

# Correlation between radiographic analysis of alveolar bone density around dental implant and resonance frequency of dental implant

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**Abstract.** The histomorphometric test is the gold standard for dental implant stability quantification; however, it is invasive, and therefore, it is inapplicable to clinical patients. Consequently, accurate and objective alternative methods are required. Resonance frequency analysis (RFA) and digital radiographic analysis are noninvasive methods with excellent objectivity and reproducibility. To analyze the correlation between the radiographic analysis of alveolar bone density around a dental implant and the resonance frequency of the dental implant. Digital radiographic images for 35 samples were obtained, and the resonance frequency of the dental implant was acquired using Osstell ISQ immediately after dental implant placement and on third-month follow-up. The alveolar bone density around the dental implant was subsequently analyzed using SDEXIS-XG software. No significant correlation was reported between the alveolar bone density around the dental implant and the resonance frequency of the dental implant ( $r = -0.102$  at baseline,  $r = 0.146$  at follow-up,  $p > 0.05$ ). However, the alveolar bone density and resonance frequency showed a significant difference throughout the healing period ( $p = 0.005$  and  $p = 0.000$ , respectively). Conclusion: Digital dental radiographs and Osstell ISQ showed excellent objectivity and reproducibility in quantifying dental implant stability. Nonetheless, no significant correlation was observed between the results obtained using these two methods.

## 1. Introduction

Implants have been used increasingly in the field of dentistry since Branemark introduced the concept of osseointegration of endosseous implants in 1985 [1]. Dental implants are now the choice of procedure for restoring partial or complete loss of teeth with good prognosis [2,3]. The success of dental implant treatment is associated with the osseointegration of dental implants, with one of the main determinants being good primary implant stability. Primary implant stability is directly proportional to the bone density, which describes the amount of bone tissue in a particular bone volume [4-7]. Radiographic examination is an integral part of dental implant treatment for the preparation of a preoperative plan, surgical evaluation, and postoperative evaluation [8]. In recent years, digital radiographs are being used instead of conventional ones in dental practice [9]. Digital dental radiographic techniques aim to improve the interpretation of radiographic images with lower radiation doses, simpler work procedures, and shorter working times [10,11].



The histomorphometric technique is the gold standard for stability testing and implant osseointegration; however, it is an invasive method, and therefore, it is inapplicable to clinical patients. The resonance frequency response (AFR) method is a noninvasive method that shows high objectivity and reproducibility for measuring the stability and osseointegration of implants in patients [12]. The alveolar bone density around dental implants as determined from radiographic images is used as a parameter to evaluate dental implant stability. Digital radiography allows for more accurate determination of alveolar bone density around dental implants than conventional radiography. This study examines the relationship between alveolar bone density around dental implants based on an analysis of digital radiographic images and dental implant resonance frequency using Osstell ISQ.

## 2. Materials and Methods

This study is an analytic study with an experimental design. Research subjects are selected using consecutive sampling. The study sample included patients (subjects) who came to the clinic from mid-February 2014 to March 2015, underwent dental implant treatment. The subjects' medical history and medical records were reviewed to ensure that they met the inclusion criteria.

The subjects were male patients aged over 18 years with loss of mandibular posterior region teeth and who were indicated for dental implants with delayed loading for 3 months. The subjects were willing to comply with the control protocols for dental implant treatment, such as removal of stitches at week 2, cleaning the screw cover at month 1, and evaluation of whether the dental implants were ready for prosthesis at month 3. The subjects did not require hard tissue manipulation, such as bone-grafting procedures, for receiving implants. The subjects did not have systemic conditions such as osteoporosis, diabetes mellitus, and radiotherapy treatments as well as bad habits such as smoking that could affect alveolar bone remodeling. Subjects who did not meet the inclusion criteria, disobeyed the study protocol, or were unwilling to provide informed consent were excluded from the study.



