

BONE QUALITY ASSESSMENT OF DENTAL IMPLANT RECIPIENT SITES

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ABSTRACT

The term bone quality is not clearly defined and depends on many factors, such as bone density, bone vascularity, bone metabolism and other factors that may affect implant outcome. The assessment of bone volume and bone density is most common in planning the treatment of dental implants. Bone quality is an important predictor of primary implant stability, which influences the future implant osseointegration. Numerous classifications have been described for the evaluation of bone density. The most commonly used has been the one proposed by Lekholm and Zarb. For the objective evaluation of bone density, conventional computed tomography (CT) or Cone Beam Computed tomography (CBCT), have been proposed. Both methods are reliable for the measurement of bone density, but preference is given to CBCT, due to the lower radiation doses, greater comfort for the patient and the lower prices. Pre-operatively defined bone density is a good indicator of the future success of implant therapy. In addition to the bone density, vascularity of the jawbone is an important factor of the quality of the bone for the osseointegration of dental implants. Laser Doppler is a simple method that can determine the vascularity of bone during implant insertion. The development of modern diagnostic methods for assessing the quantity and quality of the jawbone has enabled easier implant planning and has provided a secure outcome.

Keywords: Bone quality, implant stability, computed tomography, cone beam computed tomography, jawbone vascularity.



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INTRODUCTION

The insertion of dental implants has become an increasingly common procedure in the oral rehabilitation of partially and totally edentulous patients. This trend has certainly contributed to the positive results of numerous clinical studies regarding implant survival rates (1,2,3,4). The success of any implant procedure depends on a series of patient-related and procedure dependent parameters, including general health conditions, biocompatibility of the implant material, the features of the implant surface, the surgical procedure, and the quality and quantity of the local bone (5,6). Based on the literature data, the success rate of implants is higher in the lower jaw than the upper jaw (4,5,6,7). This discrepancy may arise from the bone conditions around the implants. It is evident that, when compared with the maxilla, the bone surrounding the implant has a better volume and quality in the mandible (6).

There is no clear definition of bone quality, but it is generally presented as the sum of all of the characteristics of bone that influence its resistance to fracture (8). Many authors define bone quality as equivalent to bone mineral density. This includes physiological and structural aspects and the degree of bone tissue mineralization (9,10,11). Aspects such as bone metabolism, cell turnover, maturation, intracellular matrix and vascularity were also emphasized. Although the clinical outcome of an implant is influenced by many factors, including the implant body, the skill of the surgeon, and the oral environment, the key factor for success is the primary stability at the implant placement. Some studies have demonstrated that the quality of the alveolar bone is the most important factor for achieving good primary stability (12,13).

Primary implant stability has been acknowledged as an essential criterion for later achievement of osseointegration (14). The primary stability could be increased with increased bone quality, which would improve the osseointegration and increase the survival probability of the dental implant. Poor bone quantity and especially poor bone quality are the main risk factors for implant failure using the standard protocol for implant insertion (15). The primary stability depends on the quality of the local bone, the implant geometry and the applied surgical techniques (16). By applying additional surgical techniques, such as

the absence of threads at the implant site; the use of a profile borer at a reduced diameter; the use of a larger implant of greater diameter and length; and the presence of bicortical stabilization, can make for greater primary implant stability (17,18,19). Detailed preoperative analysis of the jawbone helps therapists in making decisions about the type of surgical procedure and the type of implants.

Bone density

Bone density seems to be of great importance not only in primary implant stability but also in the predictability for oral implant outcomes (10). The literature describes a large number of classifications and procedures for the determination of jawbone density (20,21,22). The most commonly used classification has been the one proposed by Lekholm and Zarb (1985), based on the amount of cortical and trabecular bone shown in preoperative panoramic and cephalometric radiographs. They classified bone density as Q1 to Q4 according to the ratio of cortical bone to spongy bone (10) (table 1). This method provides information on bone density but is considered to be a subjective method (23). Misch suggested that computed tomography (CT) can be used for the objective quantification of direct density measurements of bone, expressed in Hounsfield units (HU) (table 1). HU represent the relative density of body tissues according to a calibrated grey-level scale.

CT bone density

The introduction of new radiographic procedures that allow 3D analysis of the jawbone significantly facilitated the work of therapists and ensures a better treatment outcome.

In a CT scan, HU is proportional to the degree of x-ray attenuation, and it is allocated to each pixel to show the image that represents the density of the tissue. This method for pre-operative quantitative and qualitative assessment of dental implant sites is objective and reliable. The dental literature has numerous studies on the usefulness of CT for assessing bone volume and morphology and on the relationship between CT values and primary implant stability (7,9,12,14,16,19). It has been shown that there is a strong correlation between the pre-operative bone density

Table 1. Bone classifications and bone densities in Hounsfield units (HU)

Lekholm and Zarb clasiffication				
Type1	Type2	Type3	Type4	
Large homogenous cortical bone	Thick cortical layer surrounding a dense medullar bone	Thin cortical layer surrounding a dense medullar bone	Thin cortical layer surrounding a sparse medullar bone	
Misch clasification				
D1	D2	D3	D4	D5
> 1250 HU	850 to 1250 HU	350 to 850 HU	150 to 350 HU	< 150 HU
Dense cortical bone	Thick dense to porous cortical bone on crest and coarse trabecular bone	Thin porous cortical bone on crest and fine trabecular bone within	Fine trabecular bone	Immature, non-mineralized bone



