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Impact of Systemic Health Conditions on Dental Implant Success: A Narrative Review

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Abstract **Background:** Dental implants are a predictable and highly successful treatment modality; however, their long-term success is closely influenced by the patient's systemic health. As implant therapy is increasingly requested by medically compromised patients, understanding the impact of systemic conditions on implant outcomes is essential. **Objective:** This review aims to evaluate current evidence on the influence of systemic health conditions on dental implant success and to provide clinically relevant considerations for managing such patients. **Methods:** A literature search was conducted in PubMed, Scopus, and Embase, including clinical trials, cohort studies, and systematic reviews published over the past two decades that examined the relationship between systemic diseases and dental implant outcomes. **Results:** Several systemic conditions, including uncontrolled diabetes mellitus, cardiovascular disease, osteoporosis, obesity, autoimmune disorders, smoking, and chronic kidney or liver disease, were associated with impaired healing, compromised bone quality, and reduced implant stability. Additionally, medication-related factors such as bisphosphonate therapy and long-term immunosuppression were identified as contributing risks for implant-related complications. **Conclusion:** Systemic health status plays a critical role in dental implant success. Thorough medical evaluation, optimization of systemic conditions, and individualized treatment planning are essential to improve outcomes in medically compromised patients. Interdisciplinary collaboration and evidence-based decision-making are key to achieving safe and predictable implant therapy.

Keywords: *Dental Implant, Systemic Health, Diabetes, Osteoporosis*

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1. Introduction

Dental implants have revolutionised restorative dentistry by providing a reliable and long-term solution for tooth replacement. Longitudinal studies show that survival rates for osseointegrated implants remain very high. For instance, a systematic review of implants with at least 10 years of follow-up reported a cumulative survival rate of approximately 94.6 %. [1] Meta-analyses extending to 20 years also indicate that approximately 80-90 % of implants survive over two decades. [2] Furthermore, large-scale retrospective analyses (over 10,000 implants) have demonstrated survival rates above 95 % in clinical practice. [2] Despite these favorable numbers, implant success is not solely determined by surgical technique or prosthetic design. Systemic health conditions, such as diabetes, osteoporosis, cardiovascular disease, and immunosuppression, can substantially influence healing, osseointegration, and long-term stability. [3] Studies have shown that while well-controlled systemic conditions may not drastically lower success rates, poorly managed disease and associated medications can pose meaningful risks. [3]

As the global population ages and medical treatments improve, a growing number of medically compromised patients are seeking implant-based rehabilitation. Clinicians are increasingly called upon to assess not just oral health but also systemic disease burden when planning implant therapy. [4] However, guidance on how to manage such patients perioperatively remains limited, and there is a need to synthesize the evidence.

The scope of this review is to examine and critically

evaluate current literature on how various systemic health conditions affect dental implant success. Our objective is to provide a comprehensive, evidence-based framework for clinicians managing implant therapy in medically complex patients, highlighting clinical implications and strategies to optimize

2. Systemic Health Conditions Influencing Implant Success

2.1. Diabetes Mellitus

Diabetes mellitus is one of the most extensively studied systemic conditions influencing dental implant outcomes. Hyperglycemia adversely affects wound healing by impairing neutrophil function, reducing angiogenesis, and disrupting collagen synthesis, thereby compromising osseointegration. Clinical evidence indicates that poorly controlled diabetes is associated with delayed bone healing, increased marginal bone loss, and a higher incidence of peri-implantitis, ultimately leading to an elevated risk of early implant failure [5]. Conversely, several studies have demonstrated that patients with well-controlled diabetes can achieve implant survival rates comparable to those of systemically healthy individuals, with meta-analytic data showing no significant reduction in long-term implant survival when glycated hemoglobin (HbA1c) levels are maintained within recommended thresholds [6].

These findings underscore the importance of optimizing glycemic control prior to implant placement, often targeting HbA1c levels below 7-8% depending on the patient's overall medical status, as well as the consideration of adjunctive measures such as antibiotic prophylaxis, extended healing periods, and close postoperative maintenance with ongoing glycemic monitoring to enhance implant success.

2.2. Cardiovascular Disease and Hypertension

Cardiovascular diseases (CVD), including hypertension, influence implant outcomes through impaired microvascular function and reduced tissue perfusion. Chronic endothelial dysfunction may compromise healing and bone integration. [7] Common medications (antihypertensives, antiplatelets, anticoagulants) generally do not contraindicate implants, though they may increase bleeding risk. Implant survival in patients with controlled CVD remains high. [8]

2.3. Osteoporosis and Bisphosphonate / Denosumab Therapy

Osteoporosis leads to decreased bone density and altered remodeling, raising concerns about primary stability. Studies show that osteoporosis alone does not significantly reduce implant survival when the disease is controlled. [9] Antiresorptive therapies, including oral and intravenous bisphosphonates as well as denosumab, have been associated with an increased risk of medication-related osteonecrosis of the jaw (MRONJ), particularly in patients receiving intravenous formulations or long-term treatment. This risk necessitates careful patient selection and treatment planning, as implant placement is generally contraindicated in high-risk individuals receiving intravenous antiresorptive therapy. In contrast, current evidence suggests that dental implant placement may be considered relatively safe in patients undergoing oral bisphosphonate therapy for less than four to five years, provided that thorough risk assessment and appropriate clinical precautions are undertaken. [10]

2.4. Smoking and Tobacco Use

Smoking negatively affects osseointegration by reducing blood flow, impairing immune response, and altering bone metabolism. Smokers exhibit higher implant failure and peri-implantitis rates. A dose-response relationship exists; heavy smokers experience significantly greater marginal bone loss than light smokers or non-smokers. [11] Mustapha et al. conducted a systematic review and meta-analysis assessing the effect of smoking on dental implant outcomes. Analysis of 292 studies involving 35,511 implants in smokers and 114,597 in non-smokers showed a significantly higher implant failure risk in smokers (OR = 2.40; $p < 0.001$). This increased risk was observed in both the maxilla and mandible. Smokers also exhibited greater marginal bone loss, with a mean difference of 0.58 mm compared to non-smokers ($p < 0.001$). The authors concluded that smoking increases the risk of dental implant failure by approximately 140%. [12]

2.5. Obesity and Metabolic Syndrome

Obesity induces a chronic low-grade inflammatory state mediated by adipokines (TNF-α, IL-6, leptin), which can interfere with wound healing and bone regeneration. Clinical studies show an association between metabolic syndrome and increased peri-implant inflammation and bone loss. [13] However, data on implant survival remain inconclusive. In a large retrospective cohort study involving 16,921 implants, Steeds et al. reported no significant association between obesity, as defined by body mass index, and dental implant failure, while identifying smoking and male sex as significant predictors of failure. These findings suggest that although obesity may exacerbate peri-implant inflammatory responses, it does not appear to independently increase the risk of implant failure, emphasizing the need for careful management of inflammatory and metabolic factors rather than exclusion of obese patients from implant therapy. [14]

2.6. Autoimmune Disorders and Immunosuppression

Autoimmune diseases, including rheumatoid arthritis (RA), systemic lupus erythematosus (SLE), and Sjögren's syndrome, may impair wound healing due to dysregulated immunity. Immunosuppressive medications (corticosteroids, biologics, calcineurin inhibitors) further complicate healing. Implant success is generally acceptable, but higher failure and peri-implantitis rates are

observed in post-transplant and long-term steroid users. Hyldahl et al. conducted a scