Clinical Evaluation of Osseointegration on Dental Implants with Resonance Frequency Analysis

Ratna Sari Dewi[1]*, Roselani W Odang[1], Fariza Gita[1]

1. Department of Prosthodontics, Faculty of Dentistry, Universitas Indonesia, Jakarta, Indonesia.

Abstract

Clinical examinations to monitor the osseointegration process were carried out using a new tool, the Low Resonance Frequency Analyzer (LRFA), designed to overcome the deficiencies of the Resonance Frequency Analyzer (RFA). The LRFA consists of two main elements: an accelerometer sensor as a vibration detector and a basic micro-system for controlling accelerometer sensor data, which is then forwarded to the computer. We compared osseointegration in dental implants using a RFA and a LRFA to determine if the LRFA accurately detected osseointegration. Submerged dental implants, obtained from 20 patients, were subjected to RFA and LRFA examinations. We evaluated osseointegration upon placement and after the third months. Upon placement, the mean Implant Stability Quotient (ISQ) obtained with RFA was 59.05 ± 3.72. It increased to 69.25 ± 2.77 at three months. Using LRFA, the mean ISQ was 0.06 ± 0.01 upon placement and increased to 110.11 ± 0.01 at three months. Both devices measured osseointegration accurately. RFA and LRFA are equivalent methods for measuring dental implant stability at three months post-placement.

Introduction

Dental implants are widely used to treat tooth loss and restore mastication, aesthetic appearance, speech, and self-confidence.[1-4] Of the various types of implants, endosteal implants, introduced by Dr. Branemark in 1985, have experienced the most rapid development due to their shape, which resembles a tooth root.[2,3,5,6]

Successful dental implant treatments must achieve osseointegration and establish dental implant stability. Implant stability reflects the implant's mechanical stability, produced by compression of the bone that holds the implant in place. Over time, mechanical stability declines and is replaced by biological stability that results from the formation of new bone cells in the dental implant site.[1,7]

Several tools and techniques have been developed to measure the stability of primary and secondary dental implants. Primary implant stability can be measured using invasive or noninvasive methods. Invasive methods include histological and histomorphometric techniques, analysis of cutting torque resistance, reversal or removal torque tests, insertion torque analysis, and tensile tests. Noninvasive methods include radiographic analysis, finite element analysis, percussion testing, Resonance Frequency Analysis (RFA), and Low Resonance Frequency Analysis (LRFA). Invasive methods are commonly used in research and are rarely applied in clinical settings, although these methods feature higher objectivity than noninvasive methods.[7-10]

Meredith et al. first introduced RFA, a noninvasive method previously used in the field of building engineering. In dentistry, RFA involves continuously stimulating implants using dynamic vibrations. This can be achieved by connecting a piezoelectric transducer to the implant. The transducer emits signals, within a certain frequency range, that will vibrate the dental implant. In principle, this method is similar to the constant application of lateral forces on the implant, then measures implant displacement.[11-13] Resistance to the vibration is measured, then

*Corresponding author:
Ratna Sari Dewi,
Department of Prosthodontics
Faculty of Dentistry
Universitas Indonesia
Jakarta 10430, Indonesia
E-mail: ratnasaridewi.drg@gmail.com

transformed to an Implant Stability Quotient (ISQ) on a scale of 1–100, with a value of 1 indicating lowest stability and a value of 100 indicating highest stability. The ISQ value reflects the surface stiffness between the implant and the bone. Measurements using the Osstell ISQ are quite simple. First, the probe is pointed at a magnet above the SmartPeg that is attached to the implant at a distance of approximately 2–3 mm, without touching the SmartPeg.[14,15] When the probe is at the correct distance, the instrument will produce a short beep. The Osstell ISQ stimulates the SmartPeg, paired with the implant, by generating magnetic waves. These waves cause the SmartPeg to resonate at a specific frequency, according to the stability of the implant and the resonance frequency, which is recorded by the Osstell ISQ. Longer beeps indicate that valid measurements have been recorded and ISQ values can be seen on the display.[8,9] Prior studies indicated that ISQ increased significantly after three months; for the Straumann implant paired with the posterior region of the mandible, the mean primary implant stability (ISQi) was 66.3077 ± 7.40836 and the secondary implant stability (ISQf) after three months was 72.3333 ± 5.72314.[16,17] Implant stability can be measured clinically using RFA, a highly reliable process that produces an ISQ. ISQ quantifies surface stiffness between the implant and bone.[8-10]

In addition to RFA, new tools have been found to check osseointegration using LRFA. LRFA was designed to address deficiencies inherent to RFA and consists of an accelerometer sensor to detect vibrations and a basic micro-system that forwards accelerometer data to the computer. LFRA is used to determine the relationship between the bone and the surface of the implant in the absence of connective tissue. Here the LRFA device is attached to the buccal portion of the gingiva, under the implant to be measured. The implant is then tapped with the sonde. LRFA can be applied to all types of implants by detecting the vibrations caused by implant instability against the surrounding alveolar bone. LRFA can also determine the occlusal load received by the teeth. LRFA values <0.0620 indicate osseointegration, whereas values >0.0620 indicate that osseointegration has not occurred.[18,19,20]

The purpose of this study was to compare the osseointegration of dental implants evaluated by a RFA and LRFA. We sought to determine if LRFA was an approximately equal means of evaluating osseointegration.

