Assessment of Bone Density in the Posterior Maxilla Based on Hounsfield Units to Enhance the Initial Stability of Implants

Motofumi Sogo, DDS, PhD;* Kazunori Ikebe, DDS, PhD;† Tsung-Chieh Yang, DDS, PhD;‡
Masahiro Wada, DDS, PhD;§ Yoshinobu Maeda, DDS, PhD¶

ABSTRACT

Purpose: The poor bone quality that exists in the posterior maxilla is associated with lower initial stability and higher failure rates in implants. This study examined the bone densities of edentulous posterior maxillae by computed tomography (CT).

Materials and Methods: Based on CT images, the voxel values representing implant replacement in the posterior maxillary regions of 30 patients were calculated in the range from 150 to 2,000 Hounsfield units (HU). The bone densities of these regions were categorized according to Misch's classification and compared among individuals and between sexes.

Results: The average of the median individual CT values was 495 HU (95% confidence interval: 442–547 HU) and was significantly higher in males than in females. Most of the bone in the posterior maxillae was classified as D3 (350–850 HU) or D4 (150–350 HU) according to Misch's classification, comprising 50% and 32% of the entire regions, respectively.

Conclusions: More than 80% of the edentulous posterior maxillae consisted of porous cortical crest or no cortical bone according to CT, although the bone densities varied markedly among individuals. More detailed assessments of bone density may be useful to enhance initial stability of implants in the posterior maxilla.

KEY WORDS: bone density, CT value, dental implant, Hounsfield unit, maxillary molar region, Misch's classification

INTRODUCTION

Not surprisingly, lower initial stability and higher failure rates of implantation into poor quality bone, as opposed to higher quality bone, are well documented.[1–5] Notably, the poorest bone quality in the oral environment typically exists in the posterior maxilla.[6] Instead of associating inferior implant survival with location alone, bone density should be considered as an additional key predictive parameter.[7–10]

In 1988, Misch proposed the following four bone density groups based on microscopic cortical and trabecular bone characteristics:[11] D1, primarily dense cortical bone; D2, dense to thick porous cortical bone on the crest and coarse trabecular bone; D3, thin porous cortical crest and fine trabecular bone; and D4, minimal to no crestal cortical bone. Suggested implant designs, surgical protocols, healing processes, treatment plans, and progressive loading time spans should be modified for the individual bone density types.[11]

Recently, the use of computed tomography (CT) in diagnosis and treatment planning for implant placement has greatly increased, mainly because CT can determine the bone anatomy and density more precisely. Each voxel within a scan of a bone specimen generates a CT value (in Hounsfield units: HU) that is related to the density of the tissue represented by the voxel bone density classification, which is categorized as follows:[11] D1, >1,250 HU; D2, 850–1,250 HU; D3, 350–850 HU; D4, 150–350 HU. D4 bone requires careful planning for implant design, implant number, and progressive loading. Misch described bone density as being lowest in the posterior maxilla. However, the distinct bone densities of the

*Affiliate professor, †associate professor, ‡doctoral research fellow, §assistant professor, ¶professor and Chairman, Department of Prosthodontics and Oral Rehabilitation, Osaka University Graduate School of Dentistry, Suita, Japan

Reprint requests: Dr. Kazunori Ikebe, DDS, PhD, Department of Prosthodontics and Oral Rehabilitation, Osaka University Graduate School of Dentistry, 1–8 Yamadaoka, Suita 565-0871, Osaka, Japan; e-mail: ikebe@dent.osaka-u.ac.jp

DOI 10.1111/j.1708-8208.2011.00423.x

posterior maxillae and their individual variations from person to person have not been clearly indicated.

This study aimed to examine the bone densities of edentulous posterior maxillae in HU by CT to enhance the initial stability of implants.

MATERIALS AND METHODS

The study protocol was approved by the Institutional Review Board of Osaka University Graduate School of Dentistry.

