Assessing changes of peri-implant bone using digital subtraction radiography

Ji-Yung Kwon DDS, Yung-Soo Kim, DDS, MSD, PhD, MSc (OSU)
Chang-Whe Kim, DDS, MSD, PhD
Department of Prosthodontics, College of Dentistry, Seoul National University

Digital subtraction radiography may be one of the most precise and noninvasive methods for assessing subtle density changes in peri-implant bone, providing additional diagnostic information on implant tissue integration in overall maintenance.
The aims of this study were to evaluate density changes after first, second surgery of dental implant and to measure the amount of marginal bone loss 9 months after second surgery using digital subtraction radiography.
Bone change around 30 screw-shaped implants in 16 patients were assessed on radiographs. 17 Brånemark implants of 3.75mm in diameter(Nobel Biocare, Göteborg, Sweden), 2 Brånemark implants of 5.0mm in diameter, 11 Replace™ implants of 4.3mm in diameter(Nobel Biocare, Göteborg, Sweden) were used. To standardize the projection geometry of serial radiographs of implants, customized bite block was fabricated using XCP film holder(Rinn Corporation, Elgin, IL.) with polyether impression material of Impregum(ESPE, Germany) and direct digital image was obtained. Qualitative and quantitative changes on radiographs were measured with Emago software(The Oral Diagnostic System, Amsterdam, Netherlands).

The results were as follows:
1. The peri-implant bone density of 69.2% implants did not change and the peri-implant bone density of 30.8% implants decreased after 3 months following first surgery.
2. The crestal bone density of 53.9% implants decreased first 3 months after second surgery. The crestal bone density of 58.8% implants increased 9 months after second surgery. No density change was observed around the midportion of the implants after second surgery.
3. The amount of marginal bone loss between different kinds of implants showed no statistically significant differences ($p>0.05$).
4. More than 90% of total marginal bone loss recorded in a 9-month period occurred during the first 3 months.

Key Words
Digital Subtraction Radiography, Implant, Peri-implant bone, Emago

Radiographic assessments have an important role in connection with annual follow-up examinations of patients treated with dental implants.[1] From these, the condition of the peri-implant bone tissues, the degree of marginal bone loss, and the state of the mechanical components may be judged. Periapical radiographs are routinely used to evaluate changes in the peri-implant bone height and to detect angular bone defects.[2] Conventional evaluation of intraoral radiographs has shown to be of limited diagnostic value for early detection of subtle bone changes[3]: a low sensitivity and a high interexaminer and intraexaminer variability are the major drawbacks.[4-6] Radiographs are a two-dimensional picture of a three-dimensional reality. Superimposition of anatomic structures impedes the detection of small changes in bone density.[7,8] With conventional radiographs, a change in mineralization of 30% to 60% is necessary to be detected even by experienced radiologists.[7,9-11] Methods have been developed to increase the sensitivity in detecting small changes in density representing resorption, remodeling, and bone apposition, and for detecting other healing events or pathologic changes in peri-implant bone tissue before the alterations in bone height become obvious.[12]

Digital subtraction radiography analysis includes qualitative and quantitative assessments of the changes in density and may be among the most sensitive noninvasive methods for obtaining diagnostic information on density changes in studies using standardized dental radiographs.[13] The concept underlying subtraction radiography is simple. An image processing computer subtracts all unchanging structures from a set of 2 radiographs taken at 2 different examinations. The result is a neutral grey background in the areas that have not changed; areas of bone gain are shown in shades of grey darker than the background and areas of bone loss appear lighter. This method has already been introduced into dental radiology to evaluate crestal bone changes determining the effect of periodontal therapeutic procedures and has been shown to be a sensitive and specific method for the detection of small bony changes in peri-implant site. Ortman et al.[14] showed that examiners who used subtraction images could detect alveolar bone changes of 1% to 5% per unit volume as measured by iodine-125 absorptionmetry.