**Figure 1.** Radiographic analysis of bone density of jaw



**Figure 2.** Radiographic analysis of alveolar bone density around dental implants

In this study, initial measurements were taken immediately after the insertion of dental implants, and a second measurement was taken 3 months after insertion during the control visit. All dental implants were inserted by one operator who had clinical experience of more than 50 dental implants. The subjects' jawbone density was evaluated by two observers, who had clinical experience of more than 5 and 10 years, respectively (Figure 1). Digital periapical radiographic features were obtained using the Rinn XCP - ORA sensor holder and alignment instrument (Ditters Rinn LLC, Illinois), Revotek LC (GC America, California, USA) for temporary restoration, and Heliident periapical imagers (Sirona Dental Company, New York, USA) with long pre-program exposure for XIOS XG sensors with FHA funnel of 300 mm (12 inch), speed of 60 kV, and exposure time of 0.20 s. Radiographic analysis of the alveolar bone density around the dental implants was performed using 2.6x SIDEXIS-XG software (Sirona Dental Company, New York, USA) (Figure 2). Dental implant resonance frequency measurements were performed using Osstell ISQ (Integration Diagnostics Ltd. Company, Savedalen, Sweden). It was reported that SmartPeg repeatability was 0.97, whereas Osstell

ISQ repeatability was 0.97 or perfect, with 95% confidence interval; this means that repeated measurements are not required, and the measurement was performed only by the researchers. All research data was collected for analysis using SPSS software (IBM SPSS Statistics for Macintosh, Version 21.0).

### 3. Results and Discussion

#### 3.1 Results

In 35 dental implants attached in 25 subjects, bone density and alveolar bone density around dental implants were determined through radiographic image analysis, and resonance frequencies of dental implant were measured using Osstell ISQ. The Fisher test showed no significant association ( $p = 1.000$ ) between age and bone density of the jaw (Table 1). Thus, the baseline density of the jaw bone in the subjects was the same or was homogeneous.

**Table 1.** Relationship between age and bone density of the jaw

		Bone density of jaw				<i>p</i>
		Dense		Rare		
		N	%	N	%	
Age group (years)	35–59	16	80	12	80	1.000
	60–70	4	20	3	20	
Total		20	100	15	100	

Note: Using Fisher test, \* significant ( $p < 0.05$ )

Based on the Spearman test results, radiographic analysis of the alveolar bone density around dental implants and resonance frequency of dental implants is associated with the correlation coefficient ( $r = -0.102$  at baseline,  $r = 0.146$  at follow-up (control)) (Table 2). The correlation coefficient was  $0.00 \leq r \leq 0.25$ , suggesting almost no correlation. The baseline and control  $p$  values were 0.561 and 0.402, indicating non-significant correlation.

**Table 2.** Relation between radiographic analysis of alveolar bone density around dental implants and resonance frequency of dental implants

			Resonance frequency of dental implants (ISQ)	
			initial	control
Radiographic analysis of alveolar bone density around dental implants (%)	Initial	<i>r</i>	-0.102	
		<i>p</i>	0.561	
		<i>n</i>	35	
	Control	<i>r</i>		0.146
		<i>p</i>		0.402
		<i>n</i>		35

Note: Using Spearman test, \* significant ( $p < 0.05$ )

**Table 3.** Changes in alveolar bone density around dental implants during healing based on radiographic analysis.

		<i>n</i>	Mean $\pm$ standard deviation	Mean difference $\pm$ standard deviation	CI95%	<i>p</i>
Radiographic analysis of alveolar bone density around dental implants (%)	Initial	35	26.37 $\pm$ 3.18	0.18 $\pm$ 3.05	-1.24–0.86	0.005
	Control	35	26.56 $\pm$ 2.67			

Note: Using paired *t*-test, \* significant ( $p < 0.05$ )

**Table 4.** Alveolar bone density change around dental implants during healing period based on radiographic analysis in each age group.

