

Implant Stability Measurement using Resonance Frequency Analysis: A Review Update

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ABSTRACT

The resonance frequency analysis (RFA) for implant stability measurement was figured by Meredith and his partners over 20 years back. RFA uses a transducer (peg), which is appended to the implant and energized over a scope of frequencies by electro-attractive waves to evaluate the resonance frequency (RF) of the transducer. The basic RF estimations in Hz are deciphered to Implant Stability Quotients (ISQ) units from 1 being the most minimal incentive to 100 ISQ units being the most noteworthy. A propelled era of RFA innovation has been produced comprising of a compact battery-driven instrument (PenguinRFA) utilized together with autoclavable titanium transducers which can be reused (MulTiPeg). This versatile instrument can be immediately utilized by the specialist without endangering sterility as it can be stuffed in a sterile pocket and be placed on the surgical tray. RFA measures implant stability in twisting as an element of interface firmness and corresponds with implant dislodging, i.e. small scale mobility, under lateral loading. The ISQ value is controlled by the neighbourhood bone thickness and is affected by implant placement technique, implant configuration, healing time and uncovered implant stature over the alveolar crest. It appears like implants with low as well as falling ISQ values represent an expanded hazard for disappointment contrasted and implants with high or potentially expanding values. The RFA system can be utilized at any phase amid treatment as one extra parameter to bolster basic leadership amid implant treatment and development.

KEYWORDS: Resonance Frequency Analysis (RFA), Implant Stability Quotient (ISQ), Implant, Osseointegration

INTRODUCTION

Dental implants are screws that are set into the jawbone are utilized to bolster a prosthesis.¹ The fruitful result of any implant procedure requires a progression of patient-related and strategy subordinate parameters.² The volume and nature of the bone are the two contemplations, which bind the kind of surgical methodology and the kind of the implant.³ Both variables add to the accomplishment of dental implant surgery. It has been recommended that primary implant stability is essential for unbeaten osseointegration.⁴ Primary stability is a component of nearby bone quality and amount, the structure of an implant (i.e. length, width and sort), and the installation technique utilized (connection between drill size and implant estimate, whether a pre-tapped or self-tapped implant is utilized). Implant stability can be measured by non-invasive clinical test techniques (i.e. tapping, insertion torque, the Periotest, the Dental Fine tester, vibration strategies), and invasive research test techniques (i.e. removal torque).⁵ One of these quantitative strategy is the resonance frequency (RF) analysis system depicted by Meredith et al.⁶, where the implant stability is recorded by utilizing resonance frequency machine and the transducer including piezocreamic components. The

aim of this paper is to survey and dissect fundamentally the current accessible writing in the field of RFA, and to likewise talk about in view of logical proof, the prognostic estimation of RFA to identify implants at danger of disappointment.

ACCURACY OF CBCT

Meredith et al. in 1996 were the first to portray RFA strategy. The resonance frequency meter works on the principle of a tuning fork. The resonance frequency analysis technique investigations the principal resonance frequency of a little transducer joined to an implant apparatus or projection⁽⁷⁾. The resonance frequency of the resonance frequency examination framework depends on three overwhelming components⁽⁸⁾: to begin with, the construction of the transducer itself; second, the stiffness of the implant fixture and its conjugation with the tissues and encompassing bone; and, third, the aggregate effectual length over the marginal bone level (Fig. 1). The effective length is the length of the transducer, which is settled and the length of the projection, which may vary however at planned interims, and the level between the highest point of the fixture and the encompassing bone. The resonance frequency investigation method is the place a transducer utilizes a striking light bowing power

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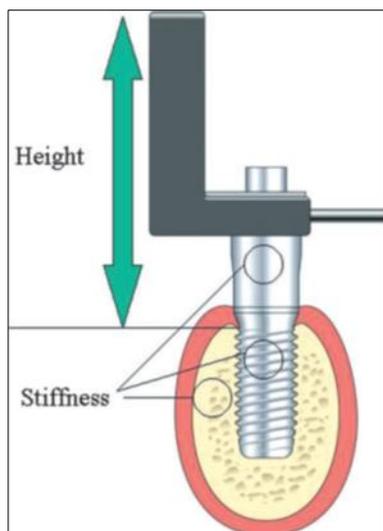


Fig.1 A schematic showing the principles of resonance frequency analysis. The stiffness of the transducer, implant and bone influences the outcome as well as the effective length of the implant above the bone crest (length).

on the implant bone complex. The twisting power conveys to manage a settled sidelong drive to the implant and measures the uprooting, in this manner copying the clinical loading condition, but of an abundantly decreased extent.

