Correlation Between Bone Quality Evaluated by Cone-Beam Computerized Tomography and Implant Primary Stability

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Purpose: *To examine the relationship between bone quality, as evaluated by cone-beam computerized tomography (CBCT), and implant primary stability, as measured by resonance frequency analysis (RFA).* ***Materials and Methods:*** *A preliminary clinical study was conducted in which implant placements were scheduled for 20 patients. The CT scan was obtained after initial drilling, and implant stability was measured with the Osstell™ Mentor instrument before flap closure. With CBCT, CT numbers of surrounding bone were calculated and the thickness of compact bone was measured at the buccal, lingual, mesial, and distal surfaces of each implant. The correlations between CT numbers and implant stability quotients (ISQs) and between compact bone thickness and ISQs were tested with the Pearson correlation coefficient.* ***Results:*** *Overall, 61 implants were examined in 20 patients. The statistics showed that the CT numbers and the thickness of compact bone had strong correlations to ISQs (P < .025).* ***Conclusion:*** *CT scanning was suggested to be effective for evaluating bone quality and predicting initial implant stability.* INT J ORAL MAXILLOFAC IMPLANTS 2009;24:59–64

Key words: *bone quality, compact bone, computerized tomography, implant stability, resonance frequency analysis*

Studies have shown that osseointegrated dental implants generally have high success rates.[1,2] This success is considered to be influenced by both the volume (quantity) and density (quality) of available bone for implant placement. Therefore, emphasis has been placed on bone quantity and quality as important predictors of implant success.[3–6]

In an early introductory book on osseointegration, Lekholm and Zarb[7] subjectively classified the radiographic bone density into four types based on the amount of cortical versus trabecular bone. Misch[8] also classified bone quality subjectively, based on perceptions sensed during drilling procedures. A method of obtaining objective measurements of cutting resistance prior to the placement of implants was developed by Johansson and Strid.[9] Other methods for evaluating bone quality are histomorphometry of bone biopsies,[10] densitometry,[11] digital image analysis of microradiographs, and ultrasound.

Computerized tomography (CT) has been an established method to evaluate cross-sectional images of jawbone before implant surgery.[12–14] It can also be used for the objective quantification of bone mineral densities. Quantitative CT (QCT) furnishes direct density measurements, expressed in Hounsfield units (HU). However, the radiation absorbed by the patient during CT scanning may limit the use of this modality for routine diagnosis or repeated surveys. Therefore, a new type of CT machine for the purpose of dental and maxillofacial imaging has been introduced.[15] This new CT machine uses a cone-shaped x-ray area detector and is termed cone-beam CT (CBCT). Like a conventional CT, quantitative bone density measurements can be retrieved (quantitative CBCT [QCBCT]). The amount of radiation absorbed by the patient during each scan is reportedly 0.62 mGy.[16]

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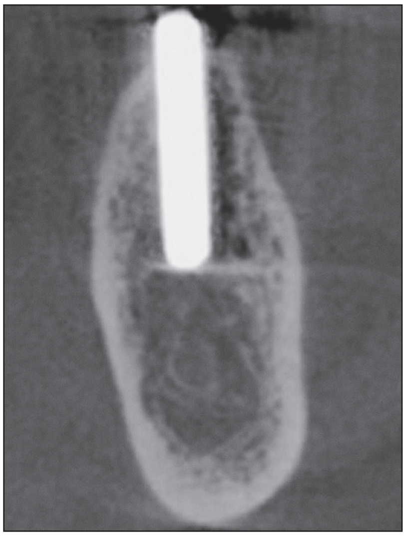

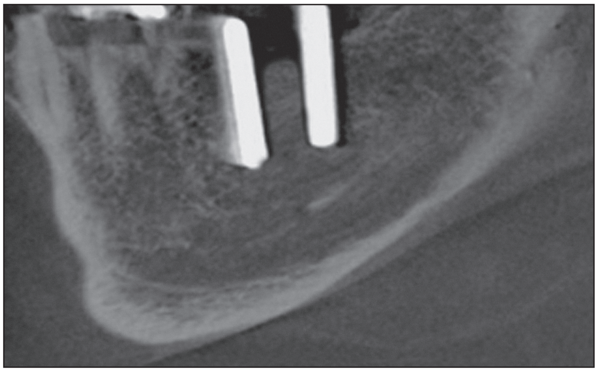

Fig 1 Cross-sectional image perpendicular to the mandible.