Materials and methods

This was an analytical study with a longitudinal design. Research subjects were selected using a consecutive sampling method. In consecutive sampling, all subjects who come in sequence and meet the inclusion criteria are included in the study until the required number of subjects is met. This method is a convenient type of non-probability sampling.

Inclusion criteria included male and female patients, aged 25 years to 60 years with tooth loss and indicated for implant treatment. We excluded patients with systemic conditions that could affect alveolar bone remodeling and bone healing processes such as osteoporosis, diabetes mellitus, and radiotherapy treatments.

The study samples consisted of implants obtained from patients who came to clinic and underwent dental implant treatment according the study's stated inclusion criteria. For selected subjects, we used anamnesis and examination of medical record data to ensure that subjects met all inclusion criteria. Primary measurements were taken immediately after dental implant installation, and secondary measurements were taken three months post-installation. This research was conducted at the Dental and Oral Hospital Faculty of Dentistry, University of Indonesia and the Ratna Medica Center Pamulang clinic.

We used the Osstell ISQ (Integration Diagnostics Ltd. Company, Savedalen, Sweden), Standard Equipment, Instrument holder and alignment controller Rinn XCP - ORA (Dentsply Rinn LLC, Illinois), SIDEXIS- XG version 2.6x, Sirona Dental Company, New York, United States) Revotek LC (GC America, California, United States), Micromotor surgery (Implanteo, Anthogyr, Sallanches, France), and dental implants (Straumann AG, Basel, Switzerland).

Each prospective subject was provided with information about this research, and after all the prospective subject's questions were answered, written informed consent was obtained. Following consent, each subject underwent digital periapical radiographic imaging to evaluate jaw bone density prior to installation of dental implants.

Implantation was accomplished through use of osteotomy procedures performed in

accordance with the Straumann dental implant system according to the manufacturer's instructions and using motor implants (Implanteo, Anthogyr, Sallanches, France). Immediately following installation, we measured the resonant frequency of each dental implant using the RFA device The resonant frequency was measured from two directions on each implant. The first measurement was taken in the buccolingual direction or perpendicular to the peak of the alveolar bone, and the second measurement was taken in the distal mesial direction or parallel to the peak of the alveolar bone. In this study osseointegration evaluation was carried out using RFA and LRFA. Both of these tools have the same function but there are differences in the technical operation of the tool. The LRFA requires a transducer that is placed in the implant. Whereas LRFA does not need additional tools. Only attach the LRFA probe to the buccal area of the implant. Besides that the difference between RFA and LRFA lies in the unit. Measurements of dental implant stability, using the RFA and LRFA devices, were repeated one month and two months post-installation.

Results

This research was conducted on 20 subjects consisting of 11 men and 9 women who met the inclusion criteria, were willing to take part in the study and signed the approval statement sheet as the research subject. The distribution of the data are listed in table 1.

	Mean (n = 20)
RFA baseline	60.00 (45.00–63.00)
RFA 3 month	69.25 ± 2.77
LRFA baseline	0.06 (0.03–0.07)
LRFA 3 month	0.11 (0.09–0.14)

Table 1. Mean (range) osseointegration values according to method (RFA or LRFA) and study time point (immediately post-implantation and three months post-implantation). RFA=Resonant Frequency Analysis; LRFA=Low Resonant Frequency Analysis; ISQ=Implant Stability Quotient.

There was a significant difference between the baseline and three month post-implantation. The value of osseointegration measures obtained by RFA and LRFA (p < 0.005) (Table 2). It appeared from the assessment in Table 2 that the value of osseointegration obtained from the treatment and the comparison groups varied from 59.05 to 69.25. Decreases were statistically significant for 10.2 values. The process of osseointegration markedly significantly (p$\leq$0.05) increased the values of osssoeintegration for both methods: RFA and LRFA.

n=20	Mean ± s.d	SD ± s.d	CI 95%	p
RFA baseline	59.05 ± 3.72	-10.20 ± 2.48	-11.36–[-9.04]	<0.001*
RFA 3 months	69.25 ± 2.77			
LRFA baseline	0.06 ± 0.01	-0.05 ± 0.01	-0.05–[-0.04]	<0.001*
LRFA 3 months	0.11 ± 0.01			