The main era of RFA turned to a transducer gathered from stainless steel or titanium and enveloped an offset cantilever beam with piezoceramic components (Fig.2).

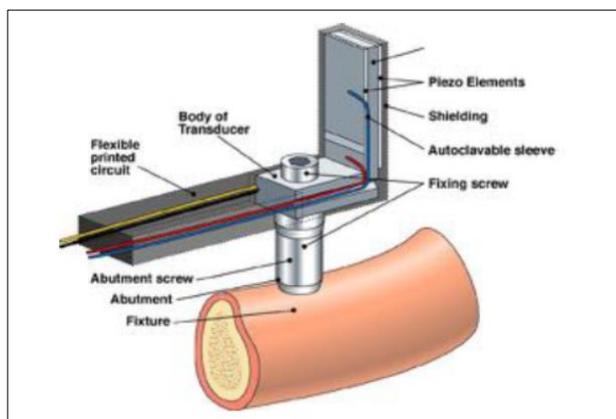


Fig.2 Schematic of a first generation RFA transducer

Frequency response analyser and a PC create a sinusoidal signal of differing frequency from 5 to 15 kHz, which is delivered by the vibration of the beam. The response of the beam was measured by the second piezoceramic component and a charge amplifier improved the signal produced. A noteworthy stride up in abundance and change in period of the received signal is seen at the flexural resonance frequency of the beam. The RF at which the pinnacle showed up was utilized to portray the stability of the implant in Hertz (Hz). Every transducer of first and second generations' resonance frequency investigation instruments had its own principal resonance frequency, this was a noteworthy disadvantage for these generations. It was unrealistic to translate resonance

frequency examination comes about chairside. In addition, the framework with the reaction analyser and a PC was thought to be difficult and vexatious. The third generation of resonance frequency examination instruments addresses to convey a little battery-driven framework, which empowers fast and easy estimations, giving chairside translations. The consequence of an estimation is submitted as a parameter – the implant stability quotient. The implant stability quotient depends on the fundamental resonance frequency and reaches from 1 (most reduced dependability) to 100 (most elevated strength).

Another generation of RFA innovation has been produced by colleagues of the first group behind the commercialisation of RFA (Integration Diagnostics Sweden AB, Gothenburg, Sweden). A little pen-like battery-driven instrument (PenguinRFA) is utilized together with reusable transducers (MulTiPeg™) (Fig.3). These are contrived from biocompatible titanium and can be autoclaved and used copious times. The instrument can be pressed in a sterile pouch and placed on the surgical tray (Fig.4).



Fig.3 showing a novel RFA instrument and reusable transducers made from titanium (PenguinRFA and MulTiPegs).

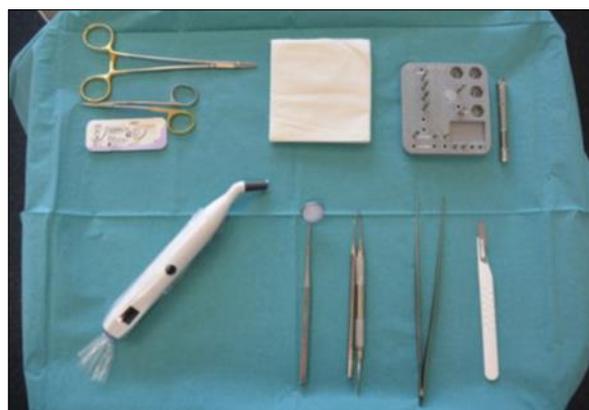


Fig. 4 Showing the PenguinRFA in a sterile pouch on a surgical tray for implant placement.

Factors determining RFA measurements:

1. Factors related to bone density: Bone density is a major determinant of RFA measurement as shown in numerous studies. A positive correlation between ISQ units and bone density as assessed with the

Lekholm & Zarb index⁹⁻¹³, with insertion torque measurements and with quantitative CT has been demonstrated¹⁴⁻²³. Early clinical work indicated a relationship between bone density and primary implant stability. Friberg et al.⁽²⁴⁾ correlated cutting resistance (i.e. bone density) with primary stability for maxillary implants. Follow-up measurements performed at the time of abutment connection (6–8 months later) and after 1 year in function indicated that all implants, irrespective of initial stability, tended to reach a similar level of stability. Andersson et al.²⁵ during a study period of 12 months examined 102 Neoss implants and found an inverse relationship between cutting torque (bone density) and changes in implant stability. They also acknowledged a correlation between bone quality, gauged by Lekholm & Zarb²⁶, and primary stability. Implants placed in soft bone with low initial primary stability showed a noticeable upsurge in stability when paralleled with implants placed in dense bone. In fact, implants placed in dense bone, type 1 and type 2 revealed a minor decrease in stability, probably as a result of marginal bone remodelling, but all implants reached a parallel level of stability after 1 year.

