

REVIEWS

INFLUENCE OF DIFFERENT FACTORS ON THE RESONANCE FREQUENCY ANALYSIS IN ASSESSMENT OF IMPLANT STABILITY – REVIEW

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ABSTRACT

INTRODUCTION: Implant stability is one of the key factors in regard to the successful outcome of implant treatment. Resonance frequency analysis (RFA) is one of the most commonly used methods in measuring the implant primary and secondary stability. The method is reliable and noninvasive, which makes it suitable at the different stages of the implant treatment.

AIM: The aim of this review was to establish some of the factors, which could affect the results obtained during RFA.

MATERIALS AND METHODS: Articles related to the subject were searched in PubMed and Google Scholar databases. Articles only in English language, published from 1996 to 2019, were included. Variety of keywords in different combinations were used to conduct the search.

RESULTS: Articles, included in this review described clinical and experimental studies. Few reviews of the literature were added as well. Some of the articles considered RFA as a single method for measuring implant stability, while others described its use in combination with other methods. Bone-related factors, implant surface, diameter, length, as well as the position of the transducer of the device were discussed as factors, which could influence the ISQ values.

CONCLUSION: It seems that among the discussed factors, BIC, bone density, implant diameter and the orientation of the transducer demonstrated more distinct relation to the RFA results. The influence of the implant surface modification and implant length on the ISQ values remains controversial.

Keywords: *resonance frequency analysis, dental implant*

INTRODUCTION

Implant stability is one of the key factors in regard to the successful outcome of the implant treatment. Resonance frequency analysis (RFA) is one of the most commonly used methods in measuring the implant primary and secondary stability. The method is reliable and noninvasive, which makes it suitable at the different stages of dental implant treatment.

AIM

The aim of this review was to establish some of the factors, which could affect the results obtained during RFA.

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MATERIALS AND METHODS

Articles related to the subject were searched in PubMed and Google Scholar databases. Articles only in English language, published from 1996 to 2019 were included. Variety of keywords in different combinations were used to conduct the search: “resonance frequency analysis”, “implant stability quotient”, “primary stability”, “secondary stability”, “macro design”, “micro design”, “length”, “diameter”, “surface” “bone to implant contact”, “transducer”.

RFA was proposed for the first time by Meredith et al. (1). In 1998 RFA was discussed by Meredith (2) and Sennerby and Meredith (3) as an alternative novel method for evaluation. The resonance frequency analysis assesses the stability of implants measuring their micromotion or moving into the bone under the influence of laterally targeted loading, exercising microscopic lateral forces on the implant via vibrating transducer (4,5). The method is based on mechanical vibration and measurement of the frequency of the so developed resonance (1, 6). According to Trisi et al. (7) there is a significant correlation between the implant micromotions and RFA.

The method defines implant stability in the range of 1 to 100, based on the Implant Stability Quotient (ISQ) (1). Meredith et al. (6) commented that the method served both for the measurement of primary stability and for the assessment of the stability during the osseointegration phase. Other authors also concluded that RFA could be used to determine the changes in implant stability over time (8). The method is widely used for planning and monitoring of cases of immediate and early loading of dental implants (8-13). It could be used for evaluating implant stability at different stages of healing and at routine examinations, because of its noninvasiveness (4,14).

According to Huwiler et al. (15), ISQ values in the range of 57 to 70, measured during the early osseointegration process, indicated homeostasis and implant stability. The authors commented that RFA cannot be used to predict the loss of implant stability over time, because its values decrease only after the clinical appearance of instability. Investigating implants with hydrophilic surface in regard to an early loading protocol (12), mean ISQ of ≥ 70 for all implants included in the study was established, where they were loaded with temporary constructions. Au-

thors observed gradual increase of the ISQ values on the 3rd and 6th month. According to other authors the immediate loading protocol requires values above 55 ISQ (11), while according to Andersson et al. (16) implants, demonstrating ISQ below 70 and 75 at insertion or after healing period of 3-4 months had a significantly higher risk of failure. The authors concluded that RFA could be useful in determining implants, which are more likely to fail (16). According to other authors RFA could not be used to predict the implant stability over time (17). Other authors also concluded that the RFA could not be used as a prognostic method in regard to the long-term success or failure of the implants (18).

Factors Influencing RFA Results

◆ Bone-Related Factors

Meredith et al. (19) found correlation between resonance frequency and effective implant length, which is calculated as a sum of the abutment length and the marginal bone loss. The last is measured by the number of threads, which were exposed and visible on intraoral periapical radiographs. The authors also suggested that alterations in implant stability after period of time of 5 years could be related to the changes in the marginal bone level.

According to Sim and Lang (17), the bone structure and implant length affect the RFA results. According to other authors, the values of RFA correlated with both bone to implant contact (BIC) and the level of the crestal cortical bone, which was penetrated by the implants, but did not correlate with the mineral bone density, trabecular bone pattern factor and the density of trabecular bone (20). Dias et al. (21) did not observe any effect of the bone microstructure on the ISQ changes. Bone density is better represented using the insertion torque than using RFA (22). There was found better correlation between maximal implantation torque and the stiffness of the bone-implant system than between the stiffness of the bone-implant system and RFA (23).

According to other authors bone quality correlated with RFA results, as they obtained lower ISQ values by inserting the implants in softer bone. They concluded that bone density related factors may influence the primary stability (24). Other authors (4,25) also observed significant correlation between primary stability, measured using RFA and the bone density.

Park et al. (26) conclude that the ISQ values obtained during primary stability measurement demonstrate significant correlation with BIC, but not with bone volume. According to the authors RFA is a reliable method in regard to observation of the BIC values and the implant stability. Other authors also commented on a positive relationship between RFA and BIC (27). Dagher et al. (28) did not establish correlation between the results obtained during RFA and BIC.

