Low Resonance Frequency Analyzer (Lrfa) as a Potential Tool for Evaluating Dental Implant Osseointegration

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Abstract

Dental implant treatment is one of the best alternatives in replacing missing teeth. Osseointegration is an important factor in determining its success, assessed from process that occurs between implant and bone as the criterion. Histomorphometry is the most accurate osseointegration evaluation method. The aim of this research was to develop and evaluate whether Low Resonance Frequency Analyzer (LRFA) could be used as an alternative tool for osseointegration evaluation. This study conducted in two stages; LRFA fabrication and diagnostic testing. Osseointegration process evaluation was the second stage. Six male Macaque fascicularis aged about 6 years, weighing from 4.5 to 6 kg were the research subject. Evaluation of were performed through clinical examination and LRFA measurement on the first and second week, then once every month until the fourth month. Animals were sacrificed after the fourth month and histomorphometric examination was performed.

The result of histomorphometric examination was compared with LRFA measurement using Pearson correlation coefficient. ROC curve of diagnostic test showed that sensitivity and specificity of LRFA was 90.2% (optimal values). Statistical analysis showed strong correlation between LRFA measurement and histomorphometric examination (R=0.8, P<0.5). With the result was as good as histomorphometric examination, therefore LRFA is an alternative osseointegration evaluation tool.

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Introduction

Osseointegration is an important factorin assessing the success of dental implant treatment. Without osseointegration dental implant could not function optimally. There are several methods used to evaluate the osseointegration such as histomorphometry and stabilization test with periotest / Osstell.[1,2] Histomorphometry is a process of bone quantification at the microscope level and the most accurate method, but could not be used clinically, since the measurement has to be done on speciment taken from bone and soft tissue around the implant.[3] Currently, available tool which is non-invasive to measure the stability of dental implantis periotest / Osstell. It has been used frequently in the dental implant treatment for clinical and research purposes.[3-5] Unfortunately it could only be used on certain types of implants and could not applied for a single piece implant. Based on facts in paragraph above, it is necessary to invent a new tool that is relatively inexpensive and very beneficial for dentistry especially in the dental implant field.

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Originality of this research is the invention of LRFA as a new tool that could be used to evaluate osseointegration and to measure the occlusal load. Thus the success of implant treatment could be achieved. The results of this study will be very meaningful for the development of science, especially in the development of prosthetic dentistry. (With the discovery of methods of tooth replacement that provides comfort, to rehabilitate lost functions such as the function of speech, chewing function, requiring only one surgical process. This treatment needs a shorter treatment time). Widespread dental practice supported by the latest technology will increase rapidly, and this will have an impact on improving the quality of life. The purpose of this research was to determine whether LRFA (after diagnostic test) could be used as an accurate tool for evaluating osseointegration clinically.

Materials and methods

This study was divided into two parts. The first study was a fabricating LRFA and diagnostic test on this tool to determine its sensitivity and specificity. Since LRFA is a device, its test was necessary to determine the quality of the tool compared to gold standard. The second study is an experimental research on animals to evaluate the osseointegration at the time of dental implants placement.LRFA is designed with components that consist of two elements of electronic devices, namely vibration accelerometer sensors, and basic micro controller system for data from accelerometer sensor that will be forwarded to the computer. Accelerometer sensors used was model Free scale Semiconductor MMA7455L 3-axis accelerometer with a digital output and low power, micro-mechanical sensors that can measure the acceleration along the X, Y and Z axis (Figure 1). This sensor has several convenient features including integrated analog to digital converter (ADC), digital low- pass filter, and wide range of sensitivity. This tool is able to detect vibrations caused by instability of dental implants on alveolar bone. The more stable the implant, the less vibration that will arise. This tool is intentionally made for the research, because tools commonly used (RFA/Osstell) could not be applied to the one-piece typed implants.

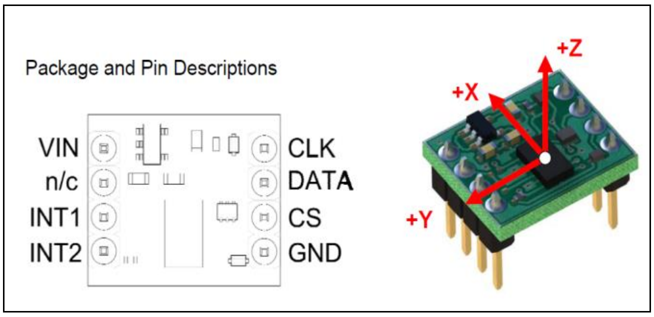

Figure 1. MMA7455L 3-Axi Semiconductor.

