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ORIGINAL ARTICLE

What is the Effect of Implant-tooth Distance on Resonance Frequency Analysis Measurements?

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ABSTRACT

Objectives: The volume and density of the bone surrounding an implant directly affect the implant stability during the healing period.

The aim of this study was to determine the correlations between resonance frequency analysis (RFA) readings and implant-tooth distances at the crestal and average apical-crestal levels.

Materials and methods: Nine patients received 22 implants. Periapical radiographs were taken at 6 weeks, and the implant-tooth mesial and distal crestal level distances were measured, along with the mesial and distal apical levels. The average mesial (AM) and average distal (AD) apical-crestal distances were calculated. In cases in which either the AM or the AD of the implant was below 4 mm, the specimens were placed in the AMD– group; when both the AM and the AD were greater than 4 mm, the specimens were placed in the AMD+ group. The lower values were used for both groups. Resonance frequency analysis measurements were taken in the mesiodistal direction at 6 weeks. The correlations between the mean RFAs and the means of the distances were examined using Spearman's or Pearson's correlation tests, depending on the distributions of the data.

Results: The mean and SD of the AD group was 3.99 ± 3.19. The mean and SD of the AM group was 3.80 ± 2.67. The mean and SD of the AD– group was 2.72 ± 0.89. The mean and SD of the AD+ group was 6.34 ± 2.94. The mean and SD of the RFAs at 6 weeks was 77.82 ± 5.24, and for the AMD– and AMD+ groups, these measures were 78 ± 5.55 and 77.64 ± 5.36, respectively. None of the correlations between the RFAs and any of the distances were significant: AD ($r = 0.114$; Pearson's test, $p < 0.05$), AM ($r = -0.217$; Spearman's test $p < 0.05$), AMD– ($r = 0.248$; Pearson's test, $p < 0.05$), and AMD+ ($r = 0.3$; Spearman's test, $p < 0.05$).

Conclusion: Within the limitations of this study, no correlations between the RFA readings and the implant-tooth distances were found at any level or distance.

Keywords: Correlation, Implant-tooth distance, Implant stability, Resonance frequency analysis.

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INTRODUCTION

Many factors affect resonance frequency analysis readings. Some of these factors are biological,[1,2] and others are technical.[3] The latter factors affect RFA readings when the orientation of the transducer is altered or when the transducer is tightly screwed into the fixture.[3,4] Different types of implants also affect RFA readings due to the use of different types of transducers.[5,6] Another technical factor is whether old electronic devices or new magnetic RFA devices, which yield different readings, are used.[3] The quality of the bone and the bone behavior during the healing period are other biological factors that can affect RFA readings.[7] Previous studies have shown that there are significant differences between RFA readings from the maxilla and mandible due to the different bone densities.[8,9] Another factor that affects RFA readings is the thickness of the marginal bone around the implant on the buccal and lingual sides.[10-12] Increases in bone thickness lead to increases in primary implant stability, whereas increases in bone density produce increases in primary and secondary implant stability. Bone density, quality, thickness and remodeling are biological factors that can affect RFA values during the healing period, and all these factors have been addressed in the aforementioned studies.

The present study sought to determine whether RFA readings are correlated with the distances between the implant and the adjacent teeth in a partially dentate jaw. An older generation of RFA devices was used in most of the previous studies, but this study used a newer magnetic device to detect implant stabilities during the healing period. This study attempts to draw the attention of clinicians to the effect of the presence of a tooth adjacent to an implant and its effect on the implant stability or RFA readings.

MATERIALS AND METHODS

Twenty-two implants were inserted into nine patients with a median age of 50 years. Each patient received two implants in the posterior maxilla or mandible with the exceptions of two patients who received four implants; i.e. two in the mandible and two in the maxilla.

After the initial screening, the patients selected for this study were confirmed to fulfill the inclusion and exclusion criteria.

The inclusion criteria are as follows:

- Age of more than 18 years
- Healthy residual dentition
- Adequate gap for instrumentation
- Dedication of the patient to maintaining oral hygiene
- Adequate alveolar bone width and length, with a width of at least 1 mm around the dental implant at a height of at least 12 mm
- Bilateral posterior missing tooth in the same jaw of the patient.