Fig 2 Cross-sectional image parallel to the mandible.

Recently, the immediate or early loading of implants with good initial stability has become widely accepted.[17] Since immediately loaded implant protocols are dependent on a certain degree of implant stability,[18] it is advantageous to determine the anticipated implant stability before treatment is initiated. Meredith et al[19] described a noninvasive method whereby bone formation around an implant could be evaluated by measuring the resonance frequency of a small transducer attached to an implant. Resonance frequency analysis (RFA) is a steady-state and nondestructive technique. A new version of a clinical instrument, the Osstell™ Mentor (Integrations Diagnostics AB, Savedalen, Sweden), was developed to analyze resonance frequency by means of a unit called the implant stability quotient (ISQ).

The specific purpose of this study was to examine the relationship between bone quality, as determined by the CT numbers and the thickness of compact bone evaluated by CBCT, and the implant primary stability measured by RFA.

MATERIALS AND METHODS

A total of 20 patients who needed more than two implants in a quadrant were included in this study. All the patients were healthy and had no uncontrolled systemic diseases. Patients who had guided bone regeneration before implant placement or who needed this procedure simultaneously were excluded.

After thorough diagnosis and treatment planning, implant placement surgery was performed. Under local anesthesia, a full-thickness flap was reflected and osteotomies were performed according to recommended sequences by the implant company. A 2-mm twist drill was used up to the exact depth of the planned implant. Next, a gutta-percha bar (E&Q PLUS Gutta Percha Bar; Meta Biomed, Chungbuk, Korea) of the same diameter but a few millimeters longer than the drilling depth was inserted into the osteotomy site, and a CT scan was obtained (Implagraphy; Vatech, Kyunggi-do, Korea). This took 24 seconds in normal mode. The implant surgery was then continued. For sites that would receive a 5-mm-diameter implant, the CT was obtained after a 3-mm twist drilling procedure with gutta-percha bar placed in the osteotomy site. Because self-tapping implants were used in this study, 3.3 mm was the final osteotomy for sites planned for 4-mm-diameter implants, and 4.3 mm was used for sites that would receive 5-mm-diameter implants. Then, Avana USII fixtures (Osstem, Seoul, Korea) were placed. These fixtures have a biocompatible RBM (resorbable blasting media) textured surface and an external hex in the same design as the original Brånemark implant. These implants were positioned so that the top of the implant platform was flush with the residual crest.

Before flap closure, implant stability was measured with the Osstell™ Mentor. The corresponding Smartpeg (Type I) was connected to the implant, and the RFA was measured four times per implant, twice from the buccal direction and twice from the lingual direction. The results were expressed in ISQs and averaged per implant. After RFA values were determined, sutures were placed and the surgery was complete.