This study has been evaluated and approved ethically by the Commission for Supervision of Animal Welfare and Use of Research Center for Primate Studies in September 3, 2009, certificate number ACUC No. 09-B002-IR.

The experimental study was conducted using six male experimental *M. fascicularis* aged 6 years, with weight ranges from 3.5 to 4 kg. In this study one-piece mini implant was used to perform a clinical osseointegration examination. This process used a tool that did not require a transducer, and can be applied to an existing implant with or without restoration Clinical examination and LRFA measument were performed to determine the osseointegration on first week, second, the first month, second, third and fourth month. After four months animals were sacrificed and histomorphometric examination was performed. The relationship of histomorphometric examination and LRFA measurement were compared using the Pearson correlation coefficient.

The sample size for Diagnostic Test Research was calculated from:n= Z 21-α 2 (2σ2)/D (1). The sample size for osseointegration prediction research at the time of titanium implant placement in the *M. fascicularis*jawbone was calculated from formula [6]:(t-1) (r-1) ≥ 15 (2); where : t = number of treatment groups; r =number of sample.

Research for making the LRFA too land the diagnostic tests were performed at the Faculty of Electrical Engineering, Universitas Indonesia. Placement of the implant conducted at the Laboratory Animal Center for Primate Studies (PSSP) IPB Bogor, Indonesia. Making bone preparations were conducted at the Laboratory of Anatomical Pathology Faculty of Medicine, Universitas Indonesia, and the analysis of histomorphometry was conducted at the Laboratory of Pathology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand.

Results

Diagnostic test was performed to determine the accuracy of LRFA as a tool for assessing clinical osseointegration which was determined by its sensitivity and specificity. RFA (osstell/periotest) was used as a gold standard. The result of the ROC curve was as follows. The statistical analysis of ROC Curve obtained the value of Area Under the Curve (AUC) 0.986. The ROC curve above the optimal value obtained from the cut off 0.0620 where the value LRFA was obtained optimal values of sensitivity and specificity (90.2%). The proportion of osseointegration with positive results among the observations indicates that in most treatment groups osseointegration occured on the 60th day of observation. In general, osseointegration was not yet formed on the day 14 of observation. On the 90th day of observation, osseointegration has occured in all with the value of 66.67%. Osseointegration distribution was positive based on LRFA value in accordance with the treatment groups (Figure 2). The number of samples that experienced osseointegration, divided according to their treatment groups. It was seen that, on the 90th day, all treatment groups attained osseointegration, except in ILKN 1 only 66.67%.

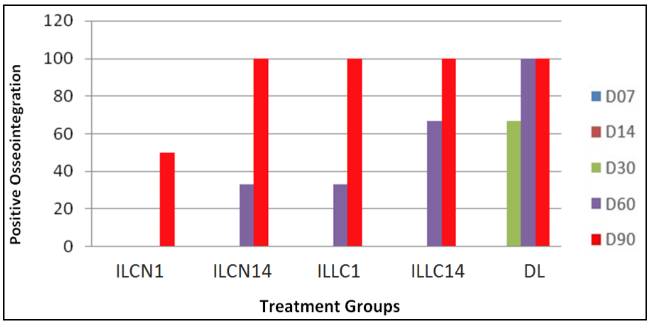

Figure 2. Positive Osseointegration Distribution in Accordance to LRFA Scores Based on Treatment Groups.

Treatment Group	LRFA Osseointegration				P
	Positive		Negative		
	N	%	N	%	
ILNC1	3	11.11	3	100.00	0.025
ILNC14	6	22.22	0	0.00	
ILLC1	6	22.22	0	0.00	
ILLC14	6	22.22	0	0.00	
Delayed Loading	6	22.22	0	0.00	
Total	27	100.00	3	100.00	

Table 1. Proportion of Osseointegration Among Groups.
Distribution of research groups:
ILNC 1 : Immediate Loading Implant, Normal Contact, Day 1.
ILNC14 : Immediate Loading Implant, Contact Normal, Day 14.
ILLC1 : Immediate Loading Implant, Contact Light, Day 1
ILLC14 : Immediate loading implants, Contacts Lightweight, Day 14.