2. Factors related to implants: The impact of implant length and width on RFA estimations is not clear and appears to change between studies. Östman et al²⁷ and Miyamoto et al²⁸ discovered higher stability with increased implant width yet diminishing stability with increasing implant length, which is clarified by the way that some long implant outlines have a lessened width (negative resistance) in the coronal part to minimize friction heat and to facilitate insertion. Other authors announced that the primary stability for a similar implant configuration put in grafted bone was noteworthy higher for 15 and 18 mm long implants than for 10 and 13 mm implants.²⁹ Bischof et al³⁰ found no impact of implant position, implant length, implant measurement and vertical position on the ISQ estimations of 106 implants put in the maxilla and the mandible, which is in accordance with the discoveries from different analysts.³¹⁻³² A clinical review found a higher stability for 12 mm than for 10 mm implants and for 4.8 mm than for 4.1 mm wide implants.³³
3. Surgical technique: The use of technique to create increased lateral compression during insertion seems to result in higher stability. This may be due to undersized preparation before placing the implant³⁴, wider implants³⁵ or the use of tapered implant.³⁶⁻³⁷ Ulisses Tavares and co-workers found higher stability of implants placed using the piezoelectric method than that of implants placed using the conventional technique.
4. Time dependence: The resonance frequency analysis system has been used in animals to study implant healing in typical bone³⁸⁻³⁹, in grafted bone⁴⁰⁻⁴² and in membrane induced bone.⁴³ Friberg and associates²⁴ detailed that all implants put in the edentulous

maxilla, independent of initial stability, tended to achieve a comparable level of stability at the time of abutment connection (6–8 months after the fact) and following 1 year in capacity. This is in accordance with a clinical review by Sennerby et al⁴⁴, where implants in soft bone with low primary stability demonstrated a checked increment in stability contrasted than implants in thick bone. The information demonstrate that healing and remodeling procedure of delicate trabecular bone appears to bring about an expanded firmness of the peri-implant bone. Studies on one-stage and immediate loading implants have exhibited an underlying decline of implant stability, which, be that as it may, appears to invert following 3 months when an expansion in implant stability is typically observed.⁴⁵⁻⁴⁹ The underlying abatement in implant stability most likely mirrors the healing and remodeling process and consequently a brief debilitating of the bone. It can be theorized that loading of the implants amid this period may highlight this underlying abatement of ISQ value.⁵⁰

5. Marginal bone loss and presence of defect: The relationship between the length of an implant abutment and resonance frequency examination information has been inspected in different model frameworks. In vitro work has shown a connection between ISQ readings and the span of 0.5 mm profound peri implant defects.²² Turkyilmaz et al⁵¹ exhibited a negative connection between uncovered implant height and ISQ values for implants put in fresh extraction sockets in human jaws. The authors proposed utilizing the resonance frequency examination system to screen the recuperating of inserts in extraction attachments. Turkyilmaz and associates⁵² found a negative connection between increased marginal bone loss around mandibular implants and diminished implant stability over the initial 6 months taking after implant position. No such connection was seen between the 6-month and the 12-month think about period. The authors proposed that the impact of bone loss was made up for by an expanded interfacial firmness coming about because of bone development and remodeling from 6 to 12 months. The progressing healing procedure may have checked and veiled the impact of minimal bone loss. Be that as it may, following 3 and 5 years, when healing must be viewed as being finished, a similar research aggregate found a solid connection between marginal bone loss and ISQ values. This is in accordance with Meredith et al, who recommended that varieties in implant stability following 5 years in capacity could be clarified by contrasts in marginal bone height.

ORIENTATION OF THE RFA TRANSDUCER

The orientation of the transducer impacts the resonance frequency analysis estimations. Veltri et al.⁵³ and Fischer

et al.⁵⁴⁻⁵⁵ found that implant stability quotient values expanded by around 10 units when performing estimations with the transducer parallel to, as opposed to opposite to, the alveolar peak. The implant–bone complex most likely shows fluctuating degrees of firmness in various load bearings. Low implant stability quotient values got in the buccal–palatal bearing are an impression of thinner bone than in the mesial–distal heading. As indicated by the producer, the new remote resonance frequency analysis system (Mentor™; Osstell AB) measures the most noteworthy and the least resonance frequency at whatever point the distinction surpasses 3 implant stability quotient units. This may clarify the watched contrast in stability readings between the new and the old resonance frequency examination strategy. Valderrama et al.⁵⁶ found that the two resonance frequency analysis methods can contrast by up to 10 implant strength quotient units, with higher stability values acquired in the mesial–distal course with the wireless strategy and lower values got in the buccal–palatal bearing with the old system. The particular orientation of the old resonance frequency examination transducer might be the reason for the diverse resonance frequency analysis readings. In aggregate, it should be valued that implant resonance frequency examination strength readings shift, contingent upon which heading the estimations are made utilizing the transducer. Fig.5 demonstrates the consequences of stability estimations in 12 distinctive transducer headings utilizing the old resonance frequency analysis instrument and a course subordinate transducer. Additionally, the new resonance frequency examination strategy, as appeared in Fig.5, yielded two distinct qualities, one recording the most astounding and one recording the least implant security quotient esteem.