The CT data used for implant diagnoses of 30 maxillary posterior regions (in 20 males and 10 females, aged 35–72 years) were utilized in this study. At various hospitals, we used clinical multislice CT machines made by Toshiba Co. (Tokyo, Japan), General Electric Co. (Fairfield, CT, USA) or Siemens AG (Munich, Germany) with 2, 4, 8, 16, or 32 slices. The machines were calibrated to −1,000 HU for air, prior to the first use every day and according to the written operating instructions, and to 0 HU for water, at least once a year by the CT manufacturer maintenance contract.

The CT images were loaded into a self-modified computer-program based on commercial implant simulation software (LANDmarker Ver. 3.5; iLAND Solutions Co. Ltd., Osaka, Japan), and three-dimensional models were reconstructed from the Digital Imaging and Communications in Medicine (DICOM) data. The maxillary posterior edentulous area to be used for evaluations was selected by manual placement of a rectangular parallelepiped region of interest (Figure 1). The CT values for

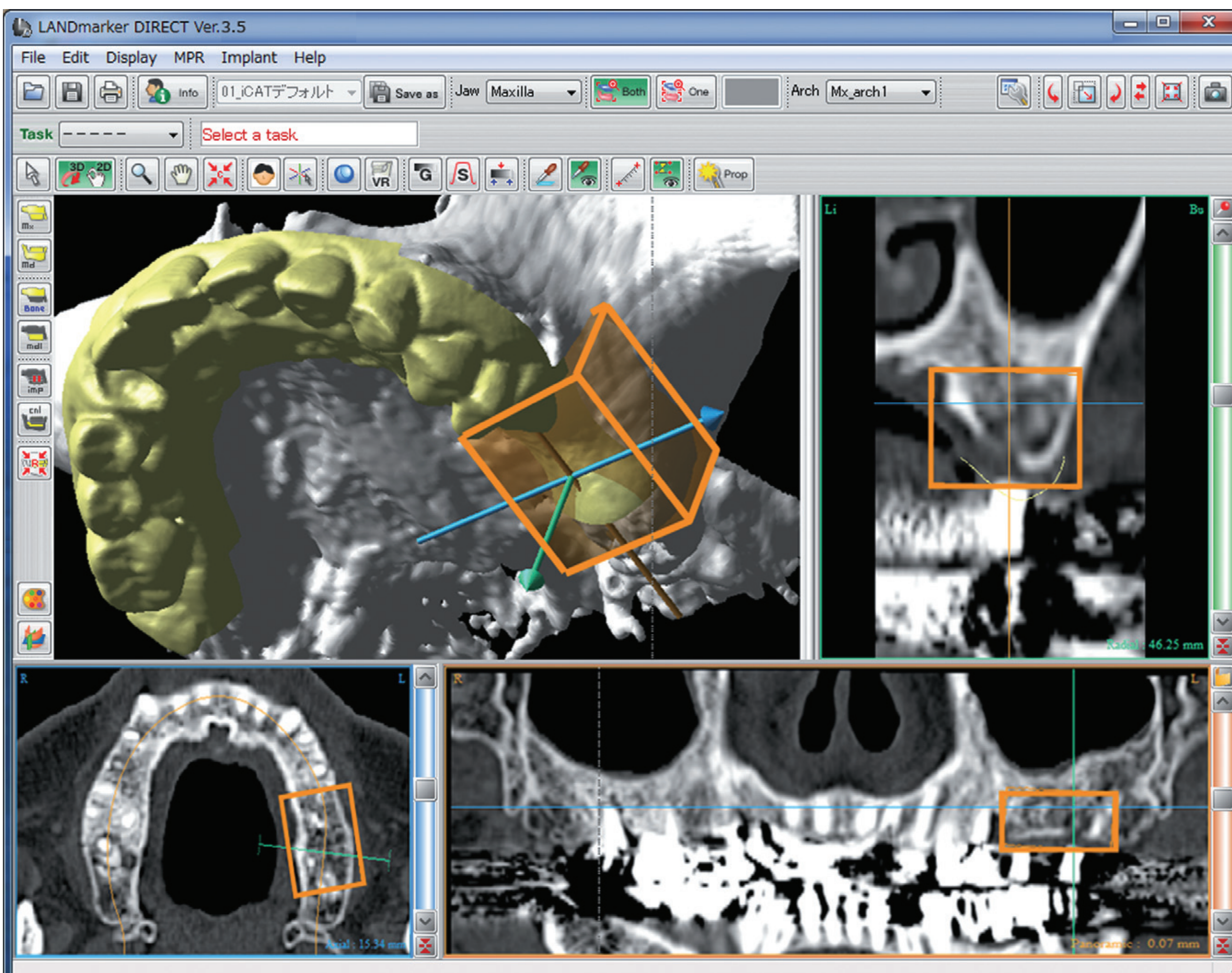

Figure 1 Simulated images of a posterior maxilla by the LANDmarker diagnosis software. A posterior edentulous area selected using a rectangular region of interest was extracted and analyzed. The areas measured on a posterior edentulous maxilla are displayed as a projected diagram with a rectangular parallelepiped solid region, including a frontal (buccolingual) section (upper right), a transverse section (lower left), and a sagittal (panoramic) section (lower right).

