Bone Density Assessments of Dental Implant Sites: 3. Bone Quality Evaluation During Osteotomy and Implant Placement

Scott Lee, DDS, MS[1]/Bernard Gantes, DDS, MS[2]/Matt Riggs, PhD[3]/Max Crigger, DDS, MS[4]

Purpose: *In previous publications of this series of studies on human cadaver jaws, bone densities were assessed and compared using subjective evaluation, conventional computed tomography (CT), and cone-beam computed tomography (CBCT). The aim of this study was to compare subjective bone quality during osteotomy and implant insertion resistance torque to noninvasive subjective and objective radiographic bone density assessments.* ***Materials and Methods:*** *Forty-two designated implant sites were selected. Self-tapping implants were inserted into these sites. The operator subjectively rated the bone density during the osteotomy procedure. Resistance torque was recorded during insertion of the implants.* ***Results:*** *Subjective drilling resistance was modestly correlated to subjective radiographic density evaluation (Lekholm and Zarb; Spearman's rho of 0.53,* $P < .001$*). Subjective drilling resistance compared to the bone density in Hounsfield units (HU) obtained using CT and CBCT showed correlation coefficients of 0.61 and 0.59, respectively (*$P < .001$*). Significant overlap of density values was found for adjacent drilling ratings. On average, a difference in bone density of 180 HU was required to identify differences between drilling resistance groups. Comparisons of 2 implant insertion resistance torque variables (highest reading and regression slope of available readings) with CT and CBCT HU showed correlation coefficients of 0.61 to 0.63 (*$P < .01$*).* ***Conclusion:*** *Insertion torque resistance was modestly correlated with objective CT and CBCT measurements of bone density. The merit of these assessments of cadavers awaits clinical study.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:208–212

Key words: *bone quality, dental implants, implant placement, radiographic bone density, resistance torque*

Traditionally, functional occlusal loading of root-form implants has been delayed to allow adequate peri-implant bone apposition, defined as osseointegration.[1,2] The delay prior to loading is usually between 3 and 6 months. The length of the delay may vary because of variations in the quality and quantity of bone as well as the specific implant features (size, shape, and texture). Reducing the preprosthetic time period appeals to most patients.[3] One-stage implant placement with immediate prosthetic loading has been proposed for implants demonstrating postplacement stability in dense bone.[4–14]

Accurate assessment of recipient sites prior to implant placement is essential, particularly when planning immediate loading of dental implants. However, at the present time, subjective assessments of the sites based on preoperative radiographs and bone resistance during osteotomy and implant placement are the accepted means of bone quality determination.

Three-dimensional radiographic surveys, such as computed axial tomographic images can give useful information on bone quality. In addition to the vol-

[1]Assistant Professor, Department of Periodontics, School of Dentistry, Loma Linda University, Loma Linda, California.
[2]Associate Professor, Advanced Education Program in Periodontics & Implant Surgery, School of Dentistry, Loma Linda University, Loma Linda, California.
[3]Professor, Department of Psychology, Graduate School, Loma Linda University, Loma Linda, California.
[4]Professor, Advanced Education Program in Periodontics & Implant Surgery, School of Dentistry, Loma Linda University, Loma Linda, California.

Correspondence to: Dr Max Crigger, Advanced Education Program in Periodontics & Implant Surgery, School of Dentistry, Loma Linda University, Loma Linda, CA 92354. Fax: +909 558 4801. E-mail: mcrigger@llu.edu

ume of bone available at the surgical site, radiographic bone density can be objectively measured in Hounsfield units (HU) or bone mineral density units. Cone-beam computed tomography (CBCT) may reduce the radiation dose to the patient.[15,16] In the previous publications of this series, human cadaver jawbone densities were assessed with conventional CT[17] and CBCT.[18] Although the bone density measurements obtained with CBCT generally provided somewhat higher HU counts, they were closely correlated to the CT HU values.[18]

Subjective postplacement stability of the implant is defined as the absence of visual and tactile movement of the implant.[19] Objective methods of postplacement implant stability are limited. One such method is the measurement in Ncm of the torque required to fully insert a screw-shaped implant.[20–23] A minimum resistance torque level of 40 Ncm has been suggested as the acceptable threshold level of initial stability when considering immediate loading.[24] This level of torque may not be achieved routinely in soft bone. There is some evidence that the amount of insertion resistance torque is dependent upon the density of surrounding bone as determined by CT.[25]

The aim of this study was to compare bone quality evaluated subjectively during osteotomy and with implant insertion resistance torque to noninvasive subjective and objective radiographic bone density assessments.

