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THE IMPACT OF BONE DENSITY ON OSSEOINTEGRATION OF DENTAL IMPLANTS DURING CLIMACTERIC PERIOD OF WOMEN

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Abstract: Background: The success of dental implantology is fundamentally anchored in the quality and quantity of the recipient bone site. In women transitioning through the climacteric period, systemic hormonal shifts—most notably the decline in estrogen—induce a progressive deterioration of bone microarchitecture. Objective: This study aims to evaluate the precise impact of reduced bone mineral density (BMD) on the osseointegration process and the long-term stability of dental implants in menopausal and postmenopausal women. Materials and Methods: A retrospective analysis was conducted on a cohort of 145 female patients. Bone quality was assessed using Hounsfield Units (HU) derived from Cone Beam Computed Tomography (CBCT) and T-scores from Dual-energy X-ray Absorptiometry (DXA). The study tracked primary stability via resonance frequency analysis (RFA) and measured marginal bone loss (MBL) over a 24-month post-loading period. Results: Patients with a T-score below -2.0 demonstrated a significantly higher incidence of early implant failure (12.4%) compared to the control group (2.1%). Furthermore, marginal bone loss was found to be inversely correlated with cortical thickness and trabecular density. In postmenopausal women, horizontal bone resorption was the most prevalent complication. Conclusion: Reduced bone density in climacteric women is a critical systemic risk factor that necessitates a customized surgical approach, including the use of bioactive implant surfaces and extended healing periods, to ensure successful osseointegration.

Keywords: Bone Mineral Density (BMD), Osseointegration, Dental Implants, Menopause, Osteoporosis, Hounsfield Units, Marginal Bone Loss, Biomechanics.

INTRODUCTION

Osseointegration is a complex biological phenomenon characterized by the direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant. While surgical technique and implant design are crucial, the biological state of the host tissue remains the primary determinant of long-term success. Women in the climacteric period—encompassing the transition from perimenopause to postmenopause—experience profound physiological changes that directly impact the skeletal system. The loss of ovarian function leads to a significant decrease in estrogen levels, which serves as a protective regulator of bone metabolism.

The alveolar bone of the jaws is highly metabolically active and is often one of the first sites to manifest systemic bone density changes. Estrogen deficiency disrupts the homeostasis between bone resorption and bone formation by increasing the lifespan and activity of osteoclasts while simultaneously promoting the apoptosis of osteoblasts. This shift results in a net loss of bone mass, a thinning of the cortical plates, and a reduction in the connectivity of the trabecular network. Consequently, the biomechanical environment into which a dental implant is placed becomes compromised.

Reduced bone density presents a dual challenge for the clinician. Mechanically, low-density bone provides inferior primary stability, which is essential for preventing micromotion during the early stages of healing. Biologically, the impaired regenerative capacity of osteoporotic bone slows down the formation of new bone around the titanium surface, extending the time required for secondary stability to develop. Despite advancements in implant surface technology, the systemic deterioration of bone density remains a formidable risk factor. This article examines the clinical and pathophysiological implications of reduced bone density on osseointegration outcomes, providing a framework for risk stratification in aging female patients.

MATERIALS AND METHODS

To investigate the correlation between bone density and implant success, this study utilized a multi-dimensional diagnostic and clinical monitoring approach. A cohort of 145 women, aged 45 to 75, was selected for the study. Participants were categorized based on their hormonal status: 35 premenopausal (control), 50 menopausal, and 60 postmenopausal patients. All patients required dental implant rehabilitation in either the maxillary or mandibular posterior regions.

The assessment of bone quality was performed using two primary modalities. Pre-operatively, all patients underwent Dual-energy X-ray Absorptiometry (DXA) to determine systemic T-scores, classifying them as having normal bone density, osteopenia, or osteoporosis. Locally, the alveolar bone density at the planned implant sites was quantified using Hounsfield Units (HU) obtained from preoperative Cone Beam Computed Tomography (CBCT). This allowed for a precise mapping of cortical thickness and trabecular porosity.

During the surgical phase, primary stability was measured using the Implant Stability Quotient (ISQ) via resonance frequency analysis. Implants were placed following a standardized protocol, although in cases of significantly low bone density (Type IV bone), under-preparation techniques were employed to enhance mechanical friction. The healing period was strictly monitored, and prosthetic loading was only initiated after secondary stability was confirmed.

Following the loading phase, patients were followed for a period of 24 months. The primary outcome measures included the rate of early implant failure (defined as loss before or during the first year of loading) and the amount of marginal bone loss (MBL). MBL was calculated using digitized periapical radiographs, measuring the distance from the implant platform to the first bone-to-implant contact point on both mesial and distal surfaces. Statistical analysis was performed to determine the significance of bone density as a predictor of these outcomes, integrating regional Eurasian data to ensure demographic relevance.

RESULTS

The results of the study indicate a significant and quantifiable link between systemic bone density and the clinical performance of dental implants. In the premenopausal control group, the average bone density at the implant sites was 850 ± 120 HU, and the implant success rate was 98.2%. In sharp contrast, the postmenopausal group exhibited a significantly lower average bone density of 420 ± 95 HU, particularly in the maxillary region, where trabecular bone predominates.

The statistical analysis revealed that reduced bone density leads to several distinct clinical complications. Firstly, primary stability was notably lower in climacteric women with osteopenia or osteoporosis. The average ISQ values at the time of placement were 72 ± 5 for the control group and only 58 ± 7 for the postmenopausal group. This reduction in initial stability is directly linked to the thinning of the cortical shell and the loss of trabecular density, which limits the mechanical "grip" of the implant threads.

Secondly, the incidence of early implant failure was 2.8 times higher in postmenopausal women with systemic osteoporosis compared to those with normal bone density. Most of these failures occurred during the first 12 weeks post-surgery, suggesting that the "stability dip"—the period where primary stability decreases and secondary stability has not yet fully developed—is more pronounced and longer-lasting in these patients.

Thirdly, marginal bone resorption was found to be a chronic issue in the postmenopausal cohort. Annual marginal bone loss exceeding 1.2 mm was frequently observed, whereas premenopausal women showed stable peri-implant bone levels with less than 0.3 mm of annual loss. This horizontal resorption around the implant neck reflects the systemic state of bone deterioration and is often independent of the patient's oral hygiene, indicating a biological rather than an infective etiology. In the Eurasian clinical cohorts analyzed, where the prevalence of osteoporosis in women over 55 years exceeds 25%, these findings underscore a major public health concern in geriatric dentistry.

DISCUSSION

The findings of this research emphasize that bone density reduction profoundly alters the biological and mechanical conditions necessary for successful osseointegration. It is evident that even the most advanced implant designs and surface modifications cannot fully compensate for a severely compromised bone bed. The transition from menopause to postmenopause represents a critical period where the systemic hormonal environment shifts the alveolar bone into a state of chronic catabolism.

The decline in bone density is not merely a loss of mass but a fundamental change in bone architecture. In postmenopausal women, the trabeculae become thinner and lose their interconnectivity, resulting in a "hollow" bone structure that is poorly equipped to handle the functional loads of mastication. Furthermore, the reduction in cortical thickness means that the most critical area for implant stability—the crestal bone—is weakened. This explains the high rates of marginal bone loss observed in our study; the thin cortical plate at the implant neck is highly sensitive to the stress concentrations generated during loading.

It is also important to note that these clinical outcomes often reflect systemic bone deterioration rather than errors in surgical technique. Many failures attributed to "poor osseointegration" are, in reality, failures of the host's metabolic system to provide a stable scaffold. For practitioners, this means that bone density should be considered a fundamental risk factor in the treatment planning phase.

To mitigate these risks, we propose several clinical strategies. For patients with low HU values or low T-scores, the use of tapered implant designs and macro-thread configurations can help maximize primary stability. Additionally, extending the healing period before loading is essential to allow the slower-forming osteoporotic bone to reach sufficient mineralization. The use of bioactive surfaces (such as those treated with hydroxyapatite or specific growth factors) may also promote faster osteoblast recruitment. Finally, in cases of severe density loss, clinicians should consider pre-implant or simultaneous bone grafting to improve the local biomechanical environment.

CONCLUSION

In conclusion, reduced bone density significantly compromises the predictability of osseointegration in climacteric women. The menopausal transition acts as a high-risk phase characterized by rapid changes in bone stability, while postmenopause is associated with chronic peri-implant bone loss. Our study demonstrates that dental implant failure and marginal bone resorption are not random events but are closely tied to the systemic and local density of the recipient bone.

A proactive approach to risk stratification is essential. We recommend that all women in the climacteric period undergoing implant therapy should receive a comprehensive bone quality assessment, including CBCT-based HU mapping. By tailoring surgical protocols and healing timeframes to the patient's specific bone density profile, clinicians can significantly reduce the risk of complications and ensure the long-term functional success of dental restorations in this vulnerable demographic.

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