Treatment Group	Mean	SD
ILNC1	0.3759	0.1326
ILNC14	0.5067	0.0803
ILLC1	0.5631	0.0755
ILLC14	0.7423	0.0859
Delayed Loading	0.7566	0.0848

Distribution of research groups :
ILNC 1: Immediate Loading Implant, Normal Contact, Day 1.
ILNC 14 : Immediate Loading Implant, Contact Normal, Day 14.
ILLC 1 : Immediate Loading Implant, Contact Light, Day 1.

Information: The table above shows that on the 90th day, almost all groups experienced osseointegration except the ILNC1 group. From six (6) samples, there were only three (3) which experienced osseointegration based on clinical examination with LRFA tool. The n code is the number of samples.

The histomorphometric examination was`performed by first digitizing the images from the microscope (Figure 3). Images were acquired through a 10 x objectives and included the entire implant surface. Subsequently, the digitized images were analyzed by image analysis software. The percentage ofbone-implant-contact (BIC%) was then calculated by percentage.[7] The linear surface of the implant directly contacted by mineralized bone and expressed as a percentage of the total implant surface. In the five treatment groups, the histomorphometry value follow a normal distribution (p> 0.05). The highest BIC value of 83.15% and the lowest BIC value of 19.17%. It was shownall every BIC value exceed 0.2 or 20%. The minimum values of occurance of osseointegration. The Pearson' coefficient between LRFA and histomorphometric examination indicated an almost a perfect correlation (r=0.8 and p<0.05).

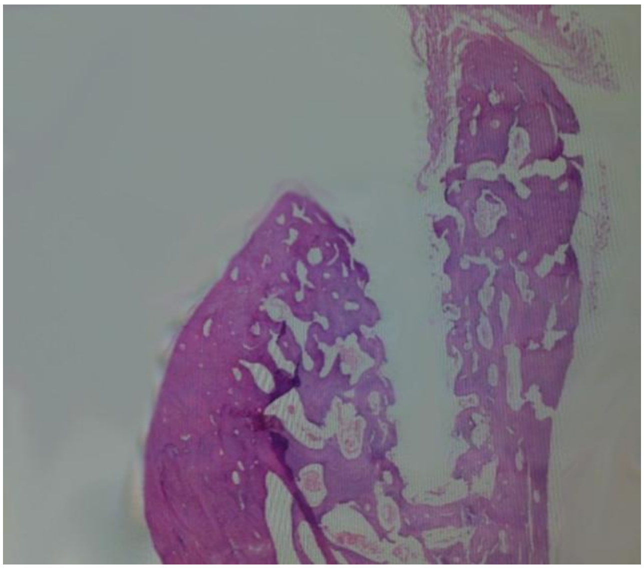

Figure 3. Histomorphometry examination. It seen direct contact between the implant with bone with BIC value 83.15%.

Therefore, it can be obtained that all of the BIC average value exceeded 0.2 or 20% which is the minimum value, has been categorized as having osseointegration.Research was conducted on experimental animals *M. fascicularis*. It is expected that the results can be applied in humans due to consideration of the proximity of these animals with humans from a genetic standpoint, particularly on the immune system, vascular conditions, teeth and alveolar bone. Further research is necessary to obtain more optimal results.

Discussion

Resonance Frequency Analyzer is a tool to measure the primary and secondary of dental implants. The primary stability of the implant can be measured using the invasive and / or non-invasive method. Invasive methods include histological techniques and histomorfometris, cutting torque resistance analysis, reverse test / removal torque, analysis of insertion torque and tensile testing. Noninvasive methods include analysis of resonance frequency(RFA).[8,9] This tool is commonly used for examination osseointegration and implant stability, but can not be applied to the one-piece typed implants. This study was conducted to evaluate the new tool that does not require a transducer, and can be applied to an existing with or without without restoration. Since LRFA is a new device it is necessary to do a the diagnostic tests to determine the sensitivity and specificity before it is used to this research.

LRFA value abovewas able to describe the difference between the positive and the negative of 98.6%.LRFA has advantages compared to the RFA (ostell/periotest). LRFA is applicable to all types of implants. Whether normal size or mini size implants, two parts (two pieces) or one part (one piece) implants. In addition, this tool can also be used to assess implant stability and implant osseointegration with and without restoration. In terms of economical tool this is certainly cheaper.

The benefits of this new tool could increase domestic production, especially health equipment. Until now, health equipments in the field of dentistry mostly are imported products. As a result, they are expensive and also has high maintenance costs. The diagnostic test done when the new examination has a higher diagnostic value, the price more affordable, easier, no risk, or have the same diagnostic value but has a more relative advantage.