MATERIALS AND METHODS

Human cadaver jaws, described in parts 1 and 2 of this series, were screened to identify those that could accommodate placement of a single-size implant.[17,18] Specimens representing edentulous areas of all regions of the jaws were retrieved. The blocks were approximately 1 cm wide and 3 to 4 cm long.

Forty-two implant sites (1 to 4 per edentulous space) were identified by the placement of 2-mm-diameter aluminum direction indicators. CT and CBCT scans were obtained.

In the previous studies, the following recordings were made: *(1)* Subjective evaluation of radiographic density by a single experienced operator using the Lekholm and Zarb[26] index (1 to 4) from sagittal images (CT and CBCT scans) of each implant site, *(2)* bone density measurements expressed in HU from CT images of the sites,[17] and *(3)* bone density measurements expressed in HU from CBCT images of the sites.[18] These recordings were used for comparison with the data acquired for this study.

A surgical unit capable of recording resistance torque up to 40 Ncm was used (OsseoCare; Nobel Biocare, Göteborg, Sweden). All instrumentations were carried out by a single experienced operator. Standardized osteotomy preparations were carried out to accommodate the placement of self-threading cylindric implants (4.0 × 10.0 mm, Mk III, Nobel Biocare). Instrumentation included 2.0-mm pilot and 3.15-mm twist drills. Drills were changed following every 10 osteotomies. No countersinking was performed. During the osteotomy procedure, the operator subjectively rated the drilling resistance using the Misch[27] classification (1 to 4).

The implant insertion resistance torque was then measured and recorded. Resistance torques were recorded for every quarter turn. Three possible insertion scenarios occurred: *(1)* The pre-set maximum torque was reached prior to full insertion, at which time, the number of supra-alveolar threads were assessed, and insertion was completed using a hand wrench. *(2)* The pre-set maximum torque was reached with full insertion. *(3)* Full insertion occurred, but the preset maximum torque was not reached. In this case, the implant was removed and a tapered implant (4.0 × 10 mm, Mark IV, Nobel Biocare) was inserted. Insertion resistance torque measurement was repeated. Resistance torque values were recorded on memory cards provided with the unit.

A varying number of positive (nonzero) quarter-turn readings were obtained for the 42 implant sites. For each series of values recorded, the resistance torque was expressed in 2 different ways: *(1)* the highest reading of the series and *(2)* the slope of the regression line after subjecting the available series of readings to linear regression analysis.

Data Analysis

Correlations between the various bone density assessments were determined by calculations of Spearman's rho. Differences in CT and CBCT HU counts between consecutive and nonconsecutive subjective drilling score groupings were evaluated using 2-tailed Student *t* tests.

RESULTS

Subjective Drilling Resistance Assessment

Subjective drilling resistance assessment of the 42 osteotomy sites resulted in the following distribution of scores: 6 sites (14%) were classified as D1, 18 sites (43%) were classified as D2, 12 sites (29%) were classified as D3, and 6 sites (14%) were classified as D4. Subjective drilling resistance assessment rating provided a correlation of 0.53 (Spearman's rho, $P \leq .001$) with subjective radiographic bone density rating (Table 1).

Table 1 Subjective Drilling Density Rating (Misch classification) Versus Subjective Radiographic Bone Density Assessment (Lekholm and Zarb Classification): No. of Sites with Concordant and Discordant Scores

Subjective drilling density rating	Subjective radiographic bone density assessment 1	2	3	4	Total
D1	4	2	0	0	6
D2	4	11	3	0	18
D3	2	8	0	2	12
D4	0	1	2	3	6
Total	10	22	5	5	42

Spearman's rho = 0.53, $P \leq .001$

Table 2 Mean HU (± SD) for Subjective Drilling Density (Misch Classification)

Subjective drilling density rating	n	CT Mean	CT SD	CBCT Mean	CBCT SD
D1	6	629	69	811	62
D2	18	508	130	685	129
D3	12	444	82	628	115
D4	6	310	111	419	205
Total	42	479	138	649	168

Table 3 Correlation Between CT and CBCT HU Counts and Subjective Drilling Density Rating (Misch Classification) and Subjective Radiographic Bone Density Assessment (Lekholm and Zarb Classification; n = 42)

	CT	CBCT
Subjective radiographic bone density assessment	0.58*	0.59*
Subjective drilling density rating	0.61*	0.59*

*$P \leq .001$.