Application software of digital subtraction radiography developed to work in the Microsoft Windows environment provides for a common graphical user interface and operating system infrastructure to develop integration and communication. An example of specially designed software is Emago(The Oral Diagnostic System, Amsterdam. Netherlands). Emago software was first developed in 1992 at version 2.0 and has been recently updated to version 3.2. This program automates the mathematical reconstruction which corrects for the differences in exposure angles and subtraction procedure.

The aim of this study was to assess the change of bone density after first, second surgery of dental implant and the amount of marginal bone loss during 9-months after second surgery using digital subtraction radiography.

MATERIALS AND METHOD

Radiographic image acquisition

Bone changes around total thirty endosseus root-form implants placed in sixteen patients were assessed on radiographs. 17 Brånemark implants of 3.75mm in diameter(Nobel Biocare, Göteborg, Sweden), 2 Brånemark implants of 5.0mm in diameter, 11 Replace™ implants of 4.3mm in diameter(Nobel Biocare, Göteborg, Sweden) were used. Only partially edentulous patients of one to three missing teeth with adjacent natural tooth were selected to standardize the X-ray projection geometry.

To standardize the projection geometry of serial radiographs of implants, customized bite block(as described by Duckworth et al.[15]) was fabricated using XCP film holder(Rinn Corporation, Elgin, IL.) with polyether impression material of Impregum(ESPE, Germany) and direct digital image was obtained(Fig.

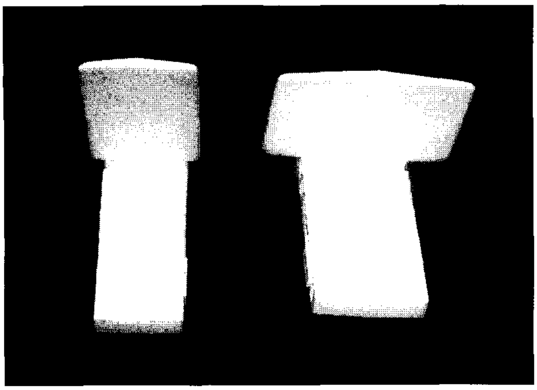

Fig. 1. XCP film holder.

Fig. 2. Customized bite block with polyether impression material.

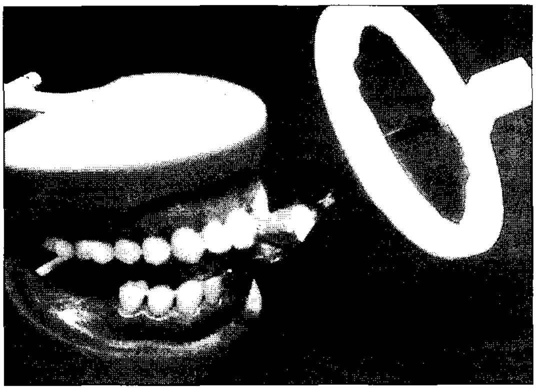

Fig. 3. Aiming ring & indicating arm.

1~3). Briefly, occlusal registrations of the area of interest were obtained by having the patient bite on a polyether impression material that was placed on a XCP film holder. Identical exposure conditions were provided for X-ray generating device.

This study was divided into two tests. The aim of test 1 was to assess changes of bone density from first surgery to second surgery. Direct digitial X-ray images were obtained 0 month, 3 months, 6 months(two implants in Maxillae only)after first surgery. thirteen implants placed in seven patients were included in test 1(Table Ⅰ).

The aims of test 2 was to assess bone density changes and the amount of marginal bone loss from the time of second surgery to nine months after the surgery. Seventeen implants placed in nine patients were included in test 2(Table Ⅱ). X-ray images were obtained 0 month, 3 months(the time of abutment connection), 9 months after the second surgery. The patients were restored with fixed partial denture and instructed not to have tough or hard diets with the new prosthesis.

