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THE INFLUENCE OF VITAMIN D ON OSSEOINTEGRATION OF DENTAL IMPLANTS DURING CLIMACTERIC PERIOD OF WOMEN

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Abstract: Background: Osseointegration serves as the fundamental biological process ensuring the stability and longevity of dental implants. In the modern era of regenerative dentistry, systemic health factors are increasingly recognized as primary determinants of surgical success. For women transitioning through the climacteric period (perimenopause, menopause, and postmenopause), the precipitous decline in estrogen levels profoundly alters bone metabolism. Objective: This article provides an in-depth analysis of the synergistic relationship between Vitamin D (25-hydroxyvitamin D) levels and dental implant osseointegration in climacteric women. Materials and Methods: The study integrates a comprehensive review of current literature with retrospective clinical observations from Eurasian patient cohorts. It examines the molecular mechanisms by which Vitamin D modulates the bone-implant interface. Results: Statistical evidence from the Eurasian region indicates a 60–80% prevalence of Vitamin D deficiency in the target demographic. Our findings suggest that serum levels below 20 ng/mL are strongly correlated with impaired primary stability, delayed secondary stability, and a significantly higher rate of marginal bone loss. Conclusion: Pre-operative screening for Vitamin D deficiency and subsequent pharmacological correction should be integrated into the standard of care for dental implantology in menopausal patients to mitigate the risk of biological complications.

Keywords: Vitamin D3, 25(OH)D, Osseointegration, Dental Implants, Menopause, Postmenopause, Bone Mineral Density (BMD), Osteoimmunology, Alveolar Bone.

INTRODUCTION

The evolution of implant dentistry has shifted focus from purely mechanical stability to the biological optimization of the host tissue. Among the various systemic factors influencing bone healing, the endocrine and nutritional status of the patient plays a pivotal role. Women in the climacteric period represent a significant and growing portion of the population seeking dental rehabilitation. This biological stage, characterized by the gradual cessation of ovarian function, leads to a systemic state of estrogen deficiency, which is intrinsically linked to accelerated bone turnover and the development of osteopenia or osteoporosis.

Estrogen exerts a protective effect on bone by inhibiting the activity of osteoclasts and promoting the survival of osteoblasts. During menopause, the reduction in 17β-estradiol leads to significant pathophysiological shifts. Firstly, the deficiency of estrogen stimulates the production of Rank-Ligand (RANKL), which binds to receptors on pre-osteoclasts, thereby accelerating their maturation and resorptive activity. Secondly, there is a notable dysregulation of cytokines, characterized by an increase in pro-inflammatory markers such as IL-1, IL-6, and TNF-alpha, which further exacerbate bone resorption in the alveolar process. Finally, the accelerated apoptosis of osteoblasts reduces the overall capacity for new bone formation around the titanium surface of the implant.

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Simultaneously, Vitamin D deficiency has emerged as a global "silent pandemic." Vitamin D is not merely a nutrient but a pre-hormone essential for calcium homeostasis and bone mineralization. Vitamin D3 (cholecalciferol) undergoes hydroxylation in the liver to 25(OH)D and subsequently in the kidneys to its active form, 1,25(OH)2D3 (calcitriol). Its influence on osseointegration is multifaceted. It regulates calcium and phosphate homeostasis by increasing intestinal absorption, ensuring an adequate mineral pool for the mineralization of the newly formed bone around the implant. Furthermore, Vitamin D promotes the differentiation of mesenchymal stem cells into osteoblasts rather than adipocytes, which is crucial during the initial weeks following implant placement. Additionally, in the field of osteoimmunology, Vitamin D modulates the local inflammatory response, ensuring a balanced transition from the inflammatory phase of healing to the proliferative phase.

For women in the climacteric period, the double burden of hormonal decline and hypovitaminosis D creates a high-risk environment for dental implant failure. This article explores the pathophysiological pathways through which Vitamin D influences the bone-implant interface, analyzes regional statistics, and provides clinical insights based on long-term monitoring.

MATERIALS AND METHODS

This study utilized a dual-methodological approach to investigate the impact of Vitamin D on osseointegration. First, a comprehensive literature review was conducted, focusing on the molecular interactions between cholecalciferol, estrogen receptors, and bone-to-implant contact (BIC) ratios. Second, a retrospective clinical observation was performed over a 5-year period, monitoring a cohort of 120 female patients aged between 48 and 72 years who were undergoing dental implant therapy.

All participants were evaluated for their systemic health status, with a specific focus on their hormonal stage (perimenopause or postmenopause) and serum Vitamin D levels. The biochemical screening involved measuring serum 25(OH)D levels at least four weeks prior to the planned surgical intervention. Based on these measurements, patients were categorized into three distinct groups. Group A (Sufficient) consisted of patients with 25(OH)D levels exceeding 30 ng/mL. Group B (Insufficient) included those with levels between 20 and 29 ng/mL. Group C (Deficient) comprised patients with levels falling below 20 ng/mL.

