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Review Article

Correlation of bone mineral density on primary implant stability in elderly edentulous patients: A literature review

Sweta. G. Pisulkar[1], Ashok. J. Pakhan[2], Surekha. R. Godbole[3], Trupti. M. Dahane[4.]
[1]Associate Professor, [2]Professor and Dean, [3]Professor and Head of Department, [4]Associate Professor, Department of Prosthodontics, Sharad Pawar Dental College (SPDC), Datta Meghe Institute of Medical Sciences (DMIMS), Wardha, Maharashtra, India

***Corresponding author**
Dr. Sweta Pisulkar
Email: drsweta15@gmail.com

Abstract: The lifespan of mankind has increased substantially since the beginning of twentieth century due to improved living conditions, better hygiene, above all by the growing importance and development of medical science. Thus, the elderly are expected to comprise a larger proportion of individuals requiring prosthetic rehabilitation. There is hypothesis in literature that systemic factors like Osteoporosis, generalized bone mineral density and body mass index also have significant effects on residual ridge resorption. Osteoporosis is the most common metabolic bone disorder, which is characterized by a decrease in bone mineral density (BMD) or changes in the bone microstructure. There is controversy over the relationship between osteoporosis of skeletal and density of jaw bones. In addition, it is not clear whether the quality and quantity of maxillary and mandibular bones decrease parallel with those of other bones or not. Treatment success of dental implants is mainly dependent on the stability of the implant-bone interface. There is insufficient evidence to demonstrate that the quantitative measurement techniques have a reliable prognostic value in predicting loss of implant stability, the damping capacity assessment (Periotest) and the resonance frequency analysis (RFA; Osstell) are currently the objective methods to monitor the state of osseointegration. This literature review has to an extent justified the correlation of bone mineral density on primary implant stability and this information is of extreme relevance for a predictable clinical outcome.
Keywords: bone mineral density (BMD), the resonance frequency analysis (RFA)

INTRODUCTION

The lifespan of mankind has increased substantially since the beginning of twentieth century due to improved living conditions, better hygiene, above all by the growing importance and development of medical science. Thus, the elderly are expected to comprise a larger proportion of individuals requiring prosthetic rehabilitation. Residual Ridge Resorption (RRR) is the most important parameter considered for patients receiving complete denture. It is a multifactorial, chronic, progressive, irreversible and disabling disease [1]. In microscopic pathology, there is an osteoclastic activity, especially on the external surface of the crest of residual ridges [2]. Bone loss varies from patient to patient, one region to other in the same patient but the most dramatic changes occur in the edentulous mandibular region. Local Factors include teeth extraction (quality, quantity, shape of the ridge and muscle attachment), edentulousness, and bite stress from the denture. Whereas the Systemic factors comprises of patient's age, gender, Calcium and phosphorous metabolism disorders, Hormone imbalance. There is hypothesis in literature that systemic factors like Osteoporosis, generalized bone mineral density and body mass index also have significant effects on residual ridge resorption. Age and hormonal related bone loss is more common in women than in men, particularly in post menopausal women due to ovarian atrophy and the related decrease in the estrogen level. Its exact origin is not known but many local and systemic factors are related with residual ridge resorption [3, 4]. Body mass index is also described in the literature as one of the atrophic jawbones predisposing factors, emphasizing that not always patients with diminished bone mineral density have atrophic jawbones or opposite. So it is possible that patients with finer body structure and anatomically smaller bones have more manifestation signs of jawbone resorption than those with increased body mass index [5, 6, 7].

Bone mineral density and implant supported prosthesis:

The rise in the proportion of elderly in our population has in large measure been due to increase of the average expectancy of life, thus comprising of a large population seeking prosthetic rehabilitation. Since the introduction of osseointegrated implants, there has been an increasing interest in the field of dental implants. Implant-supported prosthesis has proven to be of great value for the edentulous patient. The success rate of implant-supported prosthesis is considered to be influenced by both the volume (quantity) and density (quality) of available bone for implant placement. The initial bone mineral density not only provides mechanical immobilization during healing but also permits better distribution and transmission of stresses from the implant-bone interface. The density of the available bone is a determining factor in treatment planning, implant design, surgical approach, healing time and initial progressive bone loading during prosthetic construction. The most common metabolic bone disease among the elderly the implant dentist will encounter is the age related disorder characterized by changes in bone quality, quantity, and architectural configuration. This condition is common in elderly edentulous patients. Age related bone loss affects the mandible or the maxilla in the same manner as the other parts of the skeleton that serve as diagnostic markers of the disease. Preoperative evaluation of bone density is essential to assist the clinician with the treatment planning of implant-supported prosthesis. Accurate information on bone density will help the surgeon identify the suitable implant sites, thereby improving the success rates of the procedures. To obtain this preoperative knowledge, adequate radiographic examination is required. Bone mineral density has been measured by photo densitometry, photon absorptiometry and computed tomography. Of these methods computed tomography is a noninvasive preoperative method and widely accepted as the most precise means of evaluating the architecture of potential implant sites in the mandible and maxilla as according to Lindh C et al. Computed tomography has the major advantage of enabling trabecular and cortical hone density to be evaluated separately. It allows precise 3 dimensional anatomic localization and furnishes direct density measurements, expressed in Hounsfield units [5-8]. Osseoitegrated implants in the maxilla are more vulnerable to failure due poor bone quality compared to mandible. The type and architecture of bone is known to influence its load bearing capacity and it has been demonstrated that poorer quality bone is associated with higher failure rates. The success of maxillary implant may also be influenced by the presence or absence of so called bi-cortical stabilization, which can be achieved by engaging the cortical floor of maxillary sinus or nasal cavity. Branemark P-I et al and Lekholm U have suggested this technique to help compensate for the relative loss of osseous implant support observed in areas with thin cortical bone, and low trabecular density, such as in the maxilla. In the mandible the cortical region consists of DI bone (>1250 Hounsfield units) that has fewer blood vessels than the other three type of bone, and therefore is more dependent on the periosteum for its nutrition. In the cortical region the capacity to regenerate is impaired because of the poor blood circulation, therefore delicate and minimal periosteal reflection is indicated. The DI bone is more difficult to prepare, as it is easily overheated during implant osteotomy procedures thus strive to minimize the thermal and mechanical trauma [9].