According to the diagnostic test results, cut offvalue of 0.0620 is used to declare osseointegration. If the value of LRFA is below 0.0620,it means that osseointegration is achieved, and if it exceeds that number, it can be concluded that osseointegration does not happen. Other advantage that could be obtained from LRFA is the ability to determine the occlusal load. In fact, this potential will give significant benefits for prosthodontic, gnatology to evaluate occlusion. With the value of osseointegration were 66.67%, means that the implant restorationplacement on the same day asimplantplacement provides risk of failure.

The stability of dental implant is a combination of mechanical stability and biological stability. Mechanical stability generated by the compressed bone holding the implant tightly in place, while the biological stability generated by the formation of new bone cells at the installation site and the area of the dental implant osseointegration. Mechanical stability is generally high immediately after implant placement so often referred to as primary stability. The high mechanical stability is caused by mechanical compression of the bone when the dental implant is inserted and thus will decrease over time.[10,11]

The stability of an implant is determined by the osseous support at the implant-bone interface, which is commonly evaluated by histomorphometric analysis.[12,13] However, implant-bone interface histomorphometric analysis has traditionally been assessed only in two-dimensional sections in which the structural parameters are measured from sections. Recently, quantitative bone structure analysis using microcomputed tomography (micro CT) has been considered for evaluating implant stability.[14] Such analytic methods can be used to evaluate bone morphology in three dimensions, thereby providing a better understanding of the healing processes of bone surrounding the implant.

It was suggested that in doing the installation of restoration should be adjusted to the conditions of the alveolar bone, and the available space for the prosthesis and the restoration should not be placed more than 72 hours after the implant placement.[15] The restoration placement in this study done at day 14 give better results good when compared to the first day. Thus, further research is necessary regarding the placement of restoration with a variable time period that is more diverse.[16] Loading of the dental implant begins at the time of restoration placement. Restoration occlusal contact effect on the magnitude loading. Furthermore, the magnitude of occlusal force transmitted to the implant does not only depend on the magnitude of occlusal contacts. Other factors such as the number of implants, angulation of the implant, the size of the implant and the bone quality can affect the magnitude of occlusal loading transmitted to the implant.[17]

In this study, occlusal loading is limited to the amount of occlusal contacts is lightweight and normal, though there are very broad occlusal variations. This restriction is intended as an attempt to control confounding variables. The width of occlusal, plane and the occlusal form adapted were to the conditions of their respective teeth of *M. fascicularis*, so that the results was really only because of the treatment given, not influenced by other factors. Food provided at all the same animal food that is monkey chow and fruit. Monkey chow is processed foods that are specially prepared for primates. Loud enough for consistency in this study burden (loading) given truly real in the sense of the implant is conditioned to function in practice.[18,19]

A fundamental prerequisite for implant success is substantial primary stability at the time of implant insertion and following loading of the implant it self. The recent studies evaluate the effect of loading at the time of implant placement.[20] Some studies simulate loading by providing periodic load /progressing load. Even to this day it has never been tested experimentally with controls to determine the effect of occlusal load on the achievement of immediate osseointegration loading.[21]

Study on occlusal loading almost all use load simulation and experimental tests are not performed on teeth in the oral cavity. Therefore, this study provides new information and contribute to the development of science of implantology especially on the occlusal contacts loading in the treatment of the immediate implant prosthesis.

Research was conducted on experimental animals *M. fascicularis*. It is expected that the results can be applied in humans due to consideration of the proximity of these animals with humans from a genetic standpoint, particularly on the immune system, vascular conditions, teeth and alveolar bone, although further research is necessary to obtain more optimal results.

Conclusions

Osseointegration can be clinically examined with LRFA. LRFA was proven through a diagnostic test as an accurate tool for measuring dental implant stability and osseointegration clinically. It is recommended for clinicians to use the LRFA tool for osseointegration and stability measurements in implant treatment for everyday practice.In prosthodontic care and gnatology (to facilitate its use) LRFA tool needs to be modified in digital form, to simplify the readings when used for the evaluation of occlusion.

