MINI-REVIEW

REVISITING BONE DENSITY: A REVIEW ON MISCH CLASSIFICATION

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ABSTRACT
Dental implants have been the treatment trend for more than a decade. They are the most predictable modern solution for missing teeth. The success of dental implants however, depends primarily on alveolar bone quantity and quality. Compromised bone quality and quantity are considered as potential risk factors for biological complications of the implant which can eventually cause early implant loss. The external architecture of the alveolar bone and its volume are usually evaluated by default during treatment planning for dental implants. The internal architecture is often not critically evaluated. The external and internal architecture of bone regulates almost all the facets of implant dentistry practice. From implant design selection, surgical approach, healing time to type of future prosthetic reconstruction, every aspect is dependent on bone density at the planned site. Various classifications have been described till date to describe the bone quantitatively and qualitatively. An example includes, Lekholm and Zarb listed four types of bone quality found in the anterior regions of the jawbone. This classification, widely used in modern implant dentistry, is essentially qualitative and defines bone quality based on the relationship between compact cortical and the trabecular bones. Misch and associates developed a quantitative classification for the bone density which is the most commonly used classification till date. Time and again new classifications have emerged, yet the Misch classification of bone density seems to be popularly used and considered the gold standard for bone density. This review aims to describe the attributes of the Misch classification and its clinical significance.

KEYWORDS
Bone Density, Misch classification, bone quality, Dental implant

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Introduction

Dense or porous cortical bone is found on the outer surfaces of bone and includes the crest of an edentulous ridge. Coarse and fine trabecular bone types are found within the outer shell of cortical bone and occasionally on the crestal surface of an edentulous residual ridge. These four macroscopic structures of bone may be arranged from the least dense to the most dense, as first described by Frost[1,2]. In combination, these four increasing macroscopic densities con- stitute four bone categories described by Misch (D1, D2, D3, and D4) located in the edentulous areas of the maxilla and mandible (Figure 1). The regional locations of the different densities of cortical bone are more consistent than the highly variable trabecular bone

Determining Bone Density

The bone density may be determined by various techniques including tactile sensation, during surgery, the general location, or radiographic evaluation (CBCT) (Figure 2).

Location

A review of the literature and a survey of completely and partially edentulous patients' post-surgery indicated that the location of different bone densities often may be superimposed on the different regions of the mouth.[3–6](Figure 2). D1 bone is almost never observed in the maxilla and is rarely observed in most mandibles In the mandible, D1 bone is observed

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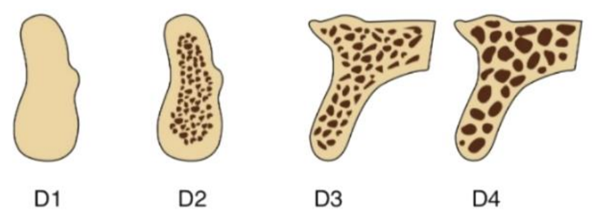

Four bone densities found in the edentulous regions of the maxilla and mandible. D1 bone is primarily dense cortical bone; D2 bone has dense-to-thick porous cortical bone on the crest and coarse trabecular bone underneath; D3 bone has a thinner porous cortical crest and fine trabecular bone within; and D4 bone has almost no crestal cortical bone. The fine trabecular bone composes almost all of the total volume of bone.

Figure 1: D1 bone is primarily dense cortical bone. D2 bone has dense- to-porous cortical bone on the crest and, within the bone, has coarse trabecular bone. D3 bone types have a thinner porous cortical crest and fine trabecular bone in the region next to the implant. D4 bone has very little to no crestal cortical bone. The fine trabecular bone composes almost all of the total volume of bone next to the implant. A very soft bone, with incomplete mineralization and large intertrabecular spaces, may be addressed as D5 bone.

approximately 6% of the time in the Division A anterior mandible and 3% of the time in the posterior mandible,

Misch Bone Density Classification Scheme

Bone Density	Description	Tactile Analog	Typical Anatomic Location
D1	Dense cortical	Oak or maple wood	Anterior mandible
D2	Porous cortical and coarse trabecular	White pine or spruce wood	Anterior mandible Posterior mandible Anterior maxilla
D3	Porous cortical and fine trabecular	Balsa wood	Anterior maxilla Posterior maxilla Posterior mandible
D4	Fine trabecular	Styrofoam	Posterior maxilla Anterior maxilla
D5	Osteoid	Soft Styrofoam	Poorly mineralized bone graft

Figure 2: Misch Bone Density Classification Scheme

primarily when the implant is engaging the lingual cortical plate of bone. In a C–h bone volume (moderate atrophy) in the ante rior mandible the prevalence of D1 bone approaches 25% in male individuals. The C–h mandible often exhibits an increase in torsion, flexure, or both in the anterior segment between the foramina during function. This increased strain may cause the bone to increase in density. The bone density D2 is the most common bone density observed in the mandible. The anterior mandible consists of D2 bone approximately two-thirds of the time. Almost half of patients have D2 bone in the posterior mandible. The maxilla presents D2 bone less often than the mandible. Bone density D3 is common in the maxilla. More than half of patients have D3 bone in the upper arch. The anterior edentulous maxilla has D3 bone approximately 75% of the time, whereas almost half of the patients have posterior maxillae with D3 bone (more often in the premolar region). The softest bone, D4, is most often found in the posterior maxilla (approximately 40%), especially in the molar regions or after a sinus graft augmentation (where almost two-thirds of the patients have D4 bone)