Correlation between bone mineral density of jaws and skeletal sites:

Different jaw regions exhibit different bone densities, which might be under the influence of various factors, including osteoporosis. Osteoporosis is the most common metabolic bone disorder, which is characterized by a decrease in bone mineral density (BMD) or changes in the bone microstructure. BMD is a medical term, which indicates the amount of material in each cm^3 of bone [8]. Various studies have shown that after 60 years of age, almost 1⁄3 of the population is affected by osteoporosis, and it is twice more prevalent in females than in males. The quality and quantity of jawbones are two notable local factors in the definitive decision-making for placement, determination of type, and success rate of implants [9, 10]. The systemic osteoporosis decreases the contact area between bone and the implant, although it does not result in definite implant failure. Knowledge about jaw regions with low bone density might assist in treatment planning and determination of implant prognosis. The hypothesis of relationship between osteoporosis and a decrease in the BMD of jaws was proposed for the first-time in 1960 [11-13]. There is controversy over the relationship between osteoporosis of skeletal and density of jaw bones. In addition, it is not clear whether the quality and quantity of maxillary and mandibular bones decrease parallel with those of other bones or not. Some studies have shown that there is a decrease in bone density of jaws in osteoporotic patients. However, other studies have failed to show such a relationship. Nasrin Esfahanizadeh et al concluded that there is a significant correlation between the densities of skeletal and jawbones; therefore, the density of skeletal bones and the presence of osteoporosis or osteopenia in these bones might reflect the same situation in the maxilla and mandible [14].

Measurement of Dental Implant Stability by Resonance Frequency Analysis and Damping Capacity Assessment:

Treatment success of dental implants is mainly dependent on the stability of the implant-bone interface. Buser *et al.;* [15]and Cochran *et al.;* [16] determined the success criteria that include (1) absence of clinically detectable implant mobility, (2) absence of pain or any subjective sensation, (3) absence of recurrent peri-implant infection, and (4) absence of continuous radiolucency around the implant after 3, 6, and 12 months of loading. However, none of the currently used assessment methods is able to predict treatment outcomes. It is documented that clinical as well as radiologic examination are of limited value in predicting treatment outcome of implants, such as implant survival and maintenance of osseointegration. Although there is insufficient evidence to demonstrate that quantitative measurement techniques have a reliable prognostic value in predicting loss of implant stability, the damping capacity assessment (Periotest) and the resonance frequency analysis (RFA; Osstell) are currently, apart from radiographs the objective methods to monitor the state of osseointegration. Both techniques are stability measurements using a controlled force to detect lateral movement, but they differ substantially in their technical aspect [17]. The Periotest consists of a small computer connected to a hand piece with an 8-g tapping rod inside. Using an electromagnetic accelerator, the tapping rod strikes a tooth or implant 16 times in 4 seconds at a velocity of 0.2 m/s. The contact time between the tapping rod and the implant is measured and converted by the computer into Periotest values. Periotest values range from 8 for maximum stability to +50 for clinical mobility. The device was initially designed for the measurement of tooth mobility, but it is also used for the stability assessment of implants. Several authors have concluded that the Periotest is a reliable method to monitor changes in the implant-bone complex and is therefore an adequate tool in assessing the stability status of an implant. However, the sensitivity and specificity of the Periotest still need to be determined [18-20]. Unlike the Periotest, which generates forces mechanically, the RFA method uses the piezo effect to produce a deflection of the implant. The transducer, which is attached either directly onto the implant or to the abutment, contains 2 piezo ceramic elements. The first piezo element generates an excitation signal (a sinusoidal wave varying in frequency from 5 to 15 kHz), which leads to a vibration of the whole transducer-implant-tissue complex. The sub- sequent response oscillation is measured by the second piezo element. This signal is then amplified, analyzed, and finally displayed graphically as well as numerically in a unit called the implant stability quotient (ISQ).ISQs range from 1 (mobility) to 100 (maximum stability). Nedir et AL found a sensitivity of 100% and a specificity of 97% for the Osstell device (Integration Diagnostics) with a cutoff ISQ of 47 for determination of implant stability [21]. Multiple studies have investigated the commercially available measuring devices Osstell and Periotest for the measurement of dental implant stability and confirmed the usefulness of both methods for this purpose. The objective of the study carried out by Jurgen Zix et al was to evaluate the presumed correlation of the RFA technique and the damping capacity assessment of the Periotest in a clinical trial. Both measuring techniques are applicable in the assessment of implant stability. The Osstell instrument seemed to be more precise than the Periotest, which exhibited a broader standard deviation and resulted in a lower interclass correlation coefficient. Periotest values appear to be more susceptible to clinical conditions [22].