The exclusion criteria are as follows:

- Infirmity and advanced age
- Medical/surgical risk
- Drug/alcohol dependence
- Recent irradiation of the orofacial region
- Heavy smoking (more than 10 cigarettes)
- Bone disease (sarcoma, Paget's disease, fibrous dysplasia, osteomyelitis and cystic bone disease)
- Soft tissue disease at the implant site (mucositis, infection, ulcer or granuloma)
- Immediate implantation
- Healing of a socket extracted within the last 4 months
- Requirement for alveolar bone grafting or maxillary sinus left.

All of the procedures were explained to the patients, and the patients provided written consent for participation in the treatment. The protocol used in this study was approved by the Research and Ethics Committee at the School of Medical Sciences, University Sains Malaysia, Kubang Kerian, Kelantan USMKK/PPP/JEPem/[200.3 (6)] on March 9, 2008. A total of 22 ITI (SLA) implants (Institut Straumann AG, Basel, Switzerland) with regular necks and lengths of 10 mm were used. The diameters of the implants were either 4.1 or 4.8 mm. Eleven implants were placed utilizing the full-thickness crestal incision flap design, and the other implants were placed utilizing a flapless punch and a manual puncture (Nobel Biocare, Goteborg, Sweden). The appropriate implant position was selected and marked with a small round bur that penetrated the outer cortex. The preparation of the implant bed was performed using spiral drills of increasing diameter up to the implant diameter, copious normal saline irrigation and an intermittent drilling technique. Bone tapping was performed for the type II bone and some of the type III bone.

Each implant was placed manually into its final position with the aid of a ratchet. The implants were not submerged and were exposed 2.8 mm above the crestal bone. The insertion torques were recorded, and these torques ranged from 20 to 35 Ncm. Only one implant in the maxillary molar area required a torque value below 20 Ncm. The healing cap was placed, and the flap was repositioned. Postoperative pain and edema were controlled by administering a 15 mg tramadol tablet to the patient three times daily for the 5 days following the operation. All patients received systemic antibiotics (amoxicillin, 500 mg tablet) three times daily for 5 days postoperatively to prevent wound infection.

Resonance Frequency Analysis Measurement

At 6 weeks, the stability of the implant was measured using an Osstell™ mentor resonance frequency analysis device (Integration Diagnostic AB; Sweden). A transducer (Smartpeg™, Integration Diagnostic AB, type 4 regular neck) was manually screwed to the fixture using a sufficient amount of torque (4–5 Ncm).

All measurements were performed by a single investigator. To improve the precision and to assess the repeatability, two additional ISQ values were obtained, and the transducer was loosened and retightened between each measurement. Single representative implant stability values were computed by averaging the three ISQ values.

Radiographic Examination

At 6 weeks, periapical radiographs were taken using an Oralix AC system (Genedex® dental system, Milan, Italy). Photosensitive phosphor plates (Gendex® size 3) were used as the periapical films.

Using the longcone parallel technique, special care was taken to position these periapical films parallel to the implant using the Rinn film holder (Dentsply International, USA). Periapical radiographs were evaluated after scanning (Den Optix, Gendex®, USA). After scanning, the image was magnified using computer software (VixWin 2000 Genedex®, Madrid). The measured pixels were converted to millimeters using the 'measure tools'

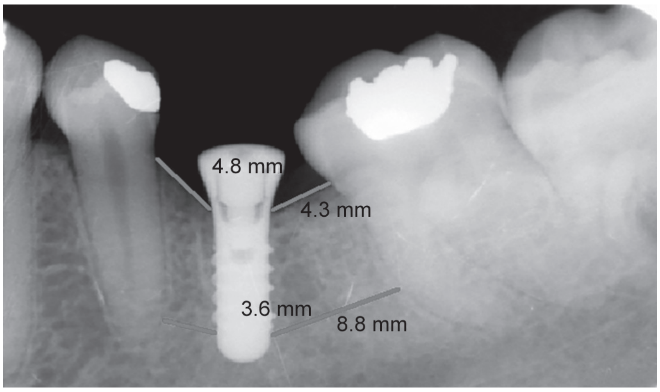


Fig. 1: Periapical radiograph showing the measurements at the crestal and apical parts between the tooth and the implant surfaces

function of this software. The known value of the inter-thread distance for the implants (the distance between each thread was 1.25 mm) was used as an internal reference distance.

