifies the length of implant above the bone. So as bone is resorbed, this value increases and thus RF decreases. In other words, ISQ is affected by the effective implant length, type of bone at implant site and bone density(Huang, et al. 2003, Huang, et al. 2003, Meredith, et al. 1996).

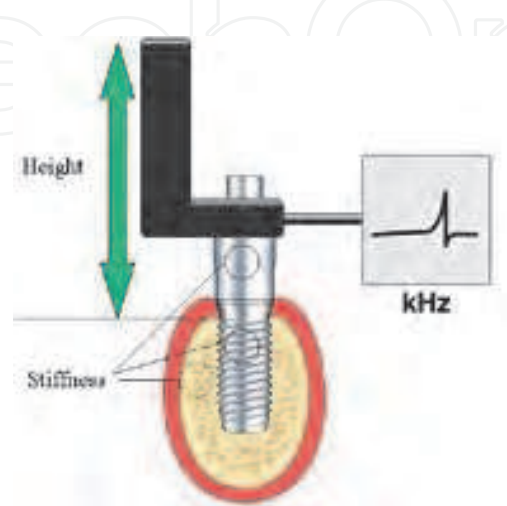


Fig. 4. Picture showing the principle of electronic resonance frequency analyzer. (The figure and illustration are cited from Osstell website, www.osstell.com, April, 2011)

3.3 Magnetic technology resonance frequency analyzer(Osstell™ Mentor, Osstell™ ISQ)
Resonance frequency between 3.5 KHz and 8.5 KHz formed from the magnetic field is converted into ISQ values by Osstell Mentor™(Fig. 5, 6). The transducer of Osstell Mentor™



Fig. 5. Osstell Mentor™ and Osstell ISQ™, both of devices measure ISQs by the magnetic technology. (The pictures are cited from Osstell website, www.osstell.com, April, 2011)

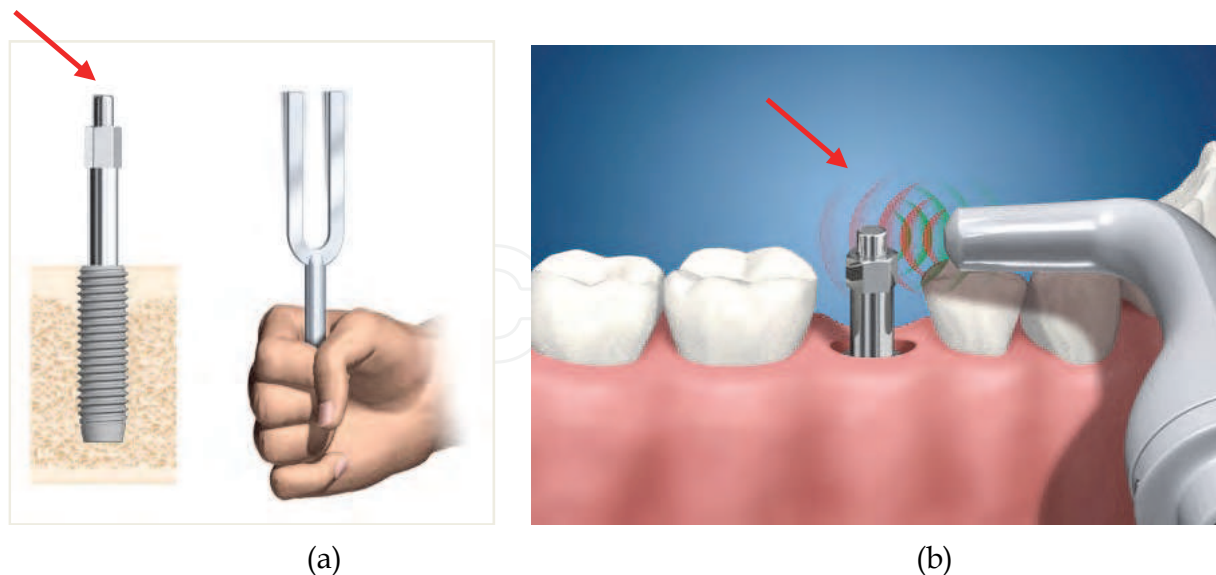


Fig. 6. Principle of the Osstell Mentor™. Magnetic peg(Smart peg™) works like a tuning fork. Red arrow is the Smart peg™. (The figure and illustration are cited from Osstell website, www.osstell.com, April, 2011)