		Alveolar bone density change around dental implants during healing based on radiographic analysis (%)			p
		n	Median (minimum - maximum)	Mean $\pm$ standard deviation	
Age group (years)	35–44	16	-0.93 (-5.97 - 4.41)	-0.87 $\pm$ 0.64	0.253
	45–59	12	2.1 (-3.68 - 6.28)	1.29 $\pm$ 1.03	
	60–70	7	-0.44 (-1.71 - 6.50)	0.72 $\pm$ 1.02	

Note: Using Kruskal-Wallis test, \* significant ( $p < 0.05$ )

**Table 5.** Changes in resonance frequency of dental implant during healing period

		n	Median (minimum - maximum)	Mean $\pm$ standard deviation	p
Resonance frequency of dental implant (ISQ)	Initial	35	65.00 (59.00 - 84.00)	67.78 $\pm$ 1.31	0.000
	Control	35	82.00 (69.50 - 86.50)	81.41 $\pm$ 0.67	

Note: Using Wilcoxon test, \* significant ( $p < 0.05$ )

**Table 6.** Changes in resonance frequency of dental implant during healing period in each age group

		Changes in resonance frequency of dental implants during healing period (ISQ)			p
		n	Median (minimum - maximum)	Mean $\pm$ standard deviation	
Age group (years)	35–44	16	16.75 (0.00 – 22.50)	13.03 $\pm$ 2.05	0.922
	45–59	12	18.25 (-5.00 – 22.50)	13.33 $\pm$ 2.74	
	60–70	7	17.00 (6.50 – 22.50)	15.50 $\pm$ 2.50	

Note: Using Kruskal-Wallis test, \* significant ( $p < 0.05$ )

**Table 7.** Changes in resonance frequency of dental implant during healing period according to diameter of dental implant

	Diameter of dental implant (mm)	n	Median (minimum - maximum)	Mean $\pm$ standard deviation	p
Changes in resonance frequency of dental implant (ISQ)	4.1	32	17.50 (-5.00 - 22.50)	13.56 $\pm$ 1.48	0.745
	4.8	3	18.00 (6.00 - 19.00)	14.33 $\pm$ 4.18	

Note: Using Mann-Whitney test, \* significant ( $p < 0.05$ )

**Table 8.** Changes in resonance frequency of dental implant during healing period according to length of dental implant

	Length of dental implant (mm)	n	Median (minimum - maximum)	Mean $\pm$ standard deviation	p
Changes in resonance frequency of dental implant (ISQ)	8	32	11.00 (6.00 - 16.00)	11 $\pm$ 5.00	0.355
	10	3	18.00 (-5.00 - 22.50)	13.79 $\pm$ 1.45	

Note: Using Mann-Whitney test, \* significant ( $p < 0.05$ )

The radiographic analysis showed a significant difference between the baseline and control alveolar bone density around the dental implant (paired t-test,  $p = 0.005$ ) (Table 3). However, there was a non-significant difference in alveolar bone density around the dental implant during the healing period between different age groups (Kruskal-Wallis test,  $p = 0.253$ ) (Table 4). There was a significant difference between the initial and control resonance frequencies of the dental implant (Wilcoxon test,  $p = 0.005$ ) (Table 5) but no significant difference between different age groups (Kruskal-Wallis test,  $p = 0.922$ ) (Table 6). There was no significant difference between the resonance frequencies of dental implants with diameters of 4.1 and 4.8 mm during the healing period (Mann-Whitney test,  $p = 0.745$ ) (Table 7). There was no significant difference between the resonance frequencies of dental implants with lengths of 8 and 10 mm during the healing period (Mann-Whitney test,  $p = 0.355$ ) (Table 8).

### 3.2 Discussion

The bone density was reported to have a high correlation with age ( $r = -0.893$ ;  $p < 0.001$ ) [13]. The different results in this study may result from the different bone density measurement methods used, such as the use of histomorphometric techniques and the interpretation of digital periapical radiographic images. It has also been reported that bone trabeculation is a more predictive indicator of age change in women than in men [14]. The different results in this study can also be attributed to the control of sex as a confounding variable.