Table Ⅰ. Number and type of implants for the test of bone change after first surgery

Type	Sex		Location		Total
	M	F	Mx.	Mn.	
Brånemark(3.75D)		6	2	4	6
Replace™(4.3D)	5	2		7	7
Total	5	8	2	11	13

Table Ⅱ. Number and type of implants for the test of bone change after second surgery

Type	Sex		Location		Total
	M	F	Mx.	Mn.	
Brånemark(3.75D)	6	5	1	10	11
Brånemark(5.0D)	2			2	2
Replace™(4.3D)	2	2	2	2	4
Total	10	7	3	14	17

Digora(direct image plate system) was used to capture radiographic image instead of conventional X-ray film. Digora includes a phosphor photo stimulation screen. This reusable screen stores the pho-

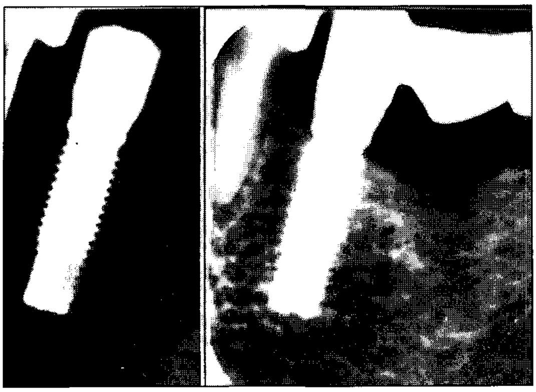

Fig. 4. (a) Reference image and (b) Subsequent image.

Fig. 5. Linear subtraction.

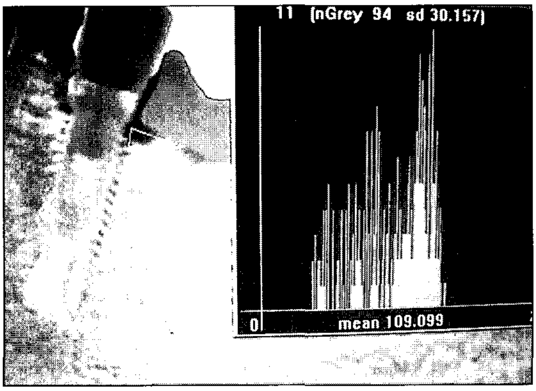

Fig. 6. Linear subtraction with grey level histogram. ROI : crestal area.

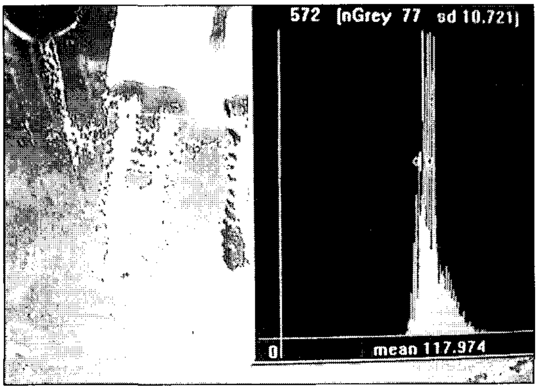

Fig. 7. An example of decreased peri-implant bone. "Region Of Interest(ROI)" of peri-implant bone was selected and the density was evaluated in grey level histogram.

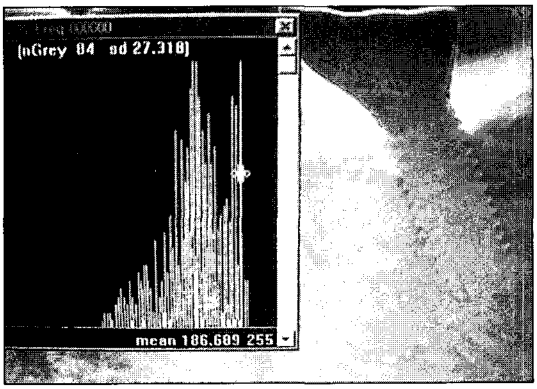

Fig. 8. An example of increased crestal bone density. "ROI "of crestal bone was selected and the density was evaluated in grey level histogram.

ton energy when hit by an X-ray beam, and emits light when it is scanned by a scanner, the measurements are displayed on the monitor, and stored in the computer as a digital image. Direct image plate systems have many advantages over film-based systems. The primary advantages of storage phosphors are a wide dynamic range due to automatic exposure control, and low dose requirements. The amount of energy stored in the image plate is linearly proportional to the X-ray exposure. The linearity is maintained throughout the entire dose range, which means that the image plate can hardly be over- or underexposured.