Table 2. The difference in mean ISQ obtained by RFA and LRFA immediately post-implantation (baseline) and at three months post-implantation. RFA=resonant frequency analysis; LRFA=low resonant frequency analysis; CI 95%, 95% confidence interval; * significant at p$\leq$0.05

Discussion

ISQ values measure dental implant stability, and an implant's success is determined by the degree of osseointegration that occurs between the implant and bone. If there is no direct bone apposition, fibrous tissue will progressively increase and eventually cause the implant to dislodge. The issue surrounding implant design is the development of materials that are physically and biologically compatible with the alveolar bone. Ideally, bone will integrate with the implant material, substance, or the surrounding device, and not form fibrous tissue around the implant.[4]

Osseointegration examination requires in-depth evaluation with the help of special methods and tools, like radiography, light microscopy, or electron microscopy. This examination looks for evidence of connective tissue growth because this can trigger dental implant mobility and failure.[21,22] According to Lawrence, implant stability is necessary for integration [30], and without stability, long-term implant treatment success cannot be achieved. Initial stability (at the time of implantation) is determined by alveolar bone quality, implant design, and surgical techniques. For example, implants attached to bones with optimal density will have higher stability than those implanted in cancellous bone.[10,20]

Later re-examinations of implant stability determine changes in the implant from the time of installation to complete osseointegration. These methods include percussion tests, radiographs, periotes, dynamic capital testing, backup technology, RFA, impulse tests, *implates analysis*, and implant FFT signature analysis. *Implates* are the latest noninvasive method for assessing implant osseointegration in implant placement and can be used over time during the osseointegration process.[23-27]

The RFA is a device designed to measure implant stability clinically, bone density, and osseointegration. This noninvasive procedure is performed by attaching the transducer directly to both implants and abutments using a special screwdriver. The resulting frequency varies from 6 to 12 kHz with the magnitude of each 25 Hz stage. Beam response is measured, and the transducer resonance frequency is calculated based on the highest amplitude of the resulting signal.[10,16] Research conducted in vivo and in vitro proved that this technique can be used to assess bone density when dental implants are installed, monitor bone formation during the healing process, and evaluate the clinical condition of a functioning dental implant.

RFA has attracted considerable scientific interest in recent years and is the subject of an increasing volume of scientific research and studies published in prominent journals. Using RFA, we found that implant stability improves over time. It means the osseointegration process that means the osseointegration process is happening gradually.

RFA has some limitations, and its resultant readings can be influenced by the firmness of the fixing screw used to attach the transducer to the implant. Additionally, measurement errors can occur secondary to tongue contact with the transducer during measurement.[10] Another disadvantage of RFA is that it cannot be applied to all types of implants. Therefore, LRFA is a new tool that improves upon the limitations associated with RFA. The benefits are very significant in the creation of this new tool is to increase domestic production, especially health equipment. Until now, health equipment to the field of dentistry are all production from abroad. As a result they're expensive, high maintenance costs also.

This study compared the LRFA and RFA values and found a equivalent result in measurement of osseointegration. LFRA measurements can identify unstable implants and objective assessments, enabling qualitative and quantitative analysis of the stability of various types of implants while examining the behavior of implants under different bone and loading conditions.

Conclusions

The osseointegration measurement method using RFA and LRFA gives equivalent results in the third month. This proves that the both tool is as accurate invaluating osseointegration implants.

Acknowledgements

Declaration of Interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial.

References

1. Misch CE. Contemporary Implant Dentistry. 3 ed. St. Louis, Missouri: Mosby; 2005.
2. Gaviria L, Salcido JP, Guda T, Ong JL. Current trends in dental implants. J Korean Assoc Oral Maxillofac Surg 2014; 40:50-60.
3. Dudley J. Implants for the ageing population. Aust Dent J 2015; 60:28-43.
4. Clementini M, Morlupi A, Agrestini C, Ottria L. Success rate of dental implants inserted in autologous bone graft regenerated areas: a systematic review. Oral & Implantology 2011; Anno IV:3-10.
5. Baqain ZH, Mogbel WY, Sawair FA. Early dental implant failure: risk factors. Br J Oral Maxillofac Surg 2012;50:239-43.
6. Powers JM. Craig's Restorative dental material. 12th ed. St Louis: Mosby Elsevier; 2006.
7. Atsumi M, Park SH, Wang HL. Methods used to assess implant stability: current status. Int J Oral Macillofac Implants 2007; 22:743-54.
8. Herrero-Climent M, Santos-Garcia R, Jaramillo-Santos R, Romero-Ruiz MM, Fernandez-Palacin A, Cazaro-Calvo P, et al. Assessment of Osstell ISQ's reliability for implant stability measurement: a cross-sectional clinical study. Med Oral Patol Oral Cir Bucal 2013; 18(6):e877-82.
9. Gonzales-Jaranay M, Moreu-Burgos G, Gomez-Moreno G, Machuca-Portillo G, Perrott V, Boquete-Castro A, et al. Changes in resonance frequency analysis assessed by Osstell mentor during osseointegration: comparison between immediately loaded implants and control implants without load. J Osseointegr 2014; 6(3):51-5.
10. Valderrama P, Oates TW, Jones AA, Simpson J, Schoolfield JD, Cochran DL. Evaluation of Two different resonance frequency devices to detect implant stability: a clinical trial. J Periodontol 2007; 78(2):262-72.