Linear measurements were taken from the surface of the implant to the mesial crestal distance (MCD) and distal crestal distance (DCD) surfaces of the tooth at the crestal and apical levels of the implant (Fig. 1 and Table 1).

The average distances at the crestal and apical levels were calculated for the AD and AM groups. For both the AM and AD groups, the cases that presented with a value below 4 mm were assigned to the AMD– group. If both the AM and AD values were above 4 mm, the case was assigned to the AMD+ group.

STATISTICAL ANALYSES

For data analyses, statistical package for the social sciences (SPSS) version 12 (SPSS Inc., Chicago, IL) was used to calculate the means of the measurement scores. When the data were normally distributed within a group, Pearson's correlation coefficients were calculated to determine the relationships between the ISQ values and the different distances of that group. When the data were abnormally distributed in both groups, Spearman's correlation tests were used to identify possible relationships between the RFA and the distances. A $p < 0.05$ was considered to be significant.

Table 1: Descriptive statistics of average distal, average mesial, average mesial-distal less than 4 mm, average mesial-distal greater than 4 mm

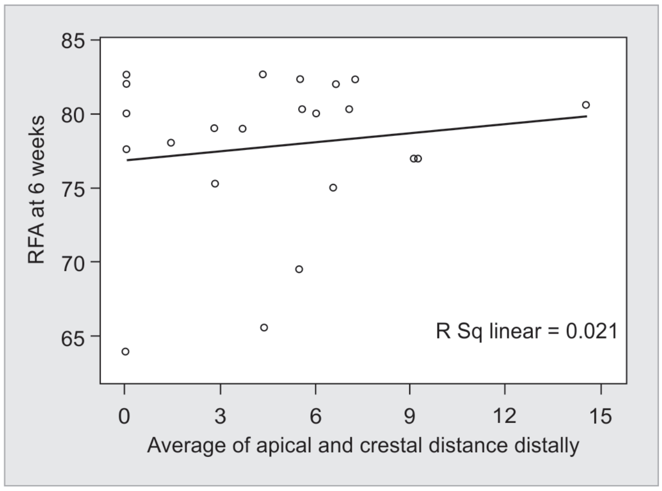
Descriptive	*AD (n = 22)*	*AM (n = 22)*	*AMD– (n = 22)*	*AMD+ (n = 22)*
Mean (SD)	3.99 (3.19)	3.80 (2.67)	2.72 (0.89)	6.34 (2.94)
Minimum	1.4	1.4	1.4	4.2
Maximum	9.1	8.65	4	14.55

Table 2: Distribution of dental implants, torque and sizes in patient mouths

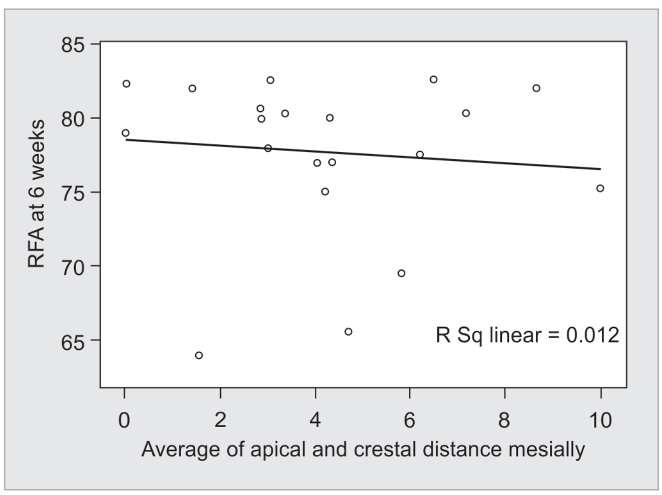
	Maxilla		*Mandible*	
	Molar area	*Premolar area*	*Molar area*	*Premolar area*
Implant distribution	3	3	12	4
Torque >35	2	2	12	4
Torque <35	1	1	—	—
Implant size	—	—	—	—
4.8	—	—	1	—
Implant size 4.2	3	3	11	4