the voxels within the rectangular area were calculated, and the voxel numbers were counted in tens of HU in the range from 150 to 2,000 HU. The component percentages (based on the predefined ranges of D1–D4) of the individual maxillae were calculated, and the CT values were also compared between the sexes by Student's *t*-test. Spearman's rank-correlation coefficient was used to evaluate whether age was correlated with the CT values. The level of significance was set at $p < .05$.

RESULTS

The average of the median individual CT values was 495 HU (95% confidence interval: 442–547) and was significantly higher in males than in females ($p = .038$). The average of the 25th percentile of the CT values (326 HU; 95% confidence interval: 291–361) was also significantly higher in males ($p = .025$). Age was not significantly correlated with the 50th and 25th percentiles of the CT values ($p = .925$ and $p = .988$, respectively).

The majority of the bone in the posterior maxillae was classified as D4 or D3, comprising averages of 32% and 50% of the selected maxillary regions, respectively. However, these component percentages differed among individuals (Figure 2). To obtain more detailed information, we divided D3 and D4 into two subgroups. The average bone densities of subgroups D3a (600–850 HU), D3b (350–600 HU), D4a (250–350 HU), and D4b (150–250 HU) comprised 20%, 30%, 13%, and 19% of the selected maxillary regions, respectively (Figure 3).

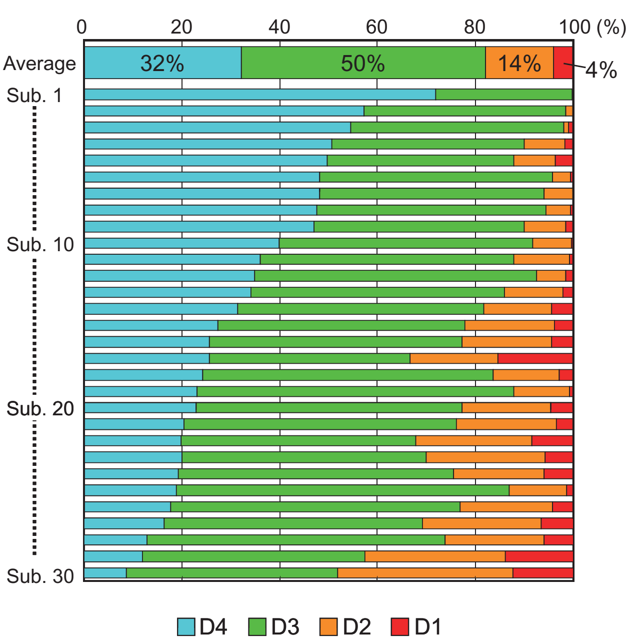

Figure 2 Percentages and averages of the voxel numbers in Misch's classification for the individual maxillae.