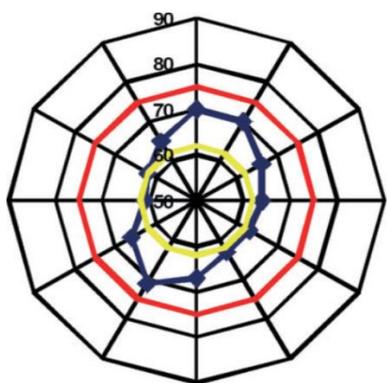


Fig.5 Resonance frequency analysis measurements of an implant in 12 directions using an Osstell™ instrument. The red and yellow circles indicate the results from one measurement using the new wireless Mentor™ technique. It is obvious that implant stability varies with the direction of the applied load and that the new resonance frequency analysis technique identifies the lowest and the highest levels of implant stability

POSSIBLE CLINICAL IMPLICATIONS

The resonance frequency examination system can possibly give clinically applicable data about the

condition of the implant–bone interface at any phase of the treatment. The question is the means by which to profit most from data acquired by a solitary resonance frequency analysis estimation in clinical practice. To date, there is an absence of studies that record clear clinical advantages from restorative choices in light of resonance frequency analysis estimations. Clearly, one noteworthy objective in implant dentistry is to maintain a strategic distance from implant disappointment. Despite the fact that the disappointment rate of implants utilized as a part of two-phase methodology is somewhat low, it is likely that higher disappointment rates are connected with immediate loaded or grafted implants. Moreover, increasingly more implant procedures are being performed by relatively inexperienced clinicians, who will be confronted with a variety of complications during their learning curve. As implant disappointments are regularly identified with biomechanical variables, an appraisal of implant stability may essentially bring down the danger of disappointment. Studies have demonstrated that high resonance frequency examination qualities are characteristic of a fruitful implant treatment with a little hazard for future disappointment. On the other hand, low or diminishing resonance frequency examination values indicate an expanded hazard for implant inconveniences, despite the fact that the correct resonance frequency analysis edge values presently can't seem to be recognized. The resonance frequency analysis method might be valuable for evaluating immediate loading implants amid the different phases of treatment. For example, a specific implant stability quotient value can be utilized as an incorporation model for immediate loaded implants. Ostman et al.⁽⁵⁸⁻⁵⁹⁾ announced low disappointment rates when utilizing implant stability quotient 60 as a consideration standard for immediate loaded implants in absolutely edentulous maxillae and in posterior mandibles. The authors discover the resonance frequency examination strategy to be useful in choosing when to supplant a immediately loaded transitory prosthesis with a permanent prosthesis after implant situation. Values above implant stability quotient 65 demonstrate an ideal reaction to immediate loading, while low implant stability quotient qualities might be characteristic of over-burden and continuous disappointment. In such cases, emptying and maybe situation of extra implants before fixing the lasting prosthesis ought to be considered. At last, the resonance frequency examination procedure may serve as a profitable apparatus for reporting the clinical result of implant treatments. This might be especially vital in a medico-legitimate setting. Additionally, for the implant specialist, who gets alluded patients for implant position for later prosthetic treatment by the alluding dental specialist, the resonance frequency examination procedure may guarantee the alluding dental practitioner and the patient of adequate implant solidness preceding initiating the prosthetic treatment stage. At the end of the day, the resonance frequency analysis method can be utilized to give a unique finger impression of inserted implants.

CONCLUSION

The RFA method furnishes with clinically significant data about the condition of the implant–bone interface at any phase after implant situation. The ISQ value mirrors the micro-mobility of an implant when loaded, which thus is controlled by the biomechanical properties of the encompassing bone tissue and the nature of the bone-implant interface. It appears like implants with low as well as falling ISQ values represent an expanded hazard for disappointment contrasted and implants with high or potentially expanding values. It is likely that ISQ estimations can be utilized as one extra parameter for analysis of implant security and basic leadership amid implant treatment and development.

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