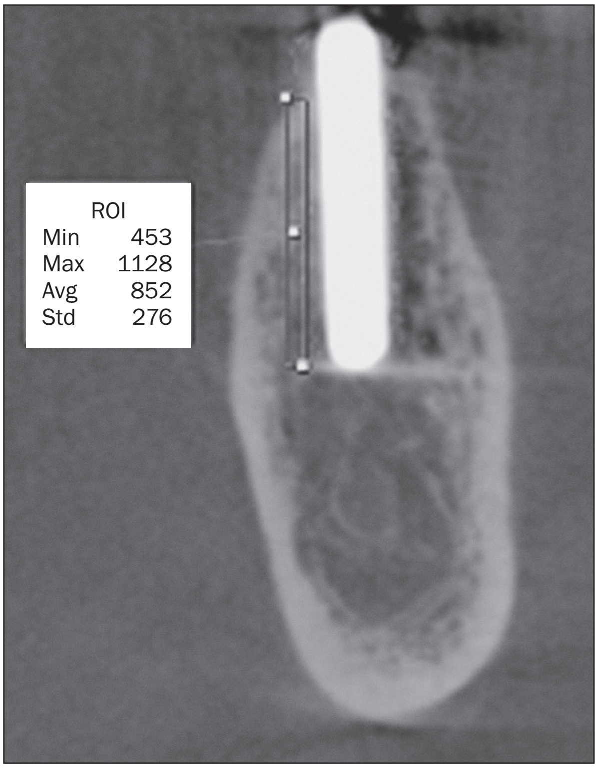

Fig 3 Example of calculating the Hounsfield units (CT numbers).

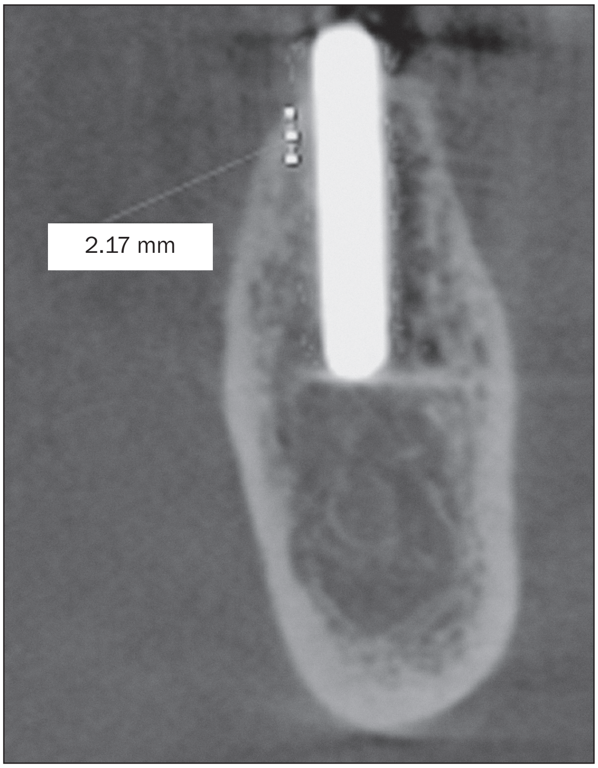

Fig 4 Example of measuring cortical plate thickness.

The CT scan images taken with gutta-percha in the osteotomy sites were processed into two types of cross-sectional images with Ezimplant (Vatech); one was perpendicular to the jawbone and the other was parallel to it (Figs 1 and 2). The gutta-percha was used to indicate the exact position of the implants. Ezimplant software (Vatech) calculated the average CT numbers in the "region of interest" (ROI) around the gutta-percha (Fig 3). In this study, the CT numbers of the surrounding bone were measured at a distance of 1 mm away from the outer surface of the gutta-percha at all buccal, lingual, mesial, and distal sides with the same length as an implant, and these CT numbers were used to indicate the quality of the bone engaged with the threads of the self-tapping implant. Also, using the same cross-sectional images, the thickness of compact bone 1 mm away from the indicators was measured at the same four sides using the measuring function of the software (Fig 4).

Therefore, each implant had (*1*) four CT numbers (buccal, lingual, mesial, and distal); (*2*) a value for the thickness of compact bone at the same four sides; and (*3*) an average ISQ.

Data Analysis

The correlations between CT numbers and ISQs and between the thickness of compact bone and ISQs were tested with the Pearson correlation coefficient. All statistical analyses were performed using SAS version 8.2 (SAS Institute, Cary, NC). A *P* value under .05 was considered statistically significant.