The results of this study are in contrast to those of studies by Turkyilmaz *et al.* (2008), who studied 300 implants attached in 111 patients from 2 different clinics. Their study reported a strong correlation between bone density based on CT images before implant insertion and the resonance frequency of the dental implant ( $r = 0.882$ ,  $p < 0.001$ ) at the time of implant insertion [15]. These contrasting results may be due to differences in the bone density analysis tools used, namely, digital periapical radiographs in this study and CT in Turkyilmaz *et al.*'s study. To date, few studies have linked bone density around dental implants based on periapical radiographic images and the resonance frequency of the dental implant; however, it has been reported that computer-assisted digital radiography of the bone around dental implants has high accuracy and certainty. 16 Studies have not reported progress in dental science and technology in terms of bone density analysis using digital dental radiographic aids with controlled trials [10,16].

Our results are consistent with those of another study that analyzed the bone density using the Eigentool software (Henry Ford Health System, Detroit, MI, USA). There were significant changes in bone density ( $p < 0.001$ ) at control visits at 2, 4, 6, 8, and 12 months [17]. Another study that used Digora for Windows software (Soredex, Finland) also reported that the mean bone density increased slowly and significantly at each measurement stage ( $p = 0.001$ ), namely, before surgery and 1 week, 1 month, and 3 months after implantation [18]. It was concluded that digital dental radiographs were a useful tool for analyzing bone density and for acquiring accurate and fast images, thereby reducing the need for histologic analysis through biopsy [10].

There were no significant differences in bone density based on an analysis of conventional digital and radiographic images as well as digital image descriptions in previous studies that did not use standardized radiographic retrieval [19]. Gulsahi *et al.* (2007) used a standardization radiographic retrieval technique and reported an increase in bone density 6 months after implantation [20].

Based on this study, there was an increase in bone density before implant loading, and therefore, it can be concluded that implant insertion can help the bone formation process. Thus, the implant plays a positive role in maintaining residual ridge and increasing alveolar bone density around dental implants.

Turkyilmaz *et al.* (2006) reported that at the location of implant insertion, older patients had higher mean bone density than younger patients, based on CT image analysis. These results can be attributed to the number of anterior mandibular samples with high bone density, which is more common in older patients. Older patients also showed more significant bone resorption, with more residual bone/cortical bone, thereby resulting in higher bone density values [21]. Our results may differ from these findings owing to the small sample size for the age group of 60–70 years (7 samples) compared with younger age groups. The increase in the resonance frequency of dental implants encountered during the third

month of control in this study is consistent with the findings of many studies that reported that the stability of osseointegrated implants increases with time. In a study of the stability of 208 dental implants during the healing period, there was a significant increase in the resonant frequency of dental implants in implants attached to the mandible [22]. Other studies reported that there was a significant increase in stability after the 6th week of mandibular implants. This increase in stability is thought to be due to bone reactions in the bone-implanted intercellular region leading to osseointegration [23].

The average dental implant resonance frequency decreased slightly from implant insertion to the 6th month of control and then increased from the 6th month to the 12th month of control [15]. Another study examined changes in implant stability at the time of insertion and the 1st week and then every 2 weeks until the 12th week; it reported a slight decrease in the pattern of implant stability during the evolutionary period [24]. It was concluded that in implants with high initial stability, decreased stability during the first 12 weeks of healing was a natural phenomenon [24,25]. In this study, the implant stability is only measured after insertion and during the 3rd month of control, and therefore, there are no observable stability fluctuations during the healing period. Note that in dental implants with low initial stability, decreased stability indicates that clinicians should pay attention to the implant, such as arranging a tighter control schedule, taking precautionary measures such as delaying the application of loads until the implant is assessed to be stable, and checking for any mechanical trauma and/or infection [24]. In this study, changes in implant stability after the first 3 months until annual control cannot be monitored because most implanted support restorations are dissipated rather than screw-retained. This emphasizes one of the limitations of the AFR method, namely, that the measurement of implant stability using this method requires the fixation of the implant transducer [23,24].

