

An Overview of Implant Stability Measurement



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Abstract

To achieve and maintain a successful osseointegration, implant stability is a determining factor in implant dentistry. Implants with sufficient primer stability are claimed to be available for immediate or early loading. In this mini-review, all methods for dental implant stability measurement and recent developments are discussed.

Keywords: Implant; Primary stability; Measurement; RFA; Osstell

Introduction

With Branemark's development of implant systems in the 1960's, dental implants have become a reliable treatment option for tooth loss [1]. One of the most important criteria for implant success is osseointegration [2]. Osseointegration is defined as the direct and functional connection between the implant and the bone surface [3]. Osseointegration also determines implant stability that is occurred in two different stages; primer and secondary stability [4]. Primer stability is related to the mechanical connection of the implant to the cortical bone. Sekonder stability is the biological stability between bone regeneration and remodeling [5]. The majority of the clinicians think that the loading should be applied after the direct relationship between the implant and the bone is obtained [6]. Mobility in implants is considered as a sign of a problem with osseointegration. For this reason, the lack of mobility and the fact that the implant-bone connection can be measured before loading is of great importance for the success of the implants in the future [7]. Although there are several methods of measuring implant stability such as radiographic analysis, insertion torque test, reverse torque tests, shear torque tests, percussion test, periotest and resonance frequency analysis [8-11], none of them provide established measurement standards yet [12]. However, simple and non-invasive methods are recommended for measuring implant stability and osseointegration [8]. In this mini-review, all methods for dental implant stability measurement and recent developments are discussed.

Methods of Measuring Implant Stability

Radiographic Analysis: Radiographic analyses are non-invasive methods that can be used at every stage of the healing

period. Bitewing radiographs provide information about crestal bone levels, which are considered to be an important criteria for implant success [13]. Crestal bone loss around dental implants of 1.5mm during the first year followed by a loss of 0.2mm in the subsequent years has been generally considered acceptable for dental implants [2,14]. This method alone is not sufficient to determine implant stability, because conventional periapical or panoramic devices only inform us about mesiodistal bone loss [15], and radiographs are incomprehensible unless the change in bone mineralization exceeds 40% [16]. Among radiographic analyses, computerized tomography is the best method to determine the change in crestal bone level. However, their clinical use is time-consuming and expensive [17].

Insertion Torque Test: Insertion torque of implants is measured during surgical implant placement [18-20]. There is a significant correlation between bone density and placement torque, which determines implant stability [21,22]. The more intense the bone, the higher the insertion torque and the implant will be stable [23,24]. Clinical trials have established a minimum torque value of 20 Ncm and a maximum torque value of 32 Ncm for a successful osseointegration [25].

Reverse Torque Test: This method was found by Roberts et al. [26] and developed by Johansson and Albrektson [27,28]. This method measures the critical torque value that will cut the connection between the implant and bone. This method measures implant stability once the implant has been surgically placed. It has been reported that the reverse torque test may be destructive, causing peri-implanter plastic deformation in the osseointegration

process and loss of implant [7,4]. This method cannot measure the degree of osseointegration and only used *in-vitro* studies [9].

Shear Torque Test: Shear torque tests were found by Johansson [20] and developed [18,19,24,29]. During surgery, energy from the electric motor (J/mm^3) is given and the delivered energy is measured. According to the amount of force applied by the operator, the energy should be unchanged and the pressure generated should be controlled [18]. It is claimed that this given energy demonstrates the density of the bone and determines the stability of the implant [18,19,24,29]. This method is used to determine the density of all kinds of bones. With this method, it is possible to have an idea about implant stability by checking the placement torque [30]. The limitations of the shear torque tests are; the lower limit in the measured energy values is unknown and it can only be used during surgery and bone healing [19].

Percussion Test: Percussion test is one of the easiest tests to understand the level of osseointegration [4,31,32]. This test is based on vibrational acoustic cognition and response theory. Implant is hit with a metallic tool and osseointegration is evaluated according to the result. A faint sound indicates a good osseointegration, while a faint sound indicates no osseointegration [31,32]. This test is a subjective evaluation method that cannot be standardized and may vary according to the clinician's experience [9].

Periotest: Periotest was produced by Siemens in 1997 [33]. It was designed to measure the properties of the periodontium of the tooth. However, it is mostly used to measure implant stability [31]. Periotest is an electromechanical device. It has an electronic monitor and a head that can be used to hit the implant or tooth 16 times in total. The measurement takes 4 seconds. The tapping head has a sensitive tip, recording the duration of the implant or tooth contact. The lower the stability, the longer the contact duration and the higher the Periotest value [33]. The periotest value ranges as follows; -8 / 0 (good osseointegration, implant can be loaded), +1 / +9 (requires clinical evaluation, implant is not ready for loading) and +10 / +50 (inadequate osseointegration) [33,34].