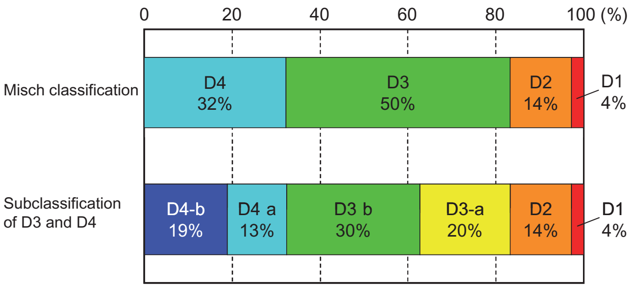

Figure 3 Percentages of voxel numbers in accordance with Misch's classification and the modified classification.

DISCUSSION

The highly satisfactory success rate obtained with dental implants in the treatment of various edentulous cases depends on the volume and quality of the bone. The initial stability of the implant is, in effect, one of the fundamental criteria for obtaining osseointegration.[12] Achieving stability depends on the bone density and surgical technique as well as the microscopic and macroscopic morphologies of the implant used. In bone that is not very dense, it is often difficult to obtain implant anchorage. The lack of initial stability in lower quality bone results in lower success rates,[12] which is especially critical for immediate loading.

Classification of bone quality has been used clinically as Lekholm and Zarb suggested a system as a means to assess the potential survival and failure of implants.[13] Using their classification, it has been possible to evaluate the bone quality by the operator's subjective tactile sense during the first drilling process or by the resonance frequency after implant installation. In recent years, CT scanning examinations have gained popularity in implant treatment, not only for evaluating bone anatomy and quantity but also for determining bone quality. In particular, Misch's classification has frequently been used for an objective evaluation of bone quality that is based on CT values.

In this study, we focused on identifying bone from 150 to 2,000 HU. Pixels with less than 150 HU were not recognized as bone structures. These areas were obviously unavailable for implantation and occupied only less than 5% of the whole bone area. Therefore, we did not use areas less than 150 HU for calculation of the voxels.

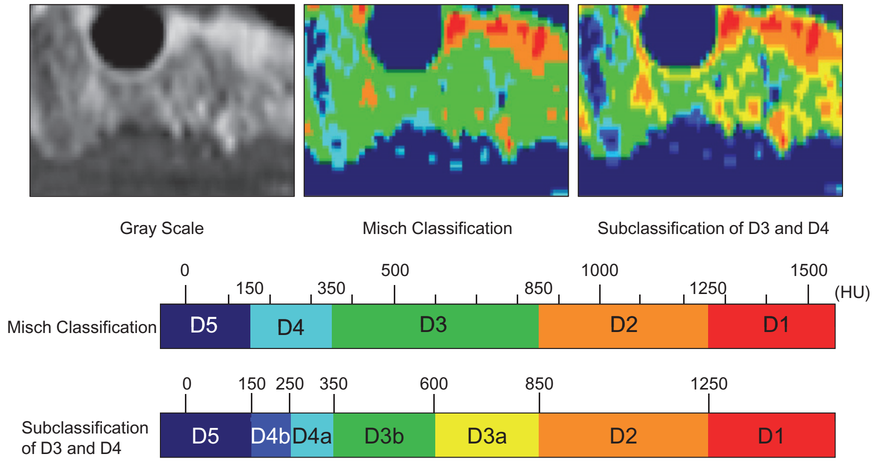

Figure 4 Sample displays of the bone densities of a posterior maxilla evaluated by Misch's original classification and the proposed modified Misch subclassification. D3a (600–850 HU; yellow) is associated with the potential for better initial implant stability. D4b (150–250 HU; royal blue) is associated with a higher risk for implant instability.

In this study, we found that women exhibited a lower bone density in the posterior maxilla than men, and that age-related loss of bone was not pronounced. In addition, the bone density in the posterior maxilla was mostly uniform according to Misch's classification, because more than 80% of the bone quality was classified as D3 or D4. To provide a more detailed and effective evaluation, we proposed to modify Misch's classification to create subcategories within D3 and D4, which were divided by the median values of their respective ranges. This modified Misch subclassification created a four-chrome range of D3 and D4 in the multiplanner reconstruction, thereby allowing a more sophisticated assessment of the bone density than the two-chrome range in the original method (Figure 4). Although the majority of bone in the posterior maxillae was classified as D3 or D4, there were remarkable variations among individual maxillae. Therefore, a thorough CT examination and a detailed display of the bone density in the prospective implantation site are required for successful tailor-made treatments of the posterior maxilla. For example, we can denote a comparatively higher bone density area (600–850 HU) in D3a as exhibiting a greater potential for implant stability during installation. In contrast, a lower bone density area (150–250 HU) in D4b, which is associated with a comparatively lower initial stability and should be avoided for early loading, can also be indicated.