has a magnetic peg on the top and is fixed to the implant fixture or abutment by a screw below. When magnetic resonance frequency is released from the probe, the magnetic peg is activated. The activated peg starts to vibrate, and the magnet induces electric volt into the probe coil and the electric volt is sampled by the magnetic resonance frequency analyzer (Fig. 6). The values are expressed as numbers between 1-100 in ISQ as Osstell™ (Valderrama, et al. 2007).

The device is relatively expensive, and each implant system requires the respective transducer for Osstell™ and magnetic peg for Osstell Mentor™. The restricted use of the transducer and the magnetic peg is a great disadvantage. Also, evaluation is impossible in a prosthesis state or when the magnetic peg is damaged or when in contact with the soft tissue. Therefore, when using Osstell Mentor™, the Smart peg™ must maintain a distance of approximately 1-3 mm, angle of 90 degrees, and 3 mm above the soft tissue, otherwise the measured value may be affected (Fig. 7). Valderrama et al.(2007) reported in a study experimenting the correlation between Osstell™ and Osstell Mentor™ that the two devices had high significant correlation.

3.4 Influencing factors of Implant Stability Quotient(ISQ)

In many literature, it has been reported that ISQ is affected by implant diameter, surface, form, bone contact ratio, implant site, implant system, surgical procedure, bone quality and bone height (Atsumi, et al. 2007). RFA is determined by the changes in the interface stiffness, and it is affected in three aspects. First, bone-implant surface stiffness affects RFA and it increases through bone healing and remodeling. Secondly, the stiffness of bone itself, and bone density as well as the ratio of cortical and cancellous bone affects RFA. Finally, the stiffness of implant components can acts as a variable and it is affected by the interlocking structures, and the composing elements of the materials. Bone and implant surface stiffness may be affected by using a small-diameter final drill, changes in surgical techniques such as