RESULTS

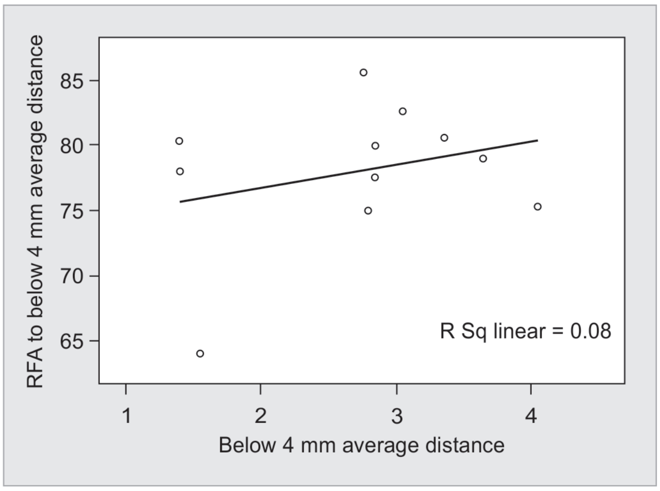
Implants were placed in the mandibles of six patients and in the maxillae of three patients (Table 2). All patients attended a 6-week follow-up examination. The postsurgical wound healing was uneventful in all cases, and none of the cases exhibited any of the following: (1) continuous pain, (2) implant mobility, (3) radiographic radiolucency, or (4) infection. The cumulative survival rate was 100%.



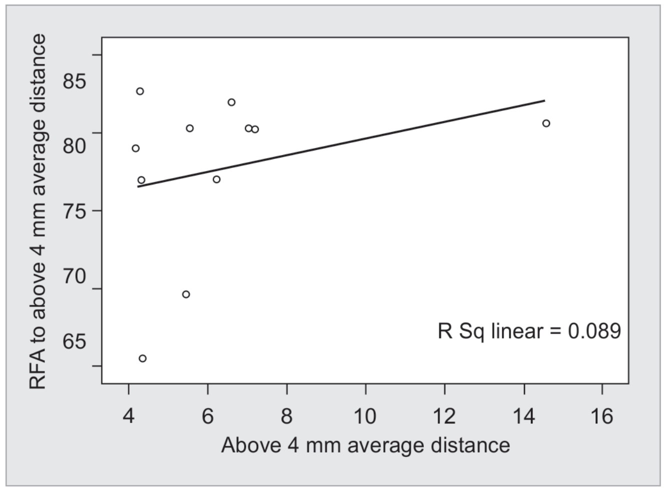
Graph 1: Correlation between the implant stability (ISQ) values and the AD (mm). There is a weak statistically significant positive correlation ($r = 0.114$, $p < 0.522$)



Graph 2: Correlation between the implant stability (ISQ) values and the AM (mm). There is a weak statistically significant negative correlation ($r = -0.217$, $p < 0.332$)



Graph 3: Correlation between the implant stability (ISQ) values and the AMD– (mm). There is a weak statistically significant positive correlation (r = 0.248, p < 0.398)



Graph 4: Correlation between the implant stability (ISQ) values and the AMD+ (mm). There is a weak statistically significant positive correlation (r = 0.3, p < 0.37)

Table 3: Descriptive statistics of resonance frequency analysis measurement at 6 weeks, above and below 4 mm average implant-tooth distance

Descriptive	*RFA (ISQ unit) 6 weeks (n = 22)*	*RFA (ISQ unit) above 4 mm (n = 22)*	*RFA (ISQ unit) below 4 mm (n = 22)*
Mean (SD)	77.82 (5.24)	77.64 (5.36)	78 (5.55)
Minimum	64	65.5	64
Maximum	82.6	82.6	85.6

None of the implants exhibited rotational movement during the removal of the healing cap screw for the placement of the transducer; this finding provided good evidence of the stabilities of the implants during the healing period (Table 3).