Resonance frequency analysis: Resonance frequency analysis (RFA) is a non-invasive device that can be used clinically in determining the implant loading time, measuring implant stability and osseointegration [35-37]. Clinically, RFA values are correlated with changes in implant stability during bone healing [4]. RFA is evaluated as Implant Stability Quotient (ISQ) from 1 to 100 as a numerical data [35]. The higher the ISQ value, the higher the implant stability [38]. The factors affecting ISQ values are the length, diameter and design of the implant with the quality and quantity of the bone [39].

The first generation of the RFA device contained a sleeve made of stainless steel or titanium and a piezoceramic element. The beam elements in the arm generate vibrations by stimulating frequency

sinusoidal signals ranging from 5-15kHz, and the incoming response is read by the frequency analyzer on the computer. The second-generation RFA device amplified the signals generated by the charge amplifier by measuring the piezoceramic arm response in Hertz (Hz) [9]. Then, a more useful device (Osstell, Osstell AB, Göteborg, Sweden) was developed between 1997-2000 [40]. According to initial prototypes, this unit had a different design and function, while the measuring unit contained a transducer that could be autoclaved and calibrated.

In the following years, the implant stability ratio (ISQ) was improved in stability measurements. The ISQ value was recorded between 1 and 100 and was developed as an increasing unit of measurement as the implant stability increased. Then, the SmartPeg device (Osstell AB, Göteborg, Sweden), which can measure without touching and operates with the same electronic principle as the resonance frequency, was produced. In this device, the sinusoidal signal in the transducer passes through the cable to create magnetic pulses, which stimulate the magnetic field. After each pulse, the electronic ring in the measurement probe rises to the measured magnetic field. The second ring in the probe forms the magnetic pulses. The aluminum column has a simpler design that does not require calibration relative to the transducer [41-44].

The transducer of the latest Osstell devices can be used for different implant systems regardless of the implant type, which can perform similar RFA measurements. The transducer consists of an aluminum rod called a smartpeg, magnetic carrier at the tip, which is screwed with a force of approximately 4-6 N/cm. The tip of the device is electromagnetically stimulated without touching the Smartpeg. The incoming signals generate two-way vibration on the Smartpeg, perpendicular to each other. It is recommended that Osstell's measuring head should be positioned at an angle of 90° with two consecutive measurements [35]. Implant stability values are recorded by reading from the device.

The next generation resonance frequency analyzers after Osstell are: Osstell Mentor, Osstell ISQ, and the Osstell Idx, which operate on the same principle and make measurements using electromagnetic signals from Smartpeg [45]. After all these developments, researchers who produced the Osstell device marketed Penguin RFA (Integration Diagnostics Sweden AB, Göteborg, Sweden), a biocompatible titanium material that can be repeatedly autoclaved with a multi-use transducer (MulTiPeg™), a small pen-shaped battery-powered new generation RFA device [41]. There are various studies conducted on the reliability and ISQ values of RFA devices, and the reliability of all of Osstell's generations from RFA devices has been compared with other methods of measuring implant stability [8,35,29,42-54]. According to author's knowledge, there is only one study which evaluated and compared the reliability and repeatability of Penguin RFA with Osstell ISQ [55]. It was found that, Osstell ISQ was more reliable than Penguin RFA, and these devices were reliable only in hard interfaces.

Conclusion

Primer stability specifies implant-loading times and protocols for implant-supported restorations. Implants with sufficient primer stability are claimed to be available for immediate or early loading. If the primer stabilization of the implants is adequate, the long-term success of the implant would be higher.

With the increasing interest in immediate loading in recent years, researches in the field of primer stabilization has increased. Several methods have been investigated to evaluate the stabilization of implants, but no standardization has been established yet. Histomorphometric analysis is an objective but invasive method with proven accuracy in measuring the distance between the implant and bone. Since invasive methods are rather destructive, they are preferred only in experimental studies. Although all other non-invasive methods are subjective, RFA devices are claimed to be more objective and superior to other methods.

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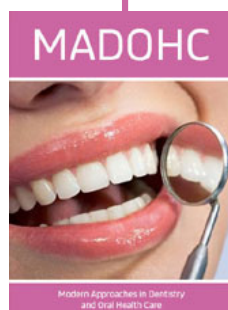
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