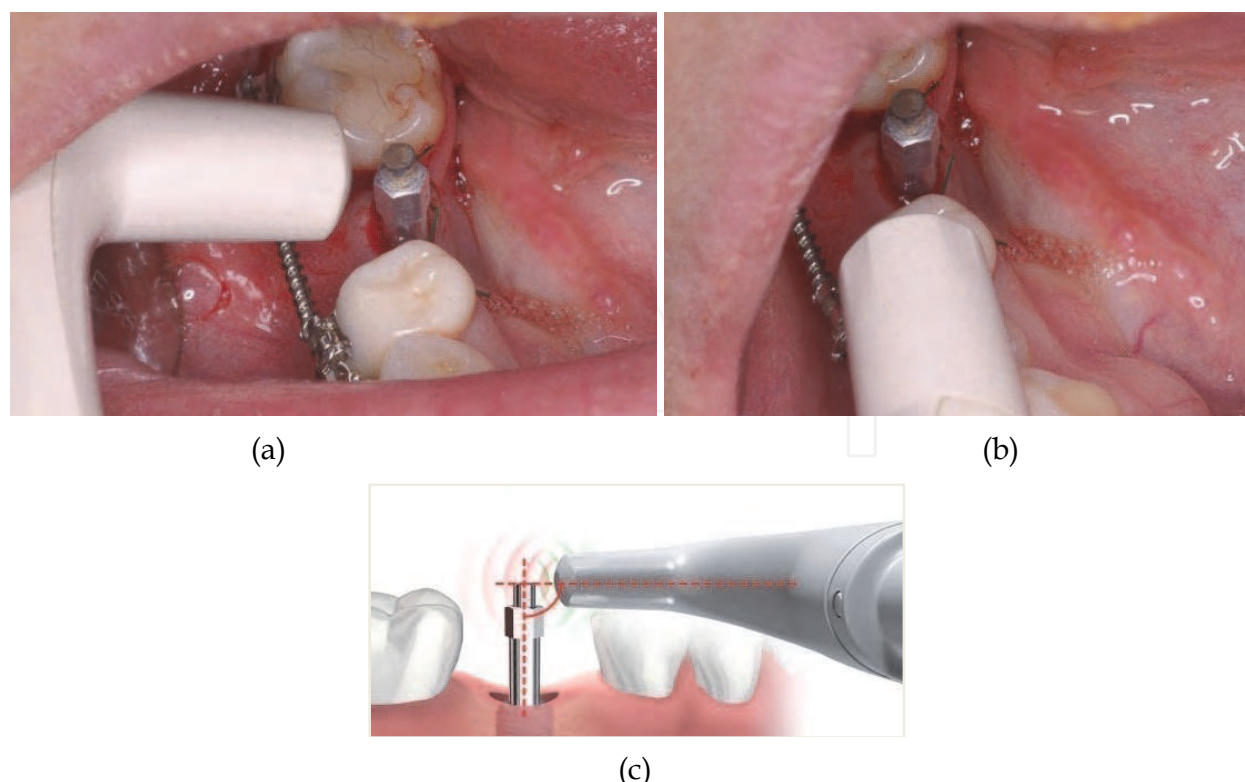


Fig. 7. Application of magnetic RFA (Osstell™ Mentor) after immediate implant installation. The manufacturer recommends that the probe be held perpendicular to the alveolar crest (a) for the first measurement, and in line with the crest for the other measurement (b). And the Smart peg™ must maintain a distance of approximately 1-3 mm, angle of 90 degrees, and 3 mm above the soft tissue (c).

bone compaction technique, self-tapping design implants and wide tapered implants, but not by implant length. In a histomorphologic study, it was reported that the resonance frequency value is highly correlated with the bone-implant contact amount (Friger, et al. 1999, Meredith, et al. 1997). There are reports showing a correlation between RFA and the histomorphometric analysis, and other reports claim that the correlation between the bone density and ISQ is not significant. Therefore RFA signifies the bone anchorage of implants but the relation of RFA and bone structure is not yet clear (Alsaadi, et al. 2007, Huwiler, et al. 2007, Rasmusson, et al. 1998, Zhou, et al. 2008). Such diverse results showed RFA value decreases during the first 2 weeks after implant placement, and this change can be related to early bone healing such as biological change and marginal alveolar bone resorption. Bone remodeling reduces primary bone contact and in the early stage after implant placement, the formation of bony callus and increasing lamellar bone in the cortical bone causes major changes in bone density. Thus, in the healing process, primary bone contact decreases and secondary bone contact increases (Barewal, et al. 2003, Zhou, et al. 2008). Also, the 3-dimensional implant-bone contact is displayed 2 dimensionally in the histological sample and BIC has possibility of inaccuracy to signify bone-implant contact (Perrotti, et al. 2010). The relationship of bone structure and RFA is not fully understood. Since primary stability is affected by bone volume or bone trabecula structure as well as cortical bone thickness and density, the effect of bone quality on implant stability cannot be explained by bone microstructure alone (Huwiler, et al. 2007).

4. Which device is more accurate to determine the stability of dental implants
- recent literature review

There are two groups of non-invasice devices. One is the RFA analyzer group and the other is the mobility measuring device. The Osstell™ is the commercial name of the RFA analyzer group. This device has a cable which is linked a electronic transducer (Fig. 3). The later version of the Osstell™ is the Ossetell™ mentor which has no cable and uses of magnetic resonance frequency (Fig. 5). Periotest® is the commercial name of the mobility measuring device. Periotest® M is the newer device of the Periotest® and it is a wireless version (Fig. 2).

