CORRELATION ASSESSMENT BETWEEN RESONANCE FREQUENCY ANALYSIS AND RADIOGRAPHIC METHOD ACCORDING TO PERI-IMPLANT BONE CHANGE

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Statement of problem. Initial stability of implant is an important factor for predicting osseointegration. It requires a rapid, non-invasive, user-friendly technique to frequently assess the implant stability and the degree of osseointegration.

Purpose. The aim of this study was to evaluate the correlation between the resonance frequency analysis (RFA) and the radiographic method for peri-implant bone change under in vitro conditions.

Material and Method. Twenty implants of 3.75 mm in diameter(Neoplant, Neobiotech, Korea) were used. To simulate peri-implant bone change, 2 mm-deep 45° range horizontal defect and 2 mm-deep 90° range horizontal defect area were serially prepared perpendicular to the X-ray beam after conventional implant insertion. Customized film holding device was fabricated to standardize the projection geometry for serial radiographs of implants and direct digital image was obtained. ISQ values and gray values inside threads were measured before and after peri-implant bone defect preparation.

Results. Within a limitation of this study, ISQ value of resonance frequency analysis was changed according to peri-implant bone change ($p<0.05$) and gray value of radiographic method was changed according to peri-implant bone change ($p<0.05$). There was no correlation between the ISQ value and the gray value for peri-implant bone change ($p>0.05$). But, in horizontal defect condition, relatively positive correlation were between ISQ and gray values(r=0.663).

Conclusion. This results provided a possibility that peri-implant bone change may be evaluated by both RFA and radiographic method.

Key Words

Dental implant, Gray values, Radiography, Resonance frequency analysis

The primary stability of implant depends on the bone density and quantity, the surgical technique and the implant design and good primary stability may be a predictor of osseointegration.[1] Several diagnostic methods have been proposed

※ This study was supported by research grants of Biochallenge from MOST of Korea and Kangnung National University(2003-0166).

for the quantitative measurement of primary stability during fixture installation and secondary stability during healing period of bone-implant interface,[2-6] but simple, non-destructive and highly reproducible methods are needed for periodic and long-term assessment.[2,7]

Resonance frequency analysis(RFA) introduced by Meredith is a method for quantitative determination of implant stability in vivo condition.[8] The vertical beam of the transducer that is fastened to implanted fixture is vibrated by sinusoidal sinewave electronical stimulus and the peak of first flexural curve of that result is utilized to evaluate implant stability. Resultant implant stability quotient(ISQ) value varies on a 1-100 scale and increases as higher stiffness of bone-implant interface or higher stiffness of surrounding bone.[2,8,9] The resonance frequency analysis is valuable method for non-destructive and quantitative assessment of stability of implant.[2]

Radiography is most useful method for presurgical evaluation of bone quantity and quality, change of marginal bone conditions around implant, evaluation of marginal adaptation of abutment, periodic assessment. Radiographic identification of unstable implants is reliable, suggested by Gröndahl et al.[10] The accuracy in radiographic diagnosis of clinical fixture instability was at least as good as that associated with other radiographic tasks such as approximal caries diagnosis and diagnosis of small periodontal bone lesions, but the probability of predicting clinical fixture instability from a radiographic examination can be low in populations with a low prevalence of fixtures showing clinical instability, according to Sundén et al.[11] And diagnostic ability of marginal bone change around implant using more than two radiographic films is very low when small increase or decrease of bone level change around implant, and inter- and intraobserver variability in reading of radiography is not enough for accurate diagnosis,[12] and it can evaluate interproximal dimension but can not evaluate buccolingual dimension. This set limits to assess the bone-implant interface.[13]

Both radiographic assessment and resonance frequency analysis are quantitative measurement methods for implant stability. But, few studys about correlation between two methods are yet suggested.

The aims of this study were to evaluate bone level change around implant using radiography and to measure stability using RFA method under in vitro condition, and to assess correlation between two methods.