Table 2. Bone densities in HU in diferent jaw regions

Jawbone region	Turkiylmaz et al. (2007)	de Oliveira et al. (2008)	Fun et al. (2010)
Anterior mandible	945 ± 207	383 ± 243	530 ± 161
Anterior maxilla	716 ± 190	370 ± 176	516 ± 132
Posterior mandible	674 ± 227	306 ± 187	359 ± 150
Posterior maxilla	455 ± 122	255 ± 184	332 ± 136

values and the primary stability measured after implant insertion (5,6,11,14,16)

The available literature indicates that the implant location greatly affects the implant success, which is approximately 4% higher in the mandible than in the maxilla, and it is higher in the anterior region than in the posterior region (approximately 12% and 4% in the maxilla and mandible, respectively). This might be explained by the mean bone density being highest in the anterior mandible, followed by the anterior maxilla, posterior mandible, and posterior maxilla (7, 24,25) (table 2).

There is also a difference in bone density between females and males, which may be explained by the hormonal peculiarities in females and the generally higher bone mass in males (25).

HU derived by CT can be used as a diagnostic parameter to predict possible implant stability. Thus, preoperative assessment of bone densities by HU is very important for optimizing primary implant stability. The use of CT has continued to grow, although its systematic use in clinical practice has been limited by concerns about high radiation doses and the relatively high cost.

Cone beam CT bone density

In recent years, due to the need for less expensive image acquisition protocols and scanners with a lower radiation dose, cone beam computed tomography (CBCT) has become widely used for oral and maxillofacial imaging. CBCT is a new medical imaging technique that generates 3-D images at a lower cost and at a lower absorbed dose compared with conventional computed tomography. This imaging technique is based on a cone-shaped X-ray beam centred on a 2-D detector that performs one rotation around the object, producing a series of 2-D images. These images are re-constructed in 3-D using a modification of the original cone-beam algorithm developed by Feldkamp et al. in 1984 (26).

In recent years, CBCT has been used for preoperative diagnosis in implant treatments. CBCT is superior because of its high definition, reduction of the exposure dose, low cost, and usability compared with CT. With the use of the CBCT, the dimensional accuracy is also comparable with CT, but in contrast to CT; the grey density values of the CBCT images (voxel value [VV]) are not absolute. In CBCT, the degree of one x-ray attenuation is shown by a grey scale (voxel value) (27). Some studies have shown

good correlation between HU and VV and suggest that CBCT can be used in pre-operative evaluation of jawbone density in planning for implants (28,29).

Many articles from the literature suggest that bone quality evaluated by CBCT has a high correlation with the primary stability of the implants (30,31,32). Hence, pre-operative density value estimations by CBCT may allow clinicians to predict implant stability.

Bone vascularity

Bone vascularity is an important factor in the process of osseointegration. After implant site preparation and implant insertion, tissue repair requires the development of a vascular system for a complete healing process (33,34). The early phase of healing proceeds from haematoma formation to woven bone formation. The late phase of healing results in bone remodelling and the formation of new bone, leading to osseointegration of the implant (35,36).

For assessment of tissue vascularity at the level of microcirculation, laser Doppler Flowmetry (LDF) is an appropriate method (37). This method has been used for the detection of blood flow in oral mucosal, pulpal, muscular and gingival tissues (38,39,40,41,42,43,44).

Recent animal and clinical studies showed that LDF is a reliable method for bone vascularity assessment during implant insertion (45,46). The method is based on a phenomenon known as the Doppler Effect i.e., a change in the frequency of light upon reflection from blood cells in motion.

Using the laser Doppler device software, the electronic impulse is expressed in perfusion units (PU), representing the number of cells multiplied by their average speed. Because the red blood cells are the majority of the mobile cells in the tissue, this means that the perfusion units are the blood velocity in the tissue (47). In their clinical study, Kokovic et al. showed that there is a statistically significant correlation between LDF measured during implant insertion and the changing values of implant stability in the late phase of osseointegration of dental implants in posterior mandibles (48).

Dental implant therapy requires an accurate preoperative assessment of the patient's hard and soft tissues. Clinicians should understand the indications, applications, and limitations of different imaging techniques to obtain information while keeping radiographic risks to a minimum. The use of CBCT with interactive planning software appears to meet the standard of care required for planning dental implant therapy (49). Bone density assessment using CBCT is an efficient method and significantly correlated with implant stability parameters and the Lekholm and Zarb index (50).

It can be concluded that CT and CBCT scanning are useful tools, providing not only morphological information but also bone density data, enabling the evaluation of the adequacy of potential dental implant sites prior to



implant placement. Keeping in mind the advantages of CBCT over conventional CT, it has to be used for the pre-operative evaluation of bone quality.

Vascularity at the implant site has been identified as an important factor for the successful outcome of dental implant treatment (51). LDF is a reliable method for the determination of bone vascularity prior to implant insertion and might determine future implant stability.

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