RESULTS

A total of 61 implants in 20 patients were examined. The patients' mean age at surgery was 57.15 ± 11.9 years (range, 24.25 years to 71.33 years). The average CT numbers obtained by CBCT are shown in Table 1. Mesial and distal sides showed lower CT numbers than buccal and lingual sides because of the shadow effect. The average thickness of compact bone and the average ISQs are shown as well. The four RFA values on each implant did not show large differences.

There were correlations between CT numbers at all four sides and ISQs at a level of significance of .025 (Table 2). Although CT numbers at mesial and distal sides were lower because of the shadow effect, they did demonstrate correlations with RFA. Statistically significant relationships were observed between the thickness of compact bone and ISQs at a level of significance of .001 (Table 3).

Table 1 Implant Data Obtained in the Study

Implant serial no.	Implant size (diameter × length)	Average CT no. (buccal and lingual)	Average CT no.	Average thickness of compact bone (mm)	Average ISQ
1	4 × 13	840.0	703.25	2.23	84.50
2	4 × 13	861.0	679.50	2.45	79.50
3	4 × 13	863.0	719.75	2.72	88.00
4	4 × 13	805.5	722.50	2.55	82.00
5	4 × 10	629.0	501.25	2.34	80.00
6	4 × 10	733.5	555.75	2.84	80.00
7	4 × 10	707.5	541.50	2.20	73.75
8	4 × 10	391.0	312.75	1.08	70.00
9	4 × 10	399.0	345.75	0.98	68.00
10	4 × 13	392.5	365.25	1.46	72.25
11	4 × 11.5	475.5	424.25	0.71	74.50
12	5 × 10	388.0	369.25	1.34	75.00
13	4 × 11.5	799.0	469.00	3.36	82.50
14	4 × 11.5	833.0	515.00	3.88	85.50
15	4 × 11.5	655.0	464.00	1.69	75.25
16	5 × 11.5	678.5	473.00	1.79	76.75
17	5 × 11.5	663.5	446.25	1.31	70.00
18	4 × 13	903.0	777.25	2.23	85.50
19	4 × 11.5	514.5	423.50	2.69	78.75
20	4 × 10	679.5	560.25	2.25	84.50
21	4 × 13	657.5	544.25	3.12	84.75
22	4 × 13	769.0	617.00	3.61	82.25
23	4 × 13	751.0	611.00	3.37	81.50
24	4 × 13	688.0	563.25	3.23	77.00
25	4 × 10	574.0	516.25	2.32	58.00
26	5 × 13	834.0	494.75	2.42	87.00
27	5 × 11.5	841.5	524.75	2.77	87.50
28	4 × 11.5	760.0	631.25	2.80	75.25
29	4 × 10	629.5	451.25	2.58	76.00
30	4 × 10	660.0	485.25	3.57	84.25
31	5 × 10	527.5	388.50	1.33	71.00
32	5 × 10	512.5	356.25	1.06	67.00
33	4 × 10	748.5	581.50	2.98	81.00
34	4 × 10	767.0	589.75	3.17	81.50
35	5 × 11.5	814.5	561.75	3.47	83.25
36	5 × 11.5	784.5	533.50	3.55	80.75
37	5 × 11.5	611.0	456.75	3.29	80.50
38	5 × 10	604.5	450.50	3.24	80.50
39	5 × 13	731.0	497.00	3.43	84.00
40	5 × 11.5	716.0	512.00	3.38	82.50
41	4 × 11.5	322.5	238.00	0.80	63.50
42	4 × 11.5	319.0	240.00	0.75	63.50
43	4 × 11.5	319.0	242.50	0.82	65.50
44	4 × 11.5	323.5	240.25	0.80	64.00
45	4 × 11.5	517.0	422.25	1.18	68.50
46	5 × 10	503.0	409.50	0.92	66.25
47	5 × 10	482.0	451.75	0.78	59.00
48	5 × 11.5	639.0	553.25	2.89	74.00
49	5 × 11.5	644.5	533.75	2.87	75.50
50	4 × 11.5	712.5	545.25	1.96	66.00
51	5 × 11.5	758.5	537.75	2.50	74.50
52	5 × 10	750.5	562.75	2.60	72.50
53	4 × 13	714.0	567.25	2.35	72.00
54	4 × 13	700.5	553.25	2.25	70.75
55	4 × 10	722.0	595.75	3.23	76.75
56	4 × 10	741.0	629.75	3.17	77.25
57	4 × 13	865.5	693.00	3.69	81.25
58	4 × 13	869.5	698.25	3.76	83.25
59	4 × 13	861.0	688.25	3.65	82.00
60	4 × 10	768.0	604.75	3.36	77.75
61	4 × 10	773.5	610.00	3.38	79.00