The linear or finer color map allows for a more detailed and gradual image. However, we believe that strict HU boundaries are clinically useful to identify potential bone for implantation. From the results of this study, 80% of the total volume consisted of D3 or D4 bone in the maxillary posterior area. We believe it is important to denote the denser bone in D3, which is adequate for implantation, as D3a, and to distinguish the more porous bone in D4, which is not suitable for implantation, as D4b, in a single color.

CONCLUSIONS

More than 80% of the edentulous posterior maxillae consisted of porous cortical crest or no cortical bone according to CT, although the bone densities varied markedly among individuals. More detailed assessments of bone density may be useful to enhance initial stability of implants in the posterior maxilla.

REFERENCES

1. Becker W, Becker BE, Alsuwyed A, Al-Mubarak S. Long-term evaluation of 282 implants in maxillary and mandibular molar positions: a prospective study. J Periodontol 1999; 70:896–901.
2. Balshe AA, Eckert SE, Koka S, Assad DA, Weaver AL. The effects of smoking on the survival of smooth- and rough-surface dental implants. Int J Oral Maxillofac Implants 2008; 23:1117–1122.
3. Herrmann I, Lekholm U, Holm S, Kultje C. Evaluation of patient and implant characteristics as potential prognostic factors for oral implant failures. Int J Oral Maxillofac Implants 2005; 20:220–230.
4. Noguerol B, Munoz R, Mesa F, de Dios Luna J, O'Valle F. Early implant failure. Prognostic capacity of Periotest: retrospective study of a large sample. Clin Oral Implants Res 2006; 17:459–464.
5. Holahan CM, Wiens JL, Weaver A, Assad D, Koka S. Relationship between systemic bone mineral density and

local bone quality as effectors of dental implant survival. Clin Implant Dent Relat Res 2011; 13:29–33.

6. Turkyilmaz I, Tozum TF, Tumer C. Bone density assessments of oral implant sites using computerized tomography. J Oral Rehabil 2007; 34:267–272.
7. Khang W, Feldman S, Hawley CE, Gunsolley J. A multi-center study comparing dual acid-etched and machined-surfaced implants in various bone qualities. J Periodontol 2001; 72:1384–1390.
8. Weng D, Jacobson Z, Tarnow D, et al. A prospective multi-center clinical trial of 3i machined-surface implants: results after 6 years of follow-up. Int J Oral Maxillofac Implants 2003; 18:417–423.
9. Rocci A, Martignoni M, Gottlow J. Immediate loading of Branemark System TiUnite and machined-surface implants in the posterior mandible: a randomized open-ended clinical trial. Clin Implant Dent Relat Res 2003; 5(Suppl 1):57–63.
10. Degidi M, Piattelli A. 7-year follow-up of 93 immediately loaded titanium dental implants. J Oral Implantol 2005; 31:25–31.
11. Misch CE. Bone density: a key determinant for clinical success. In: Misch CE, ed. Dental implant prosthetics. 1st ed. Philadelphia, PA: Elsevier Health Sciences, 2004:130–141.
12. Martinez H, Davarpanah M, Missika P, Celletti R, Lazzara R. Optimal implant stabilization in low density bone. Clin Oral Implants Res 2001; 12:423–432.
13. Lekholm U, Zarb GA. Patient selection and preparation. In: Branemark P-I, Zarb GA, Albrektsson T, eds. Tissue-integrated prostheses: osseointegration in clinical dentistry. Chicago: Quintessence Publishing, 1985:199–209.