Image processing of digital image

Obtained images were processed on a personal computer using the Windows-based Emago/Advanced version 3.2 software(The Oral Diagnostic System, Amsterdam, The Netherlands). Two images to be subtracted were displayed side by side on the monitor. Small geometric differences were adjusted by a geometric correction algorithm. For this purpose, four references points in both images were defined. The second images were reconstructed using the same four points before the subtraction process(Fig. 4). In order to correct any changes in density due to different exposure conditions, the grey-level histograms of the two images were compared and adjusted using contrast correction algorithm.[38] After the grey-level adaptation, the subtraction was performed(Fig. 5). Within the subtraction images, areas of interest were identified clicking the mouse button to draw "region of interest" (ROI). The mean and range of the grey levels of pixels within a particular ROI were calculated(Fig. 6~8). Regions were defined as control areas, where no change was expected(ie, on the interocclusal space, on an implant head), and as test areas, where changes in peri-implant bone were probable(ie. crestal bone, bone around midportion of fixture).

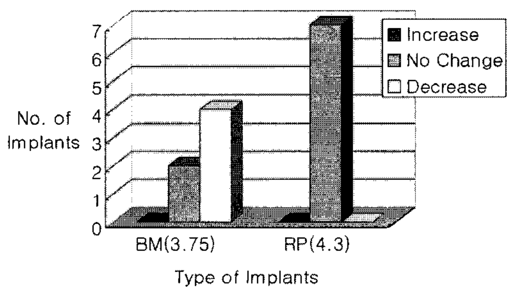

Fig. 9. Peri-implant bone density 3 months after first surgery.

Measurement of digital image

1) Bone Density

In subtracted image, minute bone density changes are not detected to naked eye. Emago software enables subtracted image to be analyzed automatically by figured gray level of pixels. Grey level over 128 means increased bone density and grey level under 128 means decreased bone density(Fig. 6~8). So, bone density change of subtracted images were evaluated in gray level-based histogram. Regions of Interest(ROI) could be selected and expressed in gray level histogram.

2) Marginal Bone Loss

After successful reconstruction, the amount of marginal bone loss were measured using measuring device in Emago. With this device the marginal bone loss was presented as the number of pixels between the two points. The actual amount of marginal bone loss was calculated as $L1 \times L2/$

$L3$($L1$=the number of pixels between bone loss, $L2$= actual length between two known points, $L3$= the number of pixels between two known points.

RESULT

In test 1, the peri-implant bone density of four implants decreased after first surgery. The histograms of the grey levels within windows at alveolar bone around implants showed a shift to the left from a grey level of 128. No density change was observed around the nine implants. During 3-6 months, no density change was observed around the 2 implants in-

Table Ⅲ. Peri-implant bone density 3 months after first surgery

Type Density	Increase	No change	Decrease	Total
Brånemark(3.75D)		2	4	6
Replace™(4.3D)		7		7
Total		9	4	13

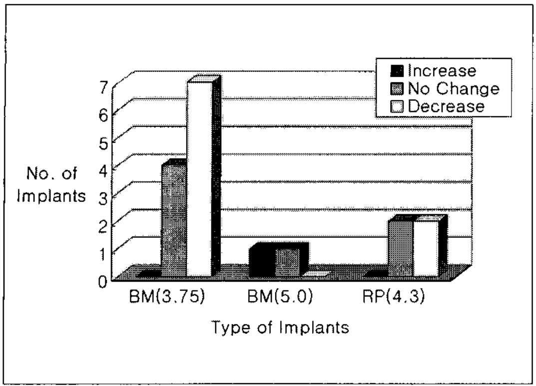

Fig. 10. Crestal bone density 3 months after second surgery.