The results of this study cannot confirm the inability of the AFR method to diagnose implants that are mobile, because the smallest initial stability values encountered were 59, which was the eligible minimum initial stability value for successfully integrated implants. All implants placed in this study were clinically stable during the control visit 3 months after insertion. The results of this study are consistent with previous studies that suggested no difference in the resonance frequency of dental implants with respect to the age of the subjects [26]. In the study, it is difficult to observe the effect of age on the measurement of the resonant frequency of dental implants because most subjects were young. The results of this study are similar to those of previous studies in that the diameter of the implant has no effect on the initial stability [22]. Other studies reported that dental implants with a narrow platform showed lower stability compared to those with regular and wide platforms. However, no significant differences were reported when comparing the stability between implants with regular and wide platforms. Implant with narrow platforms showed the lowest initial stability, especially in low-quality bones. In contrast, implants with regular and wide platforms in low-quality bones showed no significant effect on initial stability [27].

The results reported in this study support the findings of previous studies in that the length of dental implants has no significant effect on implant stability [22]. The length of dental implants is a crucial factor in achieving higher initial stability in implants attached to low-quality bone [27]. In this study, all implants were attached in the posterior region of the mandible, which largely consists of dense D2 and D3 bones.

#### 4. Conclusion

Digital dental radiographs and Ostell ISQ displayed excellent objectivity and reproducibility in quantifying dental implant stability. Nonetheless, no significant correlation was observed between results obtained using those methods.

#### References

- [1] Isoda K, Ayukawa Y, Tsukiyama Y, Sogo M, Matsushita Y and Koyano K 2012 Relationship between the bone density estimated by cone-beam computed tomography and the primary stability of dental implants. *Clinic. Oral. Implants. Res.* **23** 832-6.



- [2] Gulsahi A, Paksoy C S, Ozden S, Kucuk N O, Cebeci A R I and Genc Y 2010 Assessment of bone mineral density in the jaws and its relationship to radiomorphometric indices. *Dentomaxillofac. Radiol.* **39** 284-9.
- [3] Shibli J A, Aguiar K C D S and Melo L 2008 Histological comparison between implants retrieved from patients with and without osteoporosis. *Int. J. Oral. Maxillofac. Surg.* **37** 321-7.
- [4] Cehreli M C, Karasoy D, Akca K and Eckert S E 2009 Meta-analysis of methods used to assess implant stability. *Int. J. Oral. Maxillofac. Implants.* **24** 1015-31.
- [5] Katsavrias G 2009 *Reliability and validity of measuring implant stability with resonance frequency analysis*. (Master of Science in Dentistry), Saint Louis University, Saint Louis.
- [6] Moy P K 2008 The use of Osstell to obtain ISQ values to determine loading protocol and associated clinical outcomes of dental implants. *Paper presented at the 23rd Annual Meeting, Academy of Osseointegration*.
- [7] Park J C, Lee J W, Kim S M and Lee, J H 2011 Implant Stability - Measuring Devices and Randomized Clinical Trial for ISQ Value Change Pattern Measured from Two Different Directions by Magnetic RFA. In I. Turkyilmaz (Ed.), *Implant Dentistry - The Most Promising Discipline of Dentistry* (Croatia: InTech). p. 111-28.
- [8] Pikner S S 2008 *Radiographic follow-up analysis of Brånemark® dental implants*. (Gothenburg: University of Gothenburg).
- [9] Gulsahi A 2011 Bone quality assessment for dental implants. *Implant Dentistry: The Most Promising Discipline of Dentistry*, Turkyilmaz I (Ed.) (Croatia: InTech).
- [10] Bozzo R de O, Rocha R G, Neto F H, Paganini G A and Cavalcanti M G P 2004 Linear density analysis of bone repair in rats using digital direct radiograph. *J. Appl. Oral. Sci.* **12** 317-21.
- [11] Williamson G F 2010 Digital Radiography in Dentistry: Moving from Film-based to Digital Imaging. *Paper presented at the Continuing Education Course*.
- [12] Herrero-Climent M, Santos-García R, Jaramillo-Santos R, Romero-Ruiz M-M, Fernández-Palacin, Ana, Lázaro-Calvo, Pedro, Ríos-Santos, Jose-Vicente 2013 Assessment of Osstell ISQ's Reliability for Implant Stability Measurement: A Cross-Sectional Clinical Study. *Med. Oral. Patol. Oral. Cir. Bucal.* **18** 877-82.
- [13] Castillo R F, Ubelaker D H and Djorojevic M 2012 Age estimation through histological study of trabecular volume and cortical bone width of the iliac crest. *Sci. Justice.* 177-80.
- [14] Weinstein R S and Hutson M S 1987 Decreased trabecular width and increased trabecular spacing contribute to bone loss with aging. *Bone.* **8** 137-42.
- [15] Turkyilmaz Ilser and McGlumphy E A 2008 Influence of bone density on implant stability parameters and implant success: a retrospective clinical study. *BMC Oral. Health.* **8** 1-8.
- [16] Naser A Z, Etemadi S, Rismanchian M, Sheikhi M and Tavakoli M 2011 Comparison of conventional and standardized bone densitometry around implants in periapical radiographs during a three months period. *Dent. Res. J.* **8** 33-8.
- [17] Ghomeizi R, Alikhasi M, Siadat M-R, Siadat H and Sorouri M 2013 A radiographic comparison of progressive and conventional loading on crestal bone loss and density in single dental implants: a randomized controlled trial study. *J. Dent.* Tehran University of Medical Sciences **10** 155-64.
- [18] Naser A Z, Etemadi S, Rismanchian M, Sheikhi M and Tavakoli M 2011 Comparison of conventional and standardized bone densitometry around implants in periapical radiographs during a three months period. *Dent. Res. J.* **8**.
- [19] Bittar-Cortez J A, Passeri L A, Boscolo F N and Haiter-Neto F 2006 Comparison of hard tissue density changes around implants assessed in digitized conventional radiographs and subtraction images. *Clin. Oral. Implants. Res.* **17** 560-4.
- [20] Gulsahi A, Paksoy C S, Yazicioglu N, Arpak N, Kucuk N O and Terzioglu H 2007 Assessment of bone density differences between conventional and bone-condensing techniques using dual energy x-ray absorptiometry and radiography. *Oral. Surg. Oral. Med. Oral. Pathol. Oral. Radiol. Endodontic.* **104** 692-8.