Correlation of insertion torques and bone mineral density using dental quantitative Computed Tomography:

Friberg *et al.;* in 1991 concluded that the successful outcome 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 microscopic and macroscopic nature of the implant surface, the surgical procedure and the quality and quantity of the local bone. Primary implant stability is considered to play an essential role in successful osseointegration [23]. Senner by& Roos in 1998 suggested that it depends on bone quality and quantity; implant geometry and the site preparation technique, whereas Roos *et al.;* in 1997 concluded that the primary implant stability can remarkably decrease in ‘poor bone quality’ and thereby jeopardize the osseointegration process. Genant *et al.;* in 1985 and Cann in 1988 have suggested that the measurement of BMD with quantitative computed tomography (QCT) is an established method in osteology whereas Lang *et al.;* in 1998 suggested a correlation of reduced BMD values and increased fracture risk has been reported. In the diagnosis of osteoporotic changes a general mineral status is determined, whereas in dental implantology local bone properties are relevant. A description of the bone properties at planned implant positions is necessary here, compared to the determination of a representative BMD value averaged over large areas. Therefore, QCT procedures previously described are not directly applicable to the maxillofacial complex [24]. The bone density influences the amount of bone in contact with the implant surface, not only at first stage surgery, but also at the second stage and during prosthetic loading. The variation in bone mineral density between the pre and postmenopausal subjects showed that the postmenopausal subjects have decreased bone mineral density, but both show D3 bone (350 — 850 Hounsfield units) in the trabecular region. As the bone density decreases, the strength of the bone also decreases. To decrease the incidence of micro fracture of bone, stress and strain introduced to the implant should be reduced. Biomechanical loads on implant may he reduced by prosthetic design, for e.g. the cantilever length may be shortened or eliminated, narrower occlusal table designed and offset loads minimized. Removable prosthesis 4 (RP4 design) instead of a fixed prosthesis enables the patient to remove the restoration at night and reduce nocturnal parafunctional forces. Removable prosthesis 5 (RP5 design) permits the soft tissue to share the occlusal force and reduce the amount of stress on the implants. The load on the implant may also be influenced by the direction of force to the implant body. A load directed along the long axis of the implant body decreases the amount of stress in the crestal bone region compared to an angled load. As the bone mineral density decreases, the angle of the load on the implant body should be more axial. Increasing the functional loading area over which the force is applied by increasing the number of fixtures placed may also reduce stress. The implant macro geometry may be increased to decrease stress. By selecting a wider diameter implant also decreases stress by increasing surface area. For every 0.5mm increase in width, there is an increased surface area between 10-15% [15, 18, 20].

SUMMARY:

In edentulous patients, residual ridge resorption (RRR) is one of the most important factors affecting denture support, retention, stability, and masticatory function. The long-term high success rates of implant supported prosthesis in edentulous and partially edentulous patients, has made it the first treatment of choice. The future demands for implant treatment will probably increase in edentulous patients. In our view the bone quality must be described in a more detailed way which should include not only the mineral content but also the volume and structure of both cortical and trabecular bone. Bone mineral density measurements of trabecular bone are needed because the skeleton undergoes age related changes that affect trabecular bone, due to its higher turnover rate, more than they affect cortical bone. Computed tomography gives a site related measure of bone mineral density. Various articles presented that there is some definite correlation between primary stability of dental implants and bone mineral density of the edentulous foundation. It has been justified that as the bone density increases, the primary stability of implants also increases and indeed this information is of extreme relevance for a positive clinical outcome. If an implant has to be placed in a site with little bone density, little primary stability is expected, unless other resources are resorted to with regard to the implant dimensions and insertion technique. More data and evidence is required to support the relationship between bone mineral densities and implant primary stability, as the available literature is still weak to moderate according to the quality assessment and control of bias of the series of clinical studies found. Further research and a systematic methodological data analysis of various studies are required to produce further stronger evidences.

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