11. Pedro RE, DeCarli JP, Linden MS, Lima IF, Paranhos LR, Costa MD, et al. Influence of age on factors associated with peri-implant bone loss after prosthetic rehabilitation over osseointegrated implants. J Contemp Dent Pract 2017; 18(1):3-10.
12. Ikebe K, Wada M, Kagawa R, Maeda Y. Is old age a risk factor for dental implants? Jpn Dent Sci Rev 2009; 45:59-64.
13. Bornstein MM, Cionca N, Mombelli A. Systemic conditions and treatments as risks for implant therapy. Int J Oral Macillofac Implants 2009; 24:12-27.
14. Heitz-Mayfield LJ, Huynh-Ba G. History of treated periodontitis and smoking as risks for implant therapy. Int J Oral Macillofac Implants 2009; 24:39-68.
15. Lang NP, Salvi GE, Huynh-Ba G, Ivanovski S, Donos N, Bosshardt DD. Early osseointegration to hydrophilic and hydrophobic implant surfaces in humans. Clin Oral Impl Res 2011; 22:349-56.
16. Smeets R, Stadlinger B, Schwarz F, Beck-Broichsitter B, Jung O, Precht C, et al. Impact of dental implant surface modifications on osseointegration: review article. Biomed Res Int 2016; 2016:16.
17. Mandracci P, Mussano F, Rivolo P, Carossa S. Surface Treatments and functional coatings for biocompatibility improvement and bacterial adhesion reduction in dental implantology. Coatings 2016; 6(1):7.
18. Guehennec L, Soueidan A, Layrolle P, Amourig Y. Surface Treatments of titanium dental implants for rapid osseointegration. Dent Mate 2007; 23:844-54.
19. Hotchkiss KM, Reddy GB, Hyzy SL, Schwartz Z, Boyan BD, Olivares-Navarrete R. Titanium surface characteristics, including topography and wettability, alter macrophage activation. Acta Biomaterialia 2016; 31:425-34.
20. Dewi RS. Prediksi Oseointegrasi pada Pemasangan Implan secara Immediate Loading dan Delayed Loading dikaitkan dengan Kontak Oklusal: Tinjauan secara Klinis dengan Penganalisis Resonansi Berfrekuensi Rendah (PRBR), Radiografi, Biomolekuler, in-situ dengan Torque Test, Histomorfometri pada Macaca Fascicularis (Oseointegration Prediction on Immediate Implant Implementation Loading and Delayed Loading Linked to Oclusal Contacts: Clinical Review with Low Frequency Resonance Analyzer (PRBR), Radiography, Biomolecular, in-situ with Torque Test, Histomorphometry on Macaca Fascicularis. Jakarta: Universitas Indonesia; 2010.
21. Prawoko SS. Hubungan antara Analisis Radiografis Kepadatan Tulang Alveolar di Sekitar Implan Dental dan Frekuensi Resonansi Implan Dental (Relationship between Radiographic Analysis of Alveolar Bone Density Around Dental Implants and Resonance Frequency of Dental Implants) Jakarta: Universitas Indonesia; 2015.
22. Saini M, Singh Y, Arora P, Arora V, Jain K. Implant Biomaterials: A comprehensive Review. World J Clin Cases 2015; 3(1):52-57.
23. Chiapasco M, Casentini P, Zaniboni M, Corsi E, Anello T. Titanium-zirconium alloy narrow-diameter implants (Straumann Roxolid) for the rehabilitation of horizontally deficient edentulous ridges: prospective study on 18 consecutive patients. Clin Oral Impl Res 2012; 23:1136-41.
24. Barter S, Stone P, Bragger U. A pilot study to evaluate the success and survival rate of titanium-zirconium implants in partially edentulous patients: results after 24 months of follow up. Clin Oral Impl Res 2012; 23:873-81.
25. Buser D, Schmid B, Belser UC, Cochran DL. The new bone level implants–clinical rationale for the development and current indications for daily practice. International Dentistry SA 2010; 12(3).
26. Dewi RS, Himawan LS, Soekanto SA, Kusdhany LS. Low resonance frequency analyzer (Lrfa) as a potential tool for evaluating dental implant osseointegration. J Int Dent Med Res 2016; 9:376-81.