Merheb et al. (29) concluded that mean RFA values were not affected by the presence of bony dehiscence at the implant placement.

Hernández-Cortés et al. (30) did not detect a relationship between primary stability measured by RFA and the structure of the trabecular bone, as well as the cortical bone thickness. Other authors also did not find correlation between cortical bone thickness and the changes in the ISQ values (21). Unlike them, Tanaka et al. (31) came to the conclusion the thickness of the cortical bone may influence ISQ. Fu et al. (32) found only weak relation between the bone type in the upper jaw and ISQ, adding that RFA should be used cautiously, especially as a method for assessing the bone quality in the lower jaw. According to some authors ISQ is significantly affected by the levels of the periimplant bone (33).

In an experimental study Kwak and Kim (34) evaluated the influence of implant contact ratio and stiffness of implant-surrounding materials on the results of RFA, using resin and silicone blocks. The authors concluded that the increase in stiffness of material around implant resulted in higher RFA values.

◆ Implant Microdesign

Pimentel Lopes de Oliveira et al. (35) comparing primary and secondary stability of implants with anodized and acid-etched surface, observed statistically significant higher values for the acid-etched implants on the 21st day after the implant insertion.

Some authors did not observe significant difference in ISQ values comparing implants with different surface modification or topography (36-39), while according to others (28, 40-42) surface modification affected the RFA results.

◆ Implant Macrodesign

According to many authors implant diameter influences the RFA outcome (24,43-47), while ac-

ording to Merheb et al. (25) the implant diameter does not affect significantly the ISQ values.

Comparing the primary stability of tapered and cylindrical implants, some authors established statistically significant positive correlation between the diameter of cylindrical implants and their primary stability, but they did not find a relationship between the diameter and the primary stability of the tapered implants (48). Another study established an inverse relationship: implant diameter affected ISQ of the tapered implants, but did not affect the primary stability, measured using RFA, of the paralleled walled implants (9).

According to Han et al. (49) RFA cannot be influenced by either surface modification of implants, or implant diameter, while according to other authors ISQ values are affected more by the implant design than the bone density (22).

Horwitz et al. (44) commented on the positive relationship between implant diameter and ISQ. They did not observe significant influence of the implant length on ISQ. Rokn et al. (47) and Gultekin et al. (46) reported similar results. Other authors also found dependence between implant macrodesign and RFA, as they commented on a positive correlation between implant diameter and ISQ and negative correlation with implant length (50). Ostman et al. (24) reported similar results: longer implants demonstrated lower stability, measured using RFA.

Merheb et al. (25,29) obtained the following results: implant length had no significant impact on the mean RFA results. Gomez-Polo et al. (43) came to the similar conclusion.

Hong et al. (51) concluded that RFA is more affected by the implant length than by the presence of cortical bone. Other authors (17, 22) came to a similar conclusion: RFA was influenced by the length of the implant.

Tsolaki et al. (52) comparing the values obtained during RFA for implants of 10 mm and of 13 mm length, observed statistically significantly higher values for the longer implants. They came to the conclusion that the implant length positively affected primary stability. Other authors also shared similar observations (53,54).

◆ Device-Related Factors

Cappek et al. (55) observed the influence of the transducer orientation on the primary stability during its measurements using RFA. Authors commented that positions between 30 and 80 degrees to the long axis of the alveolar crest caused changes in the system. Other authors found that there was a difference in the results obtained, when the position of the transducer was parallel and when it was perpendicular to the alveolar crest (56,57).

Sim and Lang (17) investigating the factors influencing the RFA measurements concluded that ISQ values were not influenced by the position of the Osstell mentor device.

Although different ISQ values were observed, comparing the results obtained using the electronic and the magnetic device, Valderrama et al. (58) concluded that there was a correlation between the alterations in implant stability measured with both devices.

There is also a study about the optimum torque used to tighten the Smartpeg elements of magnetic RFA devices. According to the authors it must be within 5 to 8 Ncm to obtain objective values (59). Other authors considered torque in the range of 10 to 17 Ncm during the installation of the measuring peg as optimal to obtain precise results (60).

RESULTS

Articles, included in this review described clinical and experimental studies. Few reviews of the literature were added as well. Some of the articles considered RFA as a single method for measuring the implant stability, while others described its use in combination with other methods. Bone-related factors, implant surface, diameter, length, as well as the position of the transducer of the device were discussed as factors, which could influence ISQ values.

DISCUSSION

It seems that there is a prevalence of the reports supporting the theory, that there is a relation between RFA and BIC (20,26,27).

In regard to the influence of bone density on the RFA results there are different theories. Some of the authors support the conception that bone density related factors could influence the ISQ values (4,24,25), but others deny their effect on the results obtained during RFA (20).

The relation between the ISQ values and the implant surface modification remains debatable, because of the almost equal number articles, supporting the both theories: supporting the relation (28,40-42) and rejecting it (36-39,49).

There are many studies, which confirm the relationship between the implant diameter and the ISQ values (9,24,43-45,48,50), as some of them (9, 48) established that implant diameter influences the primary stability only of certain implant designs, without affecting the stability of others. Two studies did not report any significant effect of the implant diameter on the ISQ values (25,49).

In regard to the influence of the implant length on the ISQ values the results are more controversial. There are three theories about the way the implant length affects the RFA: in a negative way (24,50), in a positive way (52-54) or does not affect the measurements in a significant way (25,29,43,46).

According to most authors the position of the transducer affects the RFA measurement (55-57).

CONCLUSION

It seems that among the discussed factors, BIC, bone density, implant diameter and the orientation of the transducer demonstrated more distinct relation to the RFA results. The influence of the implant surface modification and implant length on the ISQ values remains controversial.

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