Table 4 Correlation Between CT and CBCT HU Counts and Implant Insertion Resistance Torque Measurement Variables (n = 42)

	CT	CBCT
Highest torque	0.62*	0.63*
Slope	0.61*	0.63*

*$P \leq .01$.

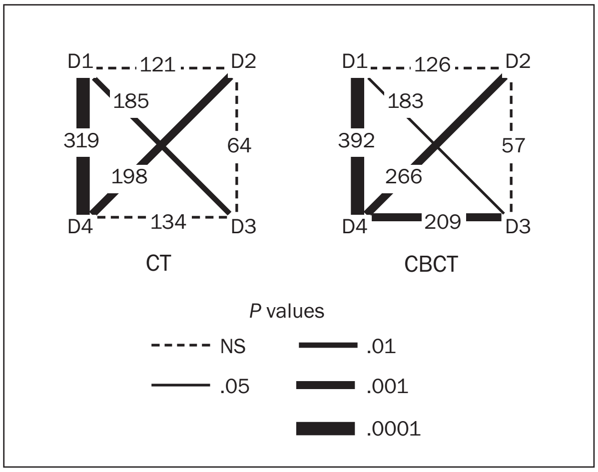

Fig 1 Comparison of CT and CBCT HU counts and subjective drilling bone assessment (Misch classification). The numbers on the lines indicate the mean differences between consecutive drilling scores (D1 versus D2, D2 versus D3, and D3 versus D4) and nonconsecutive drilling scores (D1 versus D3, D1 versus D4, and D2 versus D4) and the results of statistical analyses.

The mean (± SD) HU values for CT and CBCT scans are listed relative to sujective drilling density rating in Table 2. The differences between the HU counts for the various drilling resistance scores and the results of statistical analyses of these differences are graphically displayed in Fig 1. For consecutive drilling scores for CBCT (D1 versus D2, D2 versus D3, and D3 versus D4), only the difference between D3 and D4 (209 HU) was significant ($P \leq .001$). All of the differences between nonconsecutive drilling scores (D1 versus D3, D1 versus D4, and D2 versus D4) were large enough to be statistically significant. The magnitude of these differences ranged from 183 to 392 HU ($P \leq .05$ to $P \leq .0001$).

Comparison of subjective radiographic bone density and subjective drilling resistance assessments to CT and CBCT HU values produced coefficients of correlation between 0.58 and 0.61 ($P \leq .001$; Table 3).

Implant Insertion Resistance Torque

Preset maximum insertion torque (40 Ncm) was reached with 36 of the 42 implants. When the insertion unit reached the preset maximum torque, 11 of the 42 implants were inserted to only one third or less of the total implant length available. Six of the 42 implants were inserted more than a third but not beyond two thirds of their length. Nineteen of the implants were inserted more than two thirds and up to the entire implant length. The remaining 6 implants were fully inserted without reaching the preset maximum torque. Four of these 6 implants were subjectively rated as stable. These 6 implants were then carefully removed and replaced by tapered implants. The tapered implants were fully reinserted without reaching preset maximum torque. All 6 tapered implants were subjectively considered stable.

Comparisons of the 2 implant-insertion resistance-torque variables (highest reading of the series and the slope of the regression line of the series) with CT and CBCT HU values are presented in Table 4. Correlation coefficients of 0.61 to 0.63 ($P \leq .01$) were found for both highest torque and slope comparisons.

DISCUSSION

Accurate assessment of recipient sites prior to implant insertion is essential to guide implant placement, particularly when planning immediate loading of dental implants. For planning purposes, the bone quality can be assessed presurgically using radiographic analysis and confirmed surgically by evaluating drilling and insertion torque resistance.