The correlation between the AD and the RFA reading was not significant ($p < 0.522$). The observed correlation coefficient (r) was 0.114, which suggested a poor positive correlation (Pearson's test, $p < 0.05$) (Graph 1). The correlation between the AM and the RFA reading was not significant ($p < 0.332$). The observed correlation coefficient (r) was –0.217, which suggested a poor negative correlation (Spearman's test, $p < 0.05$; Graph 2). The correlation between the AMD– and the RFA reading was not significant ($p < 0.398$). The observed correlation coefficient (r) was 0.248, which suggested a moderate positive correlation (Pearson's test, $p < 0.05$; Graph 3). The correlation between the AMD+ and the RFA reading was not significant ($p < 0.37$). The observed correlation coefficient (r) was 0.3, which suggested a moderate positive correlation (Spearman's test, $p < 0.05$; Graph 4).

DISCUSSION

This preliminary study sought to determine the correlations between implant-tooth distances and the readings of an RFA device. Single tooth implants were placed in the limited space between the teeth; therefore, the distances between the implant and the teeth could be calculated to determine whether they correlated with the implant stability and RFA readings. Huang et al[11] found that the sensitivity to frequency changes increases with increasing boundary width regardless of density. Niimi et al[12] found that the torques required for the removal of implants in the fibulae, iliac crests and scapulae of cadavers were related to cortical bone thickness. Additionally, Miyamoto et al[10] found a correlation between the cortical bone thickness and the ISQ value; this linear correlation was strong, positive, and statistically significant (r = 0.84). This result may have occurred because RFA is affected by the thickness of the lingual and buccal plates rather than by the thickness of the proximal bone. Another study examined the combined effects of the density of the cortical layer of the bone crest and its thickness on implant stability.[6] The bone density around the implant plays a major role in implant stability.[13,14]

The coronal third is composed primarily of dense cortical bone, and the middle and apical thirds contain trabecular bone.[15] Ito et al[16] found that the correlation between RFA measurements and the bone-implant contact increased when the bone-implant contact was measured at the neck of the implant during the early weeks of the healing period. The above studies concluded that RFA readings are correlated with the cortical bone density of the coronal part of the peri-implant bone. This conclusion might explain the poor correlation between the RFA measurements and the implant-tooth distance observed in the present study; however, this poor correlation might also be due to the time of the examination in the current study (6 weeks) because bone requires 4 months to establish its mineral content and become mature[17] and because bone that has healed for 1 month contains approximately half the calcified content of mature bone.[15]

The results of the present study indicate that the correlations between RFA readings and implant-tooth distances that were above and below 4 mm were fair and positive. These findings indicate that RFA readings increase with increases in bone thickness, but this relationship was not significant. The non-significant correlation observed in the present study might be attributable to the small sample size and may be caused by the limited range of the RFA readings; these limitations make this device incapable of evaluating bone thicknesses around the implant that are greater than 1 to 2 mm.[3]

The interesting findings of the present study include the findings that the correlation between the RFA readings and the AD was positive, whereas the correlation between the readings and the AM was negative. These findings indicate that more anterior implant placements led to greater RFA readings and that this pattern was true for both the crestal and average distances. These findings can be explained in two ways. First, the anterior mandible and maxilla are denser than their posterior counterparts, and second, the RFA readings were also significantly different between these regions.[8,18] In another study by Pattijn et al,[7] implants were placed in the tibias of pigs, and the bones were initially held with two surgical clamps on the proximal and distal sides of the tibia. Another specimen that included only the proximal part was locked by the clamp. After the RFA measurements were taken, these authors found that the former specimens exhibited RFA values than those of the latter. The authors of this study concluded that greater distances between the implant and the proximal clamp result in lower resonance frequency values. The Pattijn study indicates that if we consider the midline of the jaw to be the locked clamp, then more mesial placements of the implants closer to the midline should lead to higher RFA values. In other words, implants that are placed more distally relative to the midline should exhibit lower RFA readings.

Because of the small sample size of the present study, further studies should be conducted to confirm the findings of this study.

CONCLUSION

Although this study has some limitations, no correlations between the RFA readings and the implant-tooth distances at any level or distance were found.

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