4.1 PTV and ISQ

Many studies have indicated the presence of correlation between PTVs(the values of Periotest®) and ISQ (the values of Osstell™ and Ossetell™ mentor). However, the correlation of implant stability and each value are still the controversial issue. Aparicio et al. (2006) presentd that the validity and relevance of both ISQ and PTVs for clinical use have to be questioned in their review article. Lachmann et al. (2006) compared Osstell™ and Periotest® by in vitro study and demonstrated that both methods are useful in the evaluation of implant stability but the Osstell™ was more precise than the Periotest® to determine the actual dental implant stability at peri-implant defects. Zix et al. (2008) studied with controlled clinical trial and concluded that Periotest® values appear to be more susceptible to clinical conditions and the Osstell™ instrument seemed to be more precise than the Periotest®. Winter et al.(2010) investigated the correlation between the two devices through the finite element study and demonstrated that Periotest® values had only good correlation with implant stability in case when there’s no bone loss. Oh et al.(2009) reported that the Periotest® and Osstell™ Mentor were useful and comparably reliable, showing a strong association with each other in assessing implant stability in their experimental study. In summarizing the literature, it is generally accepted that the RFA is more accurate than the mobility measuring device, but the mobility measuring device is more convenient in clinical usage than RFA (Fig.8).



Fig. 8. Application of Periotest® M. This device can measure the implant stability and mobility of natural teeth without special device, for example magnetic peg. (a) is the application of Periotest® M to natural tooth. (b) is the measurement of implant stability during follow-up period without implant crown removal.

4.2 Electronic resonance frequency and magnetic resonance frequency

Valderrama et al.(2007) performed clinical research using electronic- and magnetic-based devices on 34 non-submerged titanium dental implants in 17 patients and demonstrated that changes in implant stability measured with the magnetic device correlate well with those found with the electronic device. Both devices confirmed the initial decreases in implant stability that occur following placement and identified an increase in stability during the first 6 weeks of functional loading. Tozum et al.(2010) compared three devices which are RF with cable, RF wireless and wireless mobility measuring device using 30 dental implants in human dried cadaveric mandibles. The authors demonstrated that both RF with cable and RF wireless seem to be suitable to detect peri-implant bone loss around implants. But wireless mobility measuring device may not be suitable to detect the 1 mm peri-implant bone changes.

5. ISQ change pattern measured at different direction using magnetic RFA

Data from a conventional piezoelectric RFA are generally obtained with the transducer in the buccolingual position, because the shape of the transducer restricts its orientation when adjacent teeth remain. The measurement of the stiffness of the bone/implant complex in one direction by the use of piezoelectric RFA reflects the stability of an implant only partially, because implant-bone fusion occurs at 360° around a fixture and implant stability is a general reflection of this fusion. According to studies that used piezoelectric RFA, the ISQ of the mesiodistal(MD) measurement was 10 points higher than that of the buccolingual(BL) measurement(Fischer, et al. 2008, Veltri, et al. 2007). Unlike piezoelectric RFA, magnetic RFA(Mentor™: Ostell AB) is recommended to measure two ISQs, using the vibrations that occur in the directions of the higher and lower resonance frequency as a basis(Sennerby & Meredith 2008), because magnetic RFA can provide multi-directional measurements and it is known that the orientation of the transducer (mesiodistal or buccolingual) may affect the measurement of the implant stability quotient (ISQ). If the numerical difference of these two values is more than three ISQ units, both of them are displayed simultaneously. To ensure that both values are measured, the manufacturer of Mentor™ recommends that the probe be held perpendicular to the alveolar crest for one measurement, and in line with the crest for the other measurement. However, it is not known whether the ISQs estimated using Mentor™ vary with the direction of measurement in the same way as estimates measured using piezoelectric RFA. For this reason, the authors performed a randomized clinical trial to determine whether it is necessary to take measurements in both the mesiodistal(MD) and buccolingual(BL) directions in order to assess changes in bone-implant stiffness when such measurements are made using magnetic RFA.