The radiographic bone quality classification system of Lekholm and Zarb[26] has often been used to assess the bone quality of implant sites. As it may not be easy to demarcate one type of bone quality from the next, measuring HU from CT or CBCT can provide more objective assessment of bone quality. Studies by Shahlaie et al[17] and Aranyarachkul et al[18] compared the Lekholm and Zarb[26] classification with HU values obtained using CT and CBCT. These studies found significant overlap of the HU values comparing the various classification scores. An average difference of about 180 HU was required for the clinician to distinguish radiographic bone density of 1 level from another.

Trisi and Rao[28] reported similar difficulties in determining bone quality using the Misch[27] classification to assess resistance during bone drilling. Although the distinction of histomorphometric bone density determination was clear between types D1 and D4, major overlap was observed when the HU values for types D2 and D3 were compared. In the present study, similar observations were made, as there was significant overlap of HU density values for adjacent osteotomy drilling resistance ratings. On average, a radiographic difference of 180 HU was required to identify differences between consecutive drilling resistance groups. This result was comparable to the previous findings in the series using the Lekholm and Zarb classification.[17,18]

The correlation between subjective drilling resistance and subjective radiographic bone density by Lekholm and Zarb was limited (Spearman's rho = 0.53, $P \leq .01$). Comparisons between subjective drilling resistance and objective assessment of CT and CBCT HU values demonstrated slightly higher correlations (0.61 and 0.59, respectively; $P \leq .001$). When the maximum resistance torque was reached, all implants demonstrated initial clinical stability, regardless of radiographic or drilling resistance values. This scenario was encountered in spite of the modest Spearman's rho correlation values of 0.61 to 0.63.

If the unit had been capable of delivering and measuring torque resistance beyond 40 Ncm, it is possible that higher correlations would have been achieved. Forty percent of the implants in this study were inserted to less than two thirds of their length using a torque of 40 Ncm. Other researchers using human cadaver bone to compare objective CT radiographic bone density (bone mineral density) have reported a higher correlation to implant insertion resistance torque.[22,23]

In the present study, 6 of the cylindric implants failed to reach 40 Ncm insertion resistance torque value. In spite of this limitation, 4 of the 6 implants were subjectively judged as stable. The protocol required that the 6 be reversed and replaced with a tapered implant. This procedure resulted in subjective stability for all 6 implant replacements, although the threshold of 40 Ncm torque resistance was still not reached. Consequently, when facing this particular scenario in a clinical setting, it may seem prudent to delay functional loading or to use a wider implant.

The limitations of this study include the use of cadaver bone as the specimen model. Implant insertion resistance torque recorded in cadaver bone may differ from that recorded in living bone. A recent study comparing CT HU values with resistance insertion torque values obtained during the initial two thirds of insertion reported a 0.77 coefficient of correlation.[25] This difference may have been due to the use of vital bone.

Objective bone assessments obtained from CT or CBCT scans in combination with implant insertion resistance torque values may provide critical information regarding initial implant stability.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Dr Ben Nova for providing the cadaver material for this study, to Sam Sadanala for his graphic support, and to Nobel Biocare for providing implants and instruments.