Table Ⅳ. Crestal bone density 3 months after second surgery

Density / Type	Inc-rease	No change	Dec-rease	Total
Brånemark(3.75mm)		4	7	11
Brånemark(5.0mm)	1	1		2
Replace™(4.3mm)		2	2	4
Total	1	7	9	17

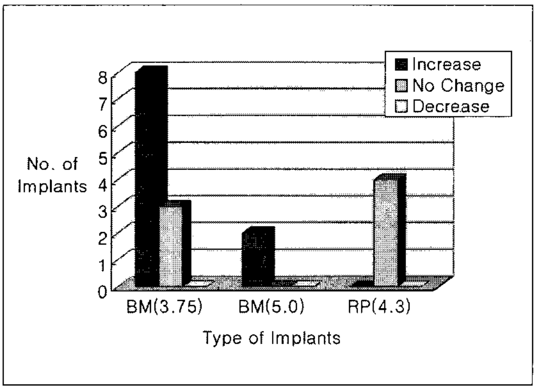

Fig. 11. Crestal bone density 9 months after second surgery.

Table Ⅴ. Crestal bone density 9 months after second surgery

Density / Type	Inc-rease	No change	Dec-rease	Total
Brånemark(3.75mm)	8	3		11
Brånemark(5.0mm)	2			2
Replace™(4.3mm)		4		4
Total	10	7		17

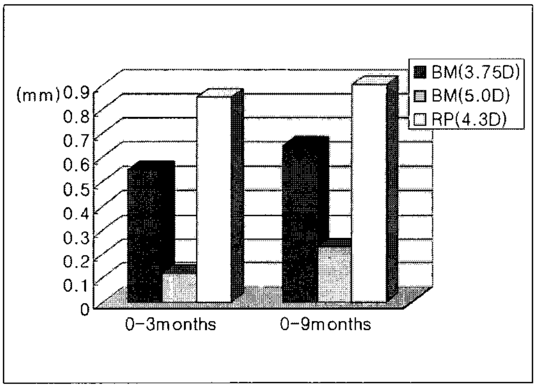

Fig. 12. Marginal bone loss(mm) after second surgery.

Table Ⅵ. Marginal bone loss(mm) for each implant at different follow-up examinations

Type	Term	0-3months	0-9months
Brånemark	Mean	-0.55	-0.65
(3.75mm)	SD	0.32	0.25
Brånemark	Mean	-0.12	0.46
(5.0mm)	SD	-0.23	0.62
Replace™	Mean	-0.85	0.32
(4.3mm)	SD	-0.90	0.14
Total	Mean	-0.57	0.39
	SD	-0.62	0.34

stalled in the maxillae(Table Ⅲ, Fig. 9).

In test 2, the density of crestal bone around seven implants decreased 3 months after second surgery. The histograms of windows placed in the area, where loss of density is visible, clearly showed a shift to the left from a grey level of 128(Table Ⅳ, Fig. 10). After 6 month of loading, the density of ten implants increased. In these implants, the his-

Table Ⅶ. Statistical analysis of marginal bone loss Test Statistics a,b

	0-3months	0-9months
Chi-square	4.226	2.476
df	2	2
Asymp.Sig.	0.121	0.290

a. Kruskal-Wallis Test

b. Grouping variables: implant type

tograms of windows placed at alveolar crest showed a shift to the right from a grey level of 128. No density change was observed around the midportion of the implants after second surgery. Windows placed more apically(midportion) showed histograms with a peak at 128 grey levels(Table Ⅴ, Fig. 11).

The mean length of marginal bone loss around total dental implants was 0.57mm±0.39mm during first 3 months and 0.62mm±0.34mm 9months after second surgery(Table Ⅵ, Fig. 12). More than 90% of total marginal bone loss recorded in a 9-month period occurred during the first 3 months. Preliminary statistical analysis with the Mann-Whitney U test indicated that no statistically significant difference existed with regard to sex, jaw, or implant length. Age was not found to be a statistically significant factor according to a correlation test. The amount of marginal bone loss during the 9-month period was statistically analyzed with the Kruskal-Wallis test using SPSS/PC+software(SPSS, Chicago, IL.). The amount of marginal bone loss after 3, 9 months had not statistically significant differences between three groups according to the Kruskal-Wallis test(P>0.05)(Table Ⅶ).