5.1 Study design, methods and materials

A prospective clinical trial was completed, in a total of 53 patients, on 71 non-submerged dental implants that were inserted to replace the unilateral loss of mandibular molars. Two non-submerged implant systems with the same diameter (4.1mm), length (10mm), and collar height (2.8mm) were used in this clinical study. Standard Straumann® Dental Implants (Institut Straumann AG, Basel, Switzerland) were used for 32 of the implants. Osstem SSII Implants (Osstem Implants, Seoul, Republic of Korea) were used for the remaining 39 implants. Mentor™ (Ostell AB, Göteborg, Sweden) was used for to make magnetic RFA measurements. In addition, Type 4 Smartpeg™ (Osstell AB. Göteborg, Sweden) pegs were used during magnetic RFA. The ISQs were measured during the surgical procedure and at 4 and 10 weeks after surgery. Measurements were taken twice in

each direction: in the buccolingual direction from the buccal side (BL) and in the mesiodistal direction from the mesial side (MD). The mean of the two measurements in each direction was regarded as the representative ISQ of that direction. The higher and lower values of the buccolingual and mesiodistal ISQs were also classified separately. In other words, the ISQ of each implant was estimated using four measures at each time: the ISQ measured from the direction perpendicular to the alveolar crest on the BL; the ISQ from the direction parallel to the alveolar crest on the MD; the ISQ showing the higher value of the BL and MD (MX); and the ISQ showing the lower value of the BL and MD (MN). Discrepancies in ISQ were calculated by subtracting the BL from the MD in each period. The variation in ISQ was quantified by subtracting the MN from the MX during surgery; it was found to be the same as the absolute value of the ISQ discrepancy. The implants tested were classified into two groups: a group with variation in ISQ of three or more (3+Group) and a group with variation of less than 3 (3-Group).

5.2 Result of the study

During the surgical procedure, the ISQ discrepancies measured from 2 different directions were 0.36 to 1. Ten weeks later, the discrepancies had decreased to -0.14 to 0.42. Eight out of the 53 implants were classified in the 3+Group, accounting for 15.1% of the total (Table 1). The bone width at the insertion area was 6.89mm for the 3+Group and 6mm for the 3-Group ($P=0.171$). The average age of the 3+Group was 51.88 years, whereas that of the 3-Group was only 47.6 years. However, the difference was not statistically significant ($P=0.398$).

No differences were found between the BL and MD, but significant differences between MX and MN were observed at every measurement point for each implant system. The average BL during surgery showed a significant difference between the 3+Group and the 3-Group ($P=0.002$). No significant differences were observed in the MD values ($P=0.177$). The average MN during surgery showed a significant difference ($P<0.001$). In contrast, there were no significant differences in the MX values ($P=0.417$) (Table 2, 3). The ISQs were compared between the 3+Group and the 3-Group to determine whether there was a change in the values over time. A significant difference between the two groups was observed for the MN values ($P=0.001$). However, no significant differences were found for the MX values between the two groups ($P=0.597$). With respect to the BL and MD values, a significant difference was found between the two groups only for the BL value ($P=0.001$ for BL, $P=0.392$ for MD; Fig. 9).

5.3 Conclusion

The variation in ISQ obtained using magnetic RFA measurements from the two different directions was lower than that reported using piezoelectric RFA. The mean of the discrepancy in ISQ that was calculated from data obtained using magnetic RFA was <1 point. This showed that the discrepancy in ISQ was not skewed to the MD in such an extreme manner as the discrepancy of 10 points found using piezoelectric RFA. With this respect, two- directional measurement is not meaningful. However, our study demonstrated the possibility of observing a different pattern of change between the higher and lower values in a single implant. A significant difference was observed between the 3+Group and the 3-Group in the lower value (MN) of the change in ISQ during the initial healing period. This suggests that a longitudinal comparison of the higher and lower values may improve the evaluation of implant stability, in comparison with the use of a single directional measurement. This suggests that the follow-up observation of scale-based ISQ (lower and higher) values may detect a significant change in the ISQ pattern more readily than the direction-based observations (MD and BL).

