Evaluation of Dental Implant Osseointegration Using Ultrasonic Spectrometry: A Phantom Study

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Abstract: - One of the challenging and important problems that still needs solution within the field of dental implant surgery is to monitor the osseointegration process. Therefore, this work aims to achieve a reliable noninvasive automatic method to evaluate dental implant stability which is directly related to the grade of osseointegration. For this purpose, an experimental phantom study was performed to simulate this process and evaluate it. Ultrasonic spectrometry was proposed and used to take measurements that were processed and analyzed to estimate the stability of the simulated dental implant. The phantom that was designed and used in the experiments simulated a jawbone with a dental implant and was made of a little pool filled with soft-tissue-equivalent material (with respect to ultrasound waves) and a solid cylinder of fresh oak-wood immersed into it to simulate the jawbone. A metal screw was used to simulate the dental implant. By screwing this screw into or out of the wooden cylinder, varying grades of stiffness and contact between the screw and the wooden tissues were obtained. And by this way, varying screw stability grades which simulate varying osseointegration grades were achieved. Pulse-echo ultrasound was used to measure the power spectra of the received ultrasonic echo-signals. These power spectra were, at first, processed and normalized then analyzed by using the partial least squares method to estimate the corresponding implant stability or stiffness grades. The number of screwing turns (for the screw into or out of the wooden cylinder) was used as a measure of stiffness grade.The feasibility of this approach was investigated through experimental tasks and promising results were achieved. A coefficient of determination R^2 of 96.4% and a mean absolute error of ±0.23 screwing turns were achieved when comparing real and estimated stiffness-grade values, indicating the high efficiency and good accuracy of this approach.

Key-Words: -Screw dental implant stability; stiffness grade; contact grade; partial least squares PLS; pulse-echo ultrasound; spectroscopy; spectral analysis; power spectra;

1 Introduction

In recent years, dental implant surgeries became common among almost all patients categories; female, male, young and elderly patients. In general, this type of surgeries is performed in a series of four phases that are different. The most critical phase of such a surgery is the second one, which is called the osseointegration phase (Branemark*et al.*, 1969 [2]), during which the integration of the dental implant into the living jawbone occurs gradually. The progression of the osseointegration process depends on many factors, such as age, gender, bone tissue density and the pathological condition of the patient. Therefore, the completion of the osseointegration phase may take a longer or a shorter period of time. Consequently, it is important to not to disturb the osseointegration process as long as that is possible. For this reason, as well as other usually desired clinical considerations, it is required to use a non-destructive, risk-free and mobile clinical routine to evaluate the osseointegration process by measuring the stability or the fixation of the dental implant in the jawbone.

In 1929, Sokolov had already proposed his novel idea to use ultrasound for non-destructive testing of