Table 2 Comparison of CT Numbers and ISQs

	Buccal CT numbers	Lingual CT numbers	Mesial CT numbers	Distal CT numbers
Correlation coefficient	.7525	.6986	.2887	.3116
P	< .0001	< .0001	.0241	.0145

Table 3 Comparison of Thickness of Compact Bone and ISQs

	Thickness of compact bone at buccal	Thickness of compact bone at lingual	Thickness of compact bone at mesial	Thickness of compact bone at distal
Correlation coefficient	.6632	.6551	.7072	.7552
P	< .0001	< .0001	< .0001	< .0001

DISCUSSION

Accurate information on bone quality will help the surgeon to identify suitable implant sites, thereby improving the possibility of success. Information on bone quality can be obtained by an adequate radiographic examination. The Hounsfield unit is a standardized and accepted scale for reporting and displaying reconstructed CT values.[20,21] This unit is based on a linear scale defined only by two points: the attenuation of dry air, set at 1,000 HU, and the attenuation of pure water at 25°C, set at 0 HU. Bone quality can be measured with CBCT as well. However, for CBCT, the standard unit of displaying bone density (HU) is not used; rather, the term "CT number" should be used. Few studies have reported on the use of QCBCT relating to oral implants. Norton and Gamble[22] examined 32 reformatted CTs, and the recorded mean measurements ranged from 77 to 1,421. In the study of Shapurian et al,[21] these measurements ranged from –240 to 1,159. In the present study, the highest number was 904, whereas the lowest was 107. The mesial and distal sides of the radiopaque indicators showed dark hollow images because of the shadow effect of CBCT.[23] Therefore, CT numbers of these areas may not accurately indicate the bone quality.

The thickness of the compact bone around the implants varied greatly according to location. Usually the anterior mandible shows the thickest compact bone. Also, the buccal side of the posterior mandible revealed a greater than average thickness. Contrary to expectation, in a few cases, the compact bone could not be identified.

In this study, CTs were performed in the middle of surgery to locate the exact site where the implants would be placed. In this way, accurate comparisons between bone quality and implant stability could be obtained. However, in a clinical situation, CT need not be performed during surgery.

The use of RFA allows clinicians to measure implant stability. Recent findings with this technique suggest that it may be used as a diagnostic tool. Moreover, since measurements can be repeated over time, changes in implant stability during loading can be monitored. In the present study, ISQs showed relatively high numbers. Except for very few implants, the ISQ values were over 70, which indicates very good implant stability. According to another study by Meredith et al,[24] ISQ values above 65 are regarded as optimal. Measurements conducted twice from the same direction showed similar ISQs with only minor differences, indicating that RFA is a repeatable and reliable technique.

In this preliminary study, the bone quality evaluated by CBCT had a very strong correlation with primary stability of the implants. Therefore, the preoperative evaluation of CT numbers and thickness of compact bone using CBCT can allow clinicians to predict implant stability after placement and the possibility of immediate or early loading. For this reason, bone quality as well as bone quantity should be considered during treatment planning.

CONCLUSION

The present study has shown that bone quality evaluated by CBCT has correlations with primary implant stability. This suggests that bone quality is one of the factors that require evaluation before implant surgery.

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