Variables	ISQ variation		P-value*
	<3	≥3	
Implant based (N=71)			
Implant number	60	11	
Location			1
molar	30	6	
2nd molar	30	5	
Age (mean±SD)	47.00 ± 12.47	53.09 ± 10.27	0.123
Age			
10-50	33	3	0.111
>50	27	8	
Sex			
male	37	7	1
female	23	4	
Smoking			
Yes	26	4	0.75
No	34	7	
Width(mean±SD) †	6.93 ± 2.02	6.09 ± 0.30	0.12
Implant type			
Straumann	27	5	1
SSII	33	6	
Insertion depth (mean±SD) ‡			
Proximal	1.81 ± 0.56	1.85 ± 0.86	0.844
Distal	2.10 ± 0.59	1.91 ± 0.84	0.34
Participant based (N = 53)			
Participant number	45	8	
Location			
molar	20	4	0.771
2nd molar	25	4	
Age (mean±SD)			
Age			
10-50	24	3	0.486
>50	21	5	
Sex			
male	28	6	0.583
female	17	2	
Smoking			
Yes	17	3	0.99
No	28	5	
Width(mean±SD) †	6.89 ± 1.9	6 ± 0	0.171

Implant type			
Straumann	21	4	0.862
SSII	24	4	
Insertion depth (mean±SD) ‡			
Proximal	1.71 ± 0.53	2.03 ± 0.86	0.547
Distal	2.03 ± 0.6	2.13 ± 0.86	0.841

Data unit, except for continuous variables, are presented as the number. The units of age, width, and insertion depth are year, mm, respectively.

*P-values were calculated by a χ^2 -test for nominal variables, and Mann-Whitney test for continuous for continuous variables.

†Width was measured in the buccolingual direction using a microcompass, after implant insertion.

‡Insertion depth was checked by measuring the distance between the implant shoulders and the alveolar bone using a UNC periodontal probe.

Table 1. Comparison of demographic data between the two groups of patients with implants showing different levels of implant stability quotient (ISQ) variation during implant surgery (Cited from Park et al, 2010)