MATERIALS AND METHODS

A frozen bovine bone block was obtained using saw and cancellous bone was exposed though removing upper cortical bone. Twenty bone specimens were prepared to have less than 4 mm thick cancellous bone and to enable for fixtures to be engaged bilaterally. Lower portion of frozen bone specimens were fixed to stable base using tray resin(Quicky resin, Nissin Co. Japan) that were polymerized in refrigerator. Twenty implants of 3.75 mm in diameter and 10 mm in length (Neoplant, Neobiotech, Korea) were inserted to selected bone specimens that were secured to have bilateral cortical bone engagement(Fig. 1). The hex orientation of implants were controlled to connect similar relationship between customized film holding device and fixure. Customized film holding device for parallelling method(Sensor holder, Biomedisys, Korea) was fabricated and installed to standardize the projection geometry that includes film, object and X-ray generator(Fig. 2). The fixture mount was soldered to device for the connection between hex of implant and mount to standardize projection geometry between fixture and CCD sensor. The position between hex of mount and hex of implant was con-

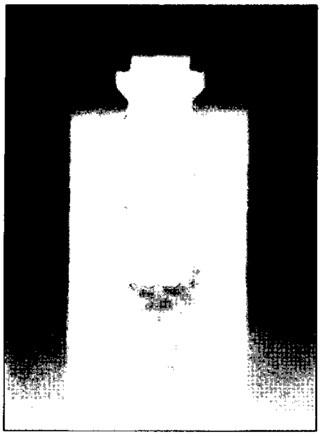


Fig. 1. Radiographic view of fixture that was bilaterally engaged to specimen.

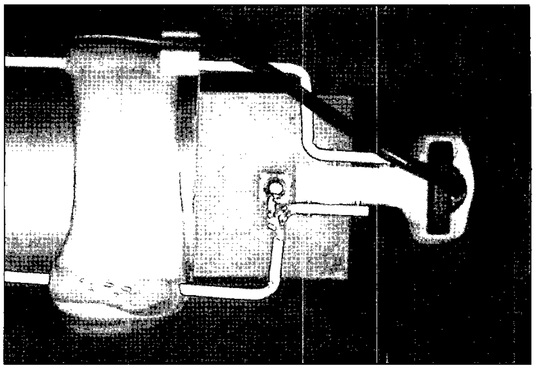
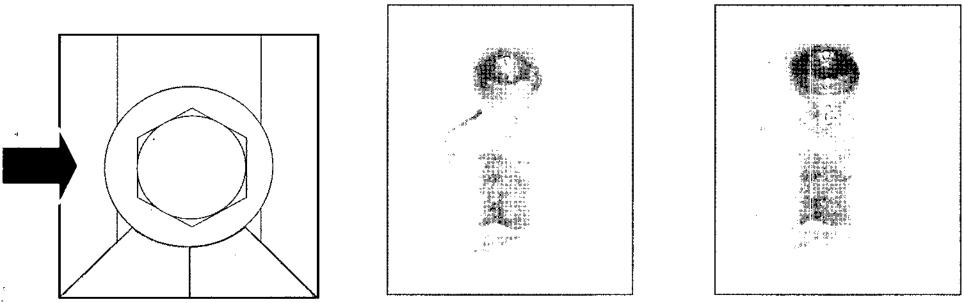


Fig. 2. Customized film holding device.



a b c

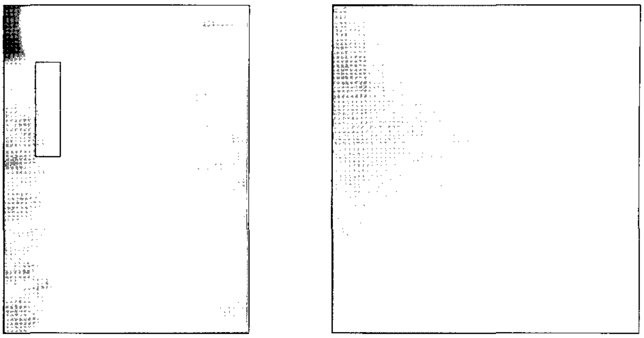
Fig. 3. Schematic diagram of X-ray source direction and simulated bone defects(a), specimen with 2 mm-deep 45 degree bony defect(b), and 2 mm-deep 90 degree bony defect(c).

trolled when the screw of mount was fastened.

The bone chip was removed to the bone defect using high speed diamond bur and sharp knife. To simulate peri-implant bone change, 2 mm-deep 45° range horizontal defect and 2 mm-deep 90° range horizontal defect area were serially prepared and they were perpendicular to the X-ray beam after conventional implant insertion. The control group has no bone defects, the 45 degree bone defect group has 2 mm-deep 45 range bone defect, and the 90 degree bone defect group has 2 mm-deep 90 range bone defect. Measuring RFA and taking digital radiography were performed before bone defect preparation and after 45 range, 90 range bone defect preparation(Fig. 3).