- [21] Turkyilmaz I, Tozum T F and Tumer C J 2006 Assessment of correlation between computerized tomography values of the bone, and maximum torque and resonance frequency values at dental implant placement. *J. Oral. Rehabil.* **33** 881-8.
- [22] Guler A U, Sumer M, Duran I, Sandikci E O and Telcioglu N T 2013 Resonance frequency analysis of 208 straumann dental implants during the healing period. *J. Implantol.* **39** 161-7. doi: 10.1 S63/AAID-JO1-D-11-00060
- [23] Bischof M, Nedir R, Szmukler-Moncler S, Bernard J-P and Samson J 2004 Implant stability measurement of delayed and immediately loaded implants during healing.
- [24] Nedir R, Bischof M, Szmukler-Moncler S, Bernard J-P and Samson J 2004 Predicting osseointegration by means of implant primary stability: A resonance-frequency analysis study with delayed and immediately loaded ITI SLA implants. *Clinic. Oral. Implantol. Res.* **15** 520-8.
- [25] Yang S-M, Shin S-Y and Kye S-B 2008 Relationship between implant stability measured by resonance frequency analysis (RFA) and bone loss during early healing period. *Oral. Surg. Oral. Med. Oral. Pathol. Oral. Radiol. Endod.* **105** e12-9.
- [26] López A B, Diago M P, Cortisoz O M and Martínez I M 2006 Resonance frequency analysis after the placement of 133 dental implants. *Med. Oral. Patol. Oral. Cir. Bucal.* **11** E272-6.
- [27] Barikani H, Rashtak S, Akbari S, Badri S, Daneshparvar N and Rokn A 2013 The effect of implant length and diameter on the primary stability in different bone types. *J. Dent.* **10** 449-55.