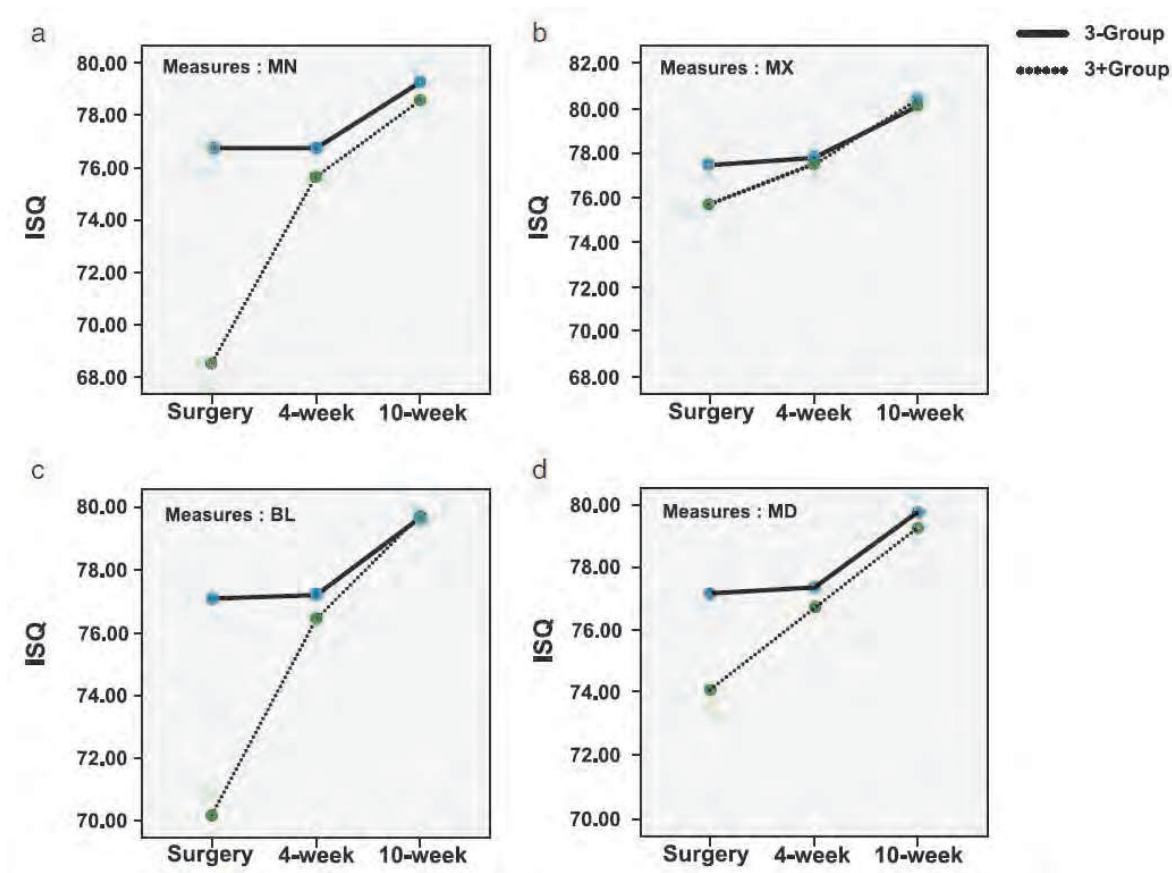


Fig. 9. The comparison of the pattern of change in the implant stability quotient (ISQs) obtained from the four measures from surgery to 10 weeks after surgery. 3+Group=the group with ISQ variation of 3 or more. 3-Group=the group with ISQ variation of < 3. (a) Pattern of change of minimum. (b) Pattern of change of maxilimum. (c)Pattern of change of buccoligual. (d) Pattern of change of mesiodistal.

	ISQ (mean ± SD)		ISQ (mean ± SD)	The difference of the paired data (mean ± SD)	<i>P</i> -value *
<i>All implants (N=53)</i>					
During surgery					
BL†	76.01 ± 6.57	MD‡	76.69 ± 6.26	0.71 ± 3.21	0.063
MX§	77.2 ± 6.13	MN	75.51 ± 6.6	1.72 ± 2.79	<0.001
At post-operative week 4					
BL	77.09 ± 5.59	MD	77.28 ± 5.58	0.19 ± 1.82	0.469
MX	77.72 ± 5.52	MN	76.3 ± 5.6	1.11 ± 1.46	<0.001
At post-operative week 10					
BL	79.65 ± 3.98	MD	79.69 ±3.97	0.01 ± 1.76	0.671
MX	74.56 ± 6.19	MN	73.04 ± 6.2	1.58 ± 2.47	<0.001
<i>Straumann (N=25)</i>					
During surgery					
BL	73.28 ± 6.38	MD	74.32 ± 6.02	1.10 ± 2.72	0.056
MX	74.56 ± 6.19	MN	73.04 ± 6.2	1.58 ± 2.47	<0.001
At post-operative week 4					
BL	74.8 ± 4.52	MD	75.22 ± 4.28	0.42 ± 1.48	0.199
MX	75.54 ±4.23	MN	74.48 ±4.54	1.06 ± 1.1	<0.001
At post-operative week 10					
BL	78.1 ± 3.65	MD	78.34 ± 3.76	0.24 ± 1.98	0.732
MX	78.78 ± 3.51	MN	77.66 ± 3.8	1.12 ± 1.64	0.001
<i>SSII (N=28)</i>					
During surgery					
BL	78.45 ± 5.82	MD	78.8 ± 5.78	0.36 ± 3.6	0.523
MX	79.55 ± 5.17	MN	77.71 ± 6.24	4.84 ± 3.09	<0.001
At post-operative week 4					