The Osstell™(Integration Diagnostic Ltd., Götteborg, Sweden) was used to measure resonance frequency and the transducer(F1L5) was fastened to prepared specimen parallel to the X-ray beam. Remeasurement was done when double peak was read at resonance frequency measurement. RFA measurement results were recorded as Implant Stability Quotient(ISQ)s.

The specimen and holding device were connected



a b

Fig. 4. Region of interest(a) and magnification of third thread(b).

using mounting screw for reproducible radiography and x-ray generator(CDX2000U, Biomedisys, Korea) and CCD sensor were used with 60kVp, 10 mA, 0.4 sec exposure time condition for projection standardization. The digital images were saved as JPG files, that were presented gray value of 256 level to facilitate visualization. The "region of interest" was selected inside successive three threads range that is suspected peri-implant bone change(Fig. 4). From the first thread to third thread was similar vertical distance with 2 mm-deep bone defect. The data was received from mean of gray values inside area from the first thread to third thread, and that area of inside thread was selected by one observer. The mean gray value of selected area was obtained by using photoshop program(Adobe photoshop 6.0, Adobe, USA), and mean gray value of three thread was calculated. This was repeated three times and that mean was calculated.

Statistical analysis was done with 95% confidence level using SPSS Ver 12.0(SPSS Inc., USA) for Window. Paired t-test was used for change of ISQ values, change of gray values according to degree of bone defect. Pearson correlation test was performed for correlation of ISQ value and gray value at each bone defect condition. The change of ISQ value between each group and the difference of gray value between each group were obtained, and Pearson correlation test was used for correlation of result of two abstracted values($p<0.05$).

RESULT

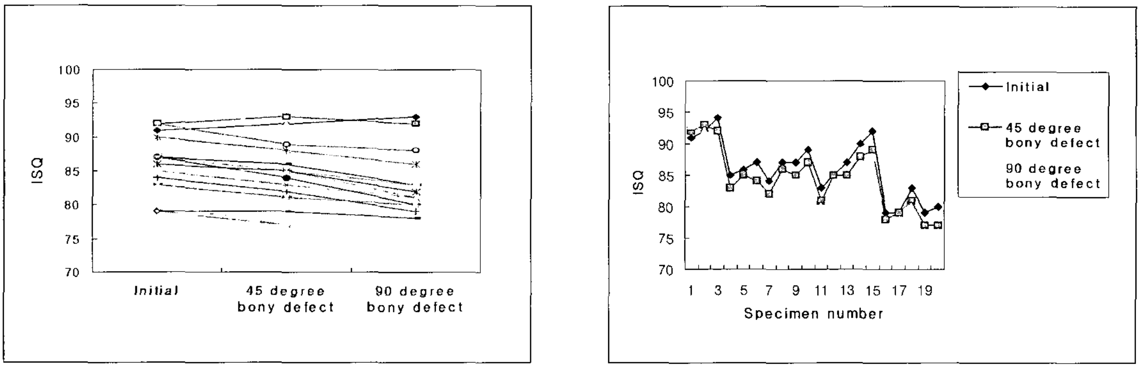
1. Change of RFA value according to bone defect change.
   There were statistically significant decrease of ISQ between control group and 45 degree bone defect group, control group and 90 degree bone defect group, 45 degree bone defect group and 90 degree bone defect group($p<0.05$)(Table I, II, Fig. 5).
2. Change of radiography according to bone defect change.
   Mean gray value to third thread was showed statistically significant decrease of bone density and gray value according to the increase of bony defect($p<0.05$)(Table I, II, Fig 6).
3. Correlation test between RFA and radiogrphic method according to bone defect.
   Pearson correlation coefficients(r) between ISQ and gray value at each bone defect group were 0.251 after insertion of implant, 0.328 at 45 degree bone defect, 0.195 at 90 degree bone defect, and there were no correlation with statistical significance(Table III).