REFERENCES

1. Brånemark P-I, Breine U, Adell R, Hansson B-O, Ohlsson Å. Intra-osseous anchorage of dental prostheses. I. Experimental studies. Scand J Plast Reconstr Surg 1969;3:81–100.
2. Brånemark P-I, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. Scand J Plast Reconstr Surg 1977;16(suppl):1–132.
3. Schropp L, Isidor F, Kostopoulos L, Wenzel A. Patient experience of, and satisfaction with, delayed-immediate vs. delayed single-tooth implant placement. Clin Oral Implants Res 2004;15:498–503.
4. Ericsson I, Nilson H, Lindh T, Randow K. Immediate functional loading of Brånemark single tooth implants. An 18 months' clinical pilot follow-up study. Clin Oral Implants Res 2000;11:26–33.
5. Chiapasco M, Abati S, Romeo E, Vogel G. Implant-retained mandibular overdentures with Brånemark system MkII implants: A prospective comparative study between delayed and immediate loading. Int J Oral Maxillofac Implants 2001;16:537–546.
6. Randow K, Ericsson I, Nilner K, Petersson A, Glantz P-O. Immediate functional loading of Brånemark dental implants. An 18-month clinical follow-up study. Clin Oral Implants Res 1999;10:8–15.
7. Lorenzoni M, Pertl C, Zhang K, Wimmer G, Wegscheider WA. Immediate loading of single-tooth implants in the anterior maxilla. Preliminary results after one year. Clin Oral Implants Res 2003;14:180–187.
8. Nikellis I, Levi A, Nicolopoulos C. Immediate loading of 190 endosseous dental implants: A prospective observational study of 40 patient treatments with up to 2-year data. Int J Oral Maxillofac Implants 2004;19:116–123.
9. Jaffin RA, Kumar A, Berman CL. Immediate loading of Brånemark system implants following placement in edentulous patients: A clinical report. Int J Oral Maxillofac Implants 2004;19:721–730.
10. Tarnow DP, Emtiaz S, Classi A. Immediate loading of threaded implants at stage 1 surgery in edentulous arches: Ten consecutive case reports with 1- to 5-year data. Int J Oral Maxillofac Implants 1997;12:319–324.
11. Schnitman PA, Wöhrle PS, Rubenstein JE, DaSilva JD, Wang NH. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. Int J Oral Maxillofac Implants 1997;12:495–503.
12. Romeo E, Chiapasco M, Lazza A, et al. Implant-retained mandibular overdentures with ITI implants. Clin Oral Implants Res 2002;13:495–501.
13. Andersen E, Haanaes HR, Knutsen BM. Immediate loading of single-tooth ITI implants in the anterior maxilla: A prospective 5-year pilot study. Clin Oral Implants Res 2002;13:281–287.
14. Gatti C, Haefliger W, Chiapasco M. Implant-retained mandibular overdentures with immediate loading: A prospective study of ITI implants. Int J Oral Maxillofac Implants 2000;15:383–388.
15. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol 1999;28:245–248.
16. Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. Oral Surg Oral Med Oral Path Oral Radiol Endod 2003;96:508–513.
17. Shahlaie M, Gantes B, Schulz E, Riggs M, Crigger M. Bone density assessments of dental implant sites: 1. Quantitative computed tomography. Int J Oral Maxillofac Implants 2003;18:224–231.
18. Aranyarachkul P, Caruso J, Gantes B, et al. Bone density assessments of dental implant sites: 2. Cone-beam computerized tomography. Int J Oral Maxillofac Implants 2005;20:416–424.
19. Orenstein IH, Tarnow DP, Morris HF, Ochi S. Factors affecting implant mobility at placement and integration of mobile implants at uncovering. J Periodontol 1998;69:1404–1412.
20. da Cunha HA, Francischone CE, Filho HN, de Oliveira RC. A comparison between cutting torque and resonance frequency in the assessment of primary stability and final torque capacity of standard and TiUnite single-tooth implants under immediate loading. Int J Oral Maxillofac Implants 2004;19:578-585.
21. Tricio J, van Steenberghe D, Rosenberg D, Duchateau L. Implant stability related to insertion torque force and bone density: An in vitro study. J Prosthet Dent 1995;74:608-612.
22. Homolka P, Beer A, Birkfellner W, et al. Bone mineral density measurement with dental quantitative CT prior to dental implant placement in cadaver mandibles: Pilot study. Radiology 2002;224:247-252.
23. Beer A, Gahleitner A, Holm A, Tschabitscher M, Homolka P. Correlation of insertion torques with bone mineral density from dental quantitative CT in the mandible. Clin Oral Implants Res 2003;14:616-620.
24. Bahat O. Treatment planning and placement of implants in the posterior maxillae: Report of 732 consecutive Nobelpharma implants. Int J Oral Maxillofac Implants 1993;8:151-161.
25. Ikumi N, Tsutsumi S. Assessment of correlation between computerized tomography values of the bone and cutting torque values at placement: A clinical study. Int J Oral Maxillofac Implants 2005;20:253-260.
26. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199-210.
27. Misch CE. Divisions of available bone in implant dentistry. Int J Oral Implantol 1990;7:9-17.
28. Trisi P, Rao W. Bone classification: Clinical-histomorphometric comparison. Clin Oral Implants Res 1999;10:1-7.