BL	79.14 ± 5.72	MD	79.13 ± 6.02	-0.02 ± 2.07	0.861
MX	79.66 ± 5.86	MN	78.5 ± 5.87	1.16 ± 1.74	0.001
At post-operative week 10					
BL	81.04 ± 3.8	MD	80.89 ± 3.82	-0.14 ± 1.54	0.71
MX	81.43 ± 3.69	MN	80.5 ± 3.88	0.93 ± 1.23	0.001

**P*- value was calculated using a Wilcoxon signed ranks test between BL and MD, or between MX and MN
†BL is the ISQ measured from the direction perpendicular to the alveolar crest at the buccal side
‡MD is the ISQ measured from the direction parallel to the alveolar crest at the mesial side
§MX is the ISQ of the direction that showed the higher value between BL and MD
|| MN is the ISQ of the direction which show the lower value between BL and MD

Table 2. Comparison of four different measures of implant stability quotient (ISQ) (Cited from Park et al, 2010)

Period	Mode	ISQ Variation				<i>P</i> -value †
		< 3 (N=45)		≥ 3 (N=8)		
		ISQ (mean ± SD)	<i>P</i> -value*	ISQ (mean ± SD)	<i>P</i> -value*	
<i>All implants (N=53)</i>						
During surgery	BL	77.08 ± 5.97	0.567	70 ± 6.95	0.161	0.002
	MD	77.17 ± 5.8		73.94±8.48		0.177
	MX	77.48 ± 5.85	<0.001	75.56±7.97	0.012	0.417
	MN	76.78 ± 5.9		68.38±6		<0.001
At post-operative week 4	BL	77.23 ± 4.81	0.663	76.31±9.26	0.553	0.650
	MD	77.4 ± 4.95		76.63±8.75		0.722
	MX	77.78 ± 4.86	<0.001	77.38±8.81	0.018	0.862
	MN	76.79 ± 4.87		75.56±9.1		0.551
At post-operative week 10	BL	79.66 ± 3.99	0.471	79.63±4.14	0.553	0.639
	MD	79.78 ± 3.83		79.19±4.93		0.731
	MX	80.16 ± 3.81	<0.001	79.86±3.93	0.018	0.866
	MN	79.28 ± 3.97		78.5±4.8		0.645

**P*- value were calculated using a Wilcoxon signed ranks test between BL and MD, or between MX and MN in each group based on ISQ variation
† *P*- value were calculated using a two-way analysis of variance between the two groups based on ISQ variation.

Table 3. Comparison of four different measures of implant stability quotient (ISQ) between the two implant groups based on the level of ISQ variation during implant surgery (Cited from Park et al, 2010)

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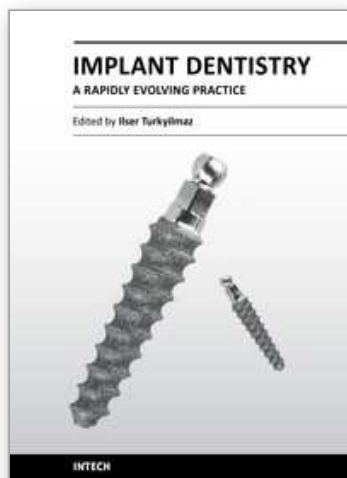
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Implant dentistry has come a long way since Dr. Branemark introduced the osseointegration concept with endosseous implants. The use of dental implants has increased exponentially in the last three decades. As implant treatment became more predictable, the benefits of therapy became evident. The demand for dental implants has fueled a rapid expansion of the market. Presently, general dentists and a variety of specialists offer implants as a solution to partial and complete edentulism. Implant dentistry continues to evolve and expand with the development of new surgical and prosthodontic techniques. The aim of *Implant Dentistry - A Rapidly Evolving Practice*, is to provide a contemporary clinic resource for dentists who want to replace missing teeth with dental implants. It is a text that relates one chapter to every other chapter and integrates common threads among science, clinical experience and future concepts. This book consists of 23 chapters divided into five sections. We believe that, *Implant Dentistry: A Rapidly Evolving Practice*, will be a valuable source for dental students, post-graduate residents, general dentists and specialists who want to know more about dental implants.

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