Radiographic Evaluation

Periapical or panoramic radiographs are minimally beneficial in deter- mining bone density, because of their two-dimensional nature and the lateral cortical plates often obscure the trabecular bone density. In addition, the more subtle changes of D2 to D3 cannot be quantified by these radiographs. Therefore the initial treatment plan, which often begins with these radiographs, follows the bone density by location method. Bone density may be more precisely determined using cone beam computerized tomography (CBCT).[7–9] With conventional computerized

CT Determination of Bone Density

D1: >1250 HU
D2: 850 to 1250 HU
D3: 350 to 850 HU
D4: 0 to 350 HU
D5: <0 HU

tomography (CT), each image is composed of pixels. Each pixel in the CT image is assigned a number, also referred to as a Hounsfield or CT number. The CT Hounsfield scale is calibrated such that the Hounsfield unit values are based on water (0 HU) and air (−1000 HU). In general the higher the CT number, the denser the tissue. The HU is a quantitative measurement used in CT scanning to express CT numbers in a standardized form. The HU was created by Sir Godfrey Hounsfield and obtained from a linear transformation of the measured attenuation coefficients of water (0 HU) and air(-1000 HU).

When evaluating dental cone beam computed tomography (CBCT) images in regard to bone density, there does not exist a direct correlation (accuracy of measurement) compared with medical CT. Most dental CBCT systems inherently have an increased variation and inconsistency with density estimates.

Figure 2: Tactile sensation of each types of bone quality and its location in jaw

The density estimates of gray levels (brightness values) are not true attenuation values (HU); thus inaccuracies in bone density estimates may result.[10] However there are studies that correlate gray scale values to HU[11]. This is mainly due to the high level of noise in the acquired images and the slight inconsistencies in the sensitivity of the CBCT detectors. Dental imaging software frequently provides attenuation values (HU); however, such values should be recognized as approximations lacking the precision of HU values derived from medical CT units

HUs have been correlated with bone density and treatment planning for dental implants.[12][13,14] In a retrospective study of CT scan images from implant patients, Kircos and Misch[15] established a correlation between CT HUs and density at the time of surgery. The Misch bone density classification may be evaluated on the CT images by correlation to a range of HU s (Fig 3).

Figure 3: Misch bone density classification may be evaluated on the CT images by correlation to a range of HUs

The very soft bone observed after some immaterialized bone grafts may be 50 to 180 units. Even negative numbers, suggestive of fat tissue, have been observed with the cortical plates of some jaws, including the anterior mandible.

Norton and Gamble[12] also found an overall correlation between subjective bone density scores of Lekholm and Zarb and the CT values. Several studies correlating torque forces at implant insertion with preoperative bone density values from CTs have reported similar conclusions.[16–18] Preoperative CT scan data of areas that lead to successful and unsuccessful implant placement have been reported. In the mandible, failed sites exhibited higher HUs than usual. This was correlated with failure in dense bone, possibly because of the lack of vascularization or overheating during surgery. By contrast, in the maxilla the bone density was low for the failed sites. The bone density may be different near the crest, compared with the apical region where the implant placement is planned.[14] The most critical region of bone density is the crestal 7 to 10 mm of bone, because this is where most stresses are applied to an Osseo integrated bone–implant interface. Therefore, when the bone density varies from the most crestal to apical region around the implant, the crestal 7 to 10 mm determines the treatment-plan protocol.

Many CBCT software programs are now available that allow for preoperative determination of bone density in the implant site area. An average HU is given inside the implant, which correlates to the bone density that the implant surgeon will be drilling into. The HU outside of the implant relays the average bone density around the periphery of the implant, which gives the clinician information on the bone–implant contact (BIC). This is especially important to determine the prosthetic protocol or progressive bone loading.

Tactile Sense

There is a great difference in the tactile sensation during osteotomy preparation in different bone densities, because the density is directly related to its strength.[18–21] To communicate more broadly to the profession relative to the tactile sense of different bone densities, Misch proposed the different densities of his classification be compared with materials of varying densities(Fig 2). Site preparation and implant placement in D1 bone is similar to the resistance on a drill preparing an osteotomy in oak or maple wood (e.g., hard wood). D2 bone is similar to the tactile sensation of drilling into white pine or spruce (e.g. soft wood). D3 bone is similar to drilling into a compressed balsa wood. D4 bone is similar to drilling into a compressed Styrofoam. This clinical observation may be correlated to different histomorphometric bone density determinations.[6] When an implant drill can operate at 1500 to 2500 rpm, it may be difficult to feel the difference between D3 and D4 bone. In D4 bone the drill may be inserted to the full desired depth without the drill rotating. In other words, a bone compression rather than extraction process may be used with the drill. D3 bone is easy to prepare but requires the drill to rotate while it is pressed into position. When this tactile method is the primary site, the surgeon should know how to modify the treatment plan if this bone density is different from first estimated when developing the treatment plan.

Conclusion

The classification system proposed by Misch based on anatomical and radiological jawbone quantity and quality evaluation is a helpful tool for planning of treatment strategy and communication or collaboration among specialists. Further clinical studies should beconducted for new classification validation and reliability evaluation.

Authors Contribution:

Aishwarya Saini: Manuscript editing, Literature search, data collection
Varun Wadhwani: Data Analysis, manuscript editing
Vaishnavi Rajaraman: Manuscript drafting and referencing

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