DISCUSSION

Radiographic analyses of maxillary and mandibular bone associated with implant placement provide the medium for evaluating the suitability of a certain site for implant placement[17] and diagnosing changes in bone tissue following implantation as well as during tissue integration.[2] Long-term clinical evaluation of dental implants and their superstructure is necessary to gain more insight in the cause of success and failure of this therapy. One of the items that need to be evaluated is the marginal bone height in the region of the implants. A decrease of bone level indicates that the implant is losing its bony anchorage. Alveolar bone resorption commonly progressed to the sidewall of the cuff region, whether a result of stress on the implants[17,18] or bacteria-induced peri-implant destruction.[19,20] It was stabilized when the bone loss reached the threaded area. Another factor related to initial bone loss is the damage from the initial surgical procedure. Adell et al.[21] claimed that surgical trauma such as that evolving from periosteal elevation and alveolar bone removal could speed up bone loss.

These small changes emphasize the requirement for accurate and reproducible techniques in radiographic evaluation of the state of the bone height.[26] Conventional radiographs are of limited value for reliable assessment of subtle alveolar bone changes.[3] The application of digital image analysis in peri-implant tissue has increased sensitivity in the detection of subtle bone density changes.[13]

The increasing tendency in bone density in digital subtraction was not observed 3 months after first surgery in this study. The decreasing tendency in bone density was observed after the first 3 months following second surgery. The following 6 months showed some increasing trends near the crest bone. Adell[22] and Brånemark et al.[23] observed successfully osseointegrated implants and found increases in bone density with horizontal orientation of peri-implant trabeculae from the threads. Albrektsson et al.[24] reported that the horizontal lamination started at the implant edges in radiographic and in histologic observations. They suggested that the threads could distribute the stress to a large area.

A 15-year study reported by Adell et al.[21] indicated that alveolar bone loss during the first year after abutment connection averaged 1.2mm, and annual bone loss thereafter remained at approximately 0.1mm for both the maxilla and the mandible. One of the criteria for implant success suggested by Smith and Zarb[25] was that less than 0.2mm of alveolar bone loss should occurr per year after the first year. The mean length of marginal bone loss around total dental implants was 0.57mm±0.39mm during first 3 months and 0.62mm±0.34mm 9 months after second surgery. The amount of marginal bone loss between different kinds of implants had no statistical significances. Rapid bone loss occurred in the first 3 months for all types of implants. More than 90% of total marginal bone loss recorded in a 9-month period occurred during the first 3 months. Surgical trauma such as that evolving from periosteal elevation and alveolar bone removal could speed up bone loss. Periosteal stripping is said to kill a lot of osteoprogenitor cells resulting in a reduced osteogenic reaction limiting the healing response. Marginal bone loss after abutment connection was relatively small. Marginal bone loss for 3 to 9 months may be attributed to trauma at the time of abutment connection and stress on the implant during mastication. This study was relatively short-term study. Longer observation is required to compare it with the long-term studies.

CONCLUSIONS

The present study measured marginal bone loss and bone density changes through the digital subtraction radiographs around endosseous root-form implants.

The results were as follows: The peri-implant bone density of 69.2% implant did not change and the peri-implant bone density of 30.8% implants decreased 3 months after first surgery.

1. The crestal bone density of 53.9% implants decreased after first 3 months following second surgery.
2. The crestal bone density of 58.8% implants increased 9 months after second surgery. No density change was observed around the midportion of the implants after second surgery.
3. The amount of marginal bone loss between different kinds of implants had no statistically significant differences (p>0.05).
4. More than 90% of total marginal bone loss recorded in a 9-month period occurred during the first 3 months.

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Reprint request to:
Dr. Yung-Soo Kim
Dept. of Prosthodontics, College of Dentistry
Seoul National Univ.
28-1, Yeomgun-Dong, Chongno-Gu, Seoul, 110-749, Korea
Tel:+82-2-760-2661, Fax:+82-2-760-3860