Table I. The mean and standard deviation(SD) of ISQ values and gray values according to simulated defects

Simulated	N	Mean±SD	SE of mean
ISQ initial	20	85.95 ± 4.57	1.02
ISQ 45 degree	20	84.45 ± 4.84	1.08
ISQ 90 degree	20	82.35 ± 4.98	1.11
Gray value initial	20	137.10 ± 9.76	2.18
Gray value 45 degree	20	121.95 ± 7.54	1.69
Gray value 90 degree	20	106.56 ± 15.44	3.45

Table II. Change of ISQ values and gray values according to simulated defects (paired t-test)

Technique	Mean ± SD n=20	95% confidence interval	t	*p*-value*
RFA method (ISQ)				
Initial - 45 degree	-1.50 ± 1.19	.942 ~ 2.058	5.63	
Initial - 90 degree	-3.60 ± 2.06	2.635 ~ 4.565	7.81	<0.05*
45 degree - 90 degree	-2.10 ± 1.37	1.458 ~ 2.742	6.84	
Radiographic method(gray value)				
Initial - 45 degree	-15.14 ± 6.20	12.24~ 18.04	10.92	
Initial - 90 degree	-30.53 ± 13.15	24.38 ~ 36.69	10.38	<0.05*
45 degree - 90 degree	-15.39 ± 10.53	10.46~ 20.32	6.54	



a b

Fig. 5. The ISQ value changes of each specimen according to simulated bony defects(a, b).

4. Correlation between RFA and radiographic method after abstraction of each group.
   There was no correlation between control group and 45 degree bone defect group and between control group and 90 degree bone defect group(r=0.132, r=0.428), but there was correlation between 45 degree bone defect group and 90 degree bone defect group(r=0.663) (Fig. 7, Table III).

Table III. Pearson correlation test between ISQ values and gray values

ISQ value & Gray value	N	Correlation(r)	*p*-value*
initial	20	0.251	0.287
45 degree	20	0.328	0.157
90 degree	20	0.195	0.410
45 degree - initial	20	0.132	0.579
90 degree - initial	20	0.428	0.060
90 degree - 45 degree	20	0.663	0.001*

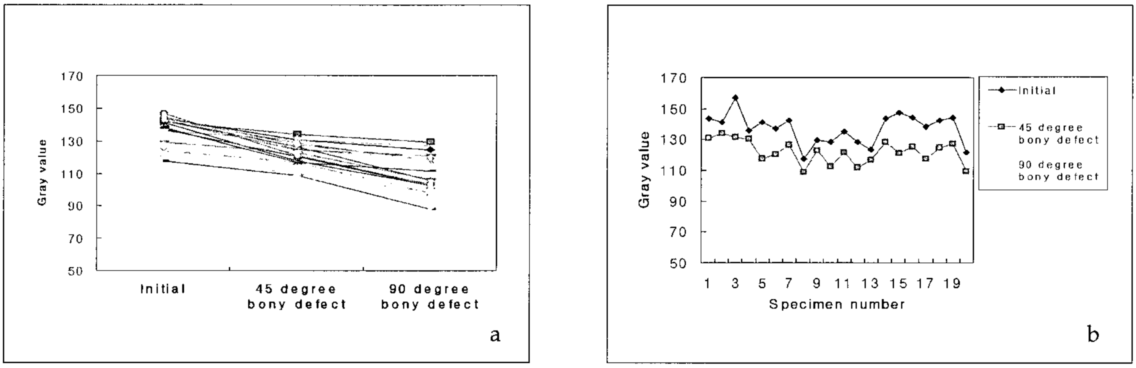


Fig. 6. The mean gray value changes of each specimen according to simulated bony defects(a, b).

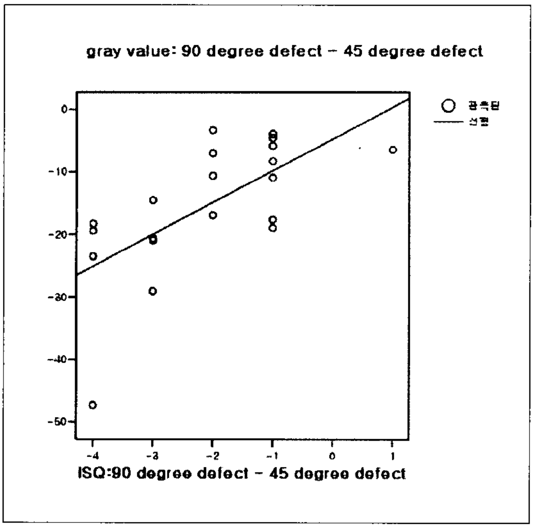


Fig. 7. Correlation between ISQ values and mean gray values.