Declaration of Interest

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References

1. Soicu S, Bratu D, Borsanu I.Damping capacity assessment versus resonance frequency analysis in the determination of the dental implant stability. TMJ. 2010;60(1):109-16.
2. Quesada-Garcia MP, Prados-Sanchez E, Olmedo-Gaya MV, Munoz-Soto E, Gonzales-Rodriguez MP, Vallecillo-Capilla M.Measurement of dental implant stability by resonance frequency analysis: A review of the literature. Med Oral Patol Oral Cir Bucal. 2009;14(10):538-46.
3. Erdogan Ö, Üstün Y, Tatli U, Damlar I, Daglıoglu K. A pig model for the histomorphometric evaluation of hard tissue around dental implants. J Oral Implantol. 2013;39(5):551-7.
4. Cairo F, Sanz I, Matesanz P, Nieri M, Pagliaro U. Quality of reporting of randomized clinical trials in implant dentistry. A systematic review on critical aspects in design, outcome assessment and clinical relevance. J Clin Periodontol. 2012;39:81-107.
5. Meijer HJ, Raghoebar GM. Quality of reporting of descriptive studies in implant dentistry. Critical aspects in design, outcome assessment and clinical relevance. J Clin Periodontol. 2012;(39):108-13.
6. Ankel S. An Introduction Primate Anatomy 2nd ed. Academic Press. San Diego. 2000:p.191-246.
7. Fanuscu MI, Chang TL, Akca K. Effect of surgical techniques on primary implant sta-bility and peri-implant bone. J Oral Maxillofac Surg. 2007;(65):2487–91.
8. Bischof M, Nedir R, Szmukler-Moncler S, Bernard J-P, Samson J. Implant stability measurement of delayed and immediately loaded implants during healing. A clinical resonance-frequency analysis study with sandblasted-and-etched ITI implants. Clin Oral Impl Res. 2004;(15):529-39.
9. Quesada-Garcia MP, Prados-Sanchez E, Olmedo-Gaya MV, Munoz-Soto E, Gonzales-Rodriguez MP, Vallecillo-Capilla M.Measurement of dental implant stability by resonance frequency analysis: A review of the literature. Med Oral Patol Oral Cir Bucal 2009;14(10):538-46.

10. Cairo F, Sanz I, Matesanz P, Nieri M, Pagliaro U. Quality of reporting of randomized clinical trials in implant dentistry. A systematic review on critical aspects in design, outcome assessment and clinical relevance. J Clin Periodontol. 2012;(39):81-107.
11. Natali AN, Carniel EL, Pavan PG. Investigation of viscoelastoplastic response of bone tissue in oral implants press fit process. J Biomed Mater Res B Appl Biomater. 2009;9:868–75.
12. Castillo RF, Ubelaker DH, Djorojevic M.Age estimation through histological study of trabecular volume and cortical bone width of the iliac crest. SciJustice. 2012;52:177-80.
13. Ghoveizi R, Alikhasi M, Siadat M-R, Siadat H, Sorouri M.A radiographic comparison of progressive and conventional loading on crestal bone loss and density in single dental implants: A randomized controlled trial study. J Dent (Tehran). 2013; 10(2):155-64.
14. Block MS, Castellon P, Zavala J. Replacement of a fixed partial denture secondary to abutment fracture. J Am Dent Assoc. 2007;138(6):758-90.
15. Nkenke E, Fenner M. Indications for immediate loading of implants and implant success. Clin Oral Implant Res. 2006; 17 (Suppl 2):19-34.
16. Siu AS-C, Chu FC-S, Li TK-L, Chow T-W, Deng F-L.Imaging modalities for preoperative assessment in dental implant therapy: An overview. Hong Kong Dent J. 2010; 7: 23-30.
17. Glauser R, Sennerby L, Meredith N, Rée A, Lundgren A, et al. Resonance frequency analysis of implans subjected to immediate or early functional occlusal loading. Successful vs. failing implans. Clin Oral Implant Res. 2004;15(4):428-34.
18. Ali ME, Rashid NRA, Hamid SBA, Hossain SMA, Asing A, et al. Development and validation of short-amplicon length PCR assay for macaques meat detection under complex matrices. Int J Food Properties. 2016:1(3):1-15.
19. Esposito M, Grusovin MG, Willings P, MarkK, Coulthard P, Worthington HV. The effectiveness of immediate. Early and conventional loading of dental implants: A Cochrane controlled clinical trials. Int J Oral Maxillofac Implants; 2007; 22 (6):893-910.
20. Cehreli MC, Karasoy D, Akca K, Eckert SE.Meta-analysis of methods used to assess implant stability. Int J Oral Maxillofac Implants. 2009;24(6):1015-31.
21. Testori T, Del Fabbro M, Galli F, Francetti L, Taschieri S, Weinstein R. Immediate occlusal loading the same day or the day after implant placement: Comparison of 2 different time frames in totally edentulous lower jaw. A multicenter prospective study. J Oral Implantol. 2004; 30 (5): 307-13.