The clinical monitoring protocol included the assessment of primary stability at the time of placement and secondary stability during the integration period. Marginal bone loss (MBL) was measured using standardized intraoral radiographs and Cone Beam Computed Tomography (CBCT) at the 6-month and 12-month marks post-loading. Regional statistical data from various Eurasian populations, including cohorts from Uzbekistan, Kazakhstan, and Turkey, were integrated to provide a broader demographic context.

RESULTS

The analysis of regional statistical data revealed a staggering prevalence of Vitamin D deficiency within the Eurasian population. Factors such as geographical latitude, which limits UV-B radiation during winter months, and dietary habits characterized by low intake of fortified foods, contribute to this trend. Additionally, cultural factors such as skin-covering practices further limit natural Vitamin D synthesis. In our analysis of Central Asian and Eastern European cohorts, the prevalence of Vitamin D deficiency among women aged 45–65 was found to range from 68% to 82%, with nearly 30% of postmenopausal women exhibiting severe deficiency below 10 ng/mL.

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The clinical outcomes for the 120 monitored patients showed a direct correlation between Vitamin D status and implant success. Group A (Sufficient) demonstrated a remarkable 98.5% success rate, with osseointegration achieving completion within the standard biological timeframes—typically three months for the mandible and four to five months for the maxilla. In contrast, Group B (Insufficient) showed a 94% success rate, with several cases exhibiting minor delays in integration that required extended healing periods before prosthetic loading.

The most significant complications were observed in Group C (Deficient), where the success rate dropped to 86%. This group accounted for four cases of early implant failure within the first eight weeks and seven cases of significant marginal bone resorption. Data from regional clinics suggested that the relative risk of failure is 2.1 times higher in women with levels below 20 ng/mL. Furthermore, marginal bone loss in the first year was significantly higher in the deficient group, averaging 1.4 mm compared to 0.6 mm in the sufficient group. CBCT analysis also indicated that even when implants were integrated in Group C, the peri-implant bone density appeared more porous and less trabeculated.

DISCUSSION

The findings of this study emphasize that the transition through the climacteric period acts as a biological "stress test" for the skeletal system. When estrogen levels fall, the bone's reliance on Vitamin D for structural integrity increases significantly. There is a clear synergy between estrogen and Vitamin D; the latter can partially compensate for hormonal loss by downregulating RANKL production. However, when both are deficient, the RANKL/OPG ratio shifts dramatically towards bone destruction, creating a "hyper-resorptive" state that is detrimental to the stabilization of titanium implants.

The molecular mechanism of osseointegration is particularly sensitive to Vitamin D levels during the early healing phase (0–14 days). In the presence of adequate levels, there is an upregulation of bone morphogenetic proteins (BMPs) and TGF-β. Deficiency leads to a prolonged inflammatory phase where excessive macrophage activity may result in fibrous encapsulation. During the subsequent secondary stability phase (2–6 weeks), the body may prioritize serum calcium levels by mobilizing minerals from the bone—a process of secondary hyperparathyroidism—which causes micro-resorption at the implant-bone interface.

Furthermore, genetic predispositions related to the Vitamin D Receptor (VDR) gene polymorphisms, such as TaqI and BsmI, may influence how efficiently a patient utilizes available Vitamin D. This suggests that some women may require even higher serum levels to achieve optimal bone-to-implant contact.

Based on these clinical insights, we propose a standardized protocol for practitioners. Biochemical screening should be mandatory, with a target level of 40–60 ng/mL for optimal healing, which is higher than the general health minimum. For patients with levels below 20 ng/mL, a pharmacological loading dose of 50,000 IU of Vitamin D3 weekly for eight weeks is recommended, followed by maintenance. Patients in the 20-30 ng/mL range should receive 2,000–4,000 IU daily. It is also vital to ensure adequate intake of co-factors like Vitamin K2 and Magnesium. Finally, for menopausal patients with a history of deficiency, we recommend extending the unloaded healing phase by an additional four to six weeks to ensure proper mineralization.

CONCLUSION

Osseointegration is not merely a mechanical outcome but a complex biological achievement. In the context of women's health during the climacteric period, Vitamin D stands out as a critical

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and modifiable factor that determines the boundary between surgical success and failure. The high prevalence of deficiency in Eurasian populations necessitates a proactive and systemic approach from dental surgeons. By identifying and correcting Vitamin D deficiency prior to intervention, clinicians can significantly improve the predictability of implant therapy, reduce early failures, and ensure the long-term stability of prosthetic restorations in aging female patients.

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