DISCUSSION

There were efforts that determined the relationship between histomorphometric study and RFA when evaluated bone-implant interface,[14] and assessed correlation between removal torque and bone-implant interface[15] and correlation between cutting torque and peri-implant bone area.[16] High correlation was found when comparing the mean torque values of the upper/crestal portion with resonance frequency values,[17] but no correlation could be found between the resonance frequency analysis and the bone mineral density.[18] Many in vitro, in vivo studies verified that resonance frequency analysis represented implant stability as objective quotient, and this method could be adopt as a clinical tool for assessing peri-implant bone condition.[19-22] Effective implant length(EIL) termed the exposed threads on peri-implant bone and added to the length of each abutment. The increase of EIL related to decrease of resonance frequency value, suggested by Meredith et al[23] Higher stiffness of implant interface relate to higher resonance frequency analysis value,[19] transducer design could effect result of measurement.

Huang et al[24] suggested that resonance frequency analysis value was decreased when the bone densities were decreased in finite element method study. A lower boundary density led to more obvious RF changes on respective increasing effective implant length.[25] Friberg et al[17] reported resonance frequency value was related to alveolar bone of upper/crestal portion, but other study proposed resonance frequency analysis was related to bone-implant complex.[14] In this study, implant fixtures were installed to be engaged bilaterally because its stabilities were not controlled when cortical bone would be removed.

ISQ values were decreased as the bone defect enlargement from control to 45 degree, 90 degree. These suggested informations about vertical, horizontal bone defect. Bone-implant connection area decreases led to decrease of stability and decreases of bone density inside region of interest. Gray values could be represented range from 0 to 255, higher values mean higher bone densities. Gray value was showed more decreasing because of presentation range of gray value were wider according to the increase of defect area(Fig. 8). Standard deviation of gray value were coincide with standard deviation range of gray value of previous study that used digital subtraction radiography,[26,27] their standard deviation were wider than ISQ' s. It may be high intraobserver variability despite of repeated measurement for three times when selected inside thread area and measured gray value in digital image(Table II). Further trials have to do for reproducible measurement about gray value.

There were no correlation between ISQs and gray values in serial bone defect area, It could be thought that ISQs were influenced by surrounding bone density, especially stiffness of cortical bone that contact with implant,[17] that gray values were influenced by not only peri-implant bony change but also superimposed bone density change because it could be gained by transferring 3-dimensional structure to 2-dimension.[13]

The control group, 45 degree bone defect group, 90 degree bone defect group were subtracted with three combination for correlation analysis between ISQ and gray value according to bone defect changes. Result of correlation analysis between two methods indicated that there were high correlation(r=0.663) when subtracted with 45 degree bone defect group and 90 degree bone defect group. No correlations were found at the other combinations. It may be related to experiment design. According to the report about microtomographic technique, embedded specimen to resin decreased the quality of the image due to some radiopacity of resin.[28] In this study, implant thread portion was superimposed by cortical bone due to parallel direction with X-ray generator. It seemed to decrease the accuracy when determining subtle bone mineral density change.

Customized film holding device was fabricated to correct 3-dimensional distortion between X-ray generator and object when taking a digital image.[29,30]

The report provided quantitative marginal bone level measurement for assessing peri-implant bone condition using radiography.[19,31] In this study, bone density change inside the thread areas were represented with gray values, and basic principle of digital subtraction method applied to evaluate the bony change.

Digital Subtraction Radiography(DSR) supplied with computerized to present the difference between two radiographs by removing the residual images of anatomical structures and is very useful to evaluate peri-implant bone change. But the quality of that is determined by geometry, standardized contrast of structure and overlapping consistency of two radiographs.[32,33]

Subtraction image was obtained to find subtle bony change of region of interest. It could determine through visible image and be diagnosis.[34] But, it was difficult to discriminate background gray value of 128 with bony change area. Because it could not select region of interest in subtraction image.[26] The mean of gray value of inside thread and the mean gray value of three thread areas in two radiographic image were obtained and those were subtracted. The standardization of geometry is needed for digital subtraction radiography,[35] but device and equipment for DSR are expensive and too cumbersome for clinical use. Furthermore, selection of proper technique is difficult because they lack comparability. Therefore, digital subtraction radiography was suggested as a simple tool while bone density change was not represented as quantitative result but as visible result for clinical use.[36]

This study made an effort to reproduce in vitro condition, but it had a limitation for applying clinic. Further studies will be needed with various bone defect conditions.

CONCLUSION

Within a limitation of this study, ISQ value of resonance frequency analysis was changed according to peri-implant bone change ($p<0.05$) and gray value of radiographic method was changed according to peri-implant bone change ($p<0.05$). There was no correlation between the ISQ value and the gray value for peri-implant bone change ($p>0.05$). But, in horizontal defect condition, relatively positive correlation were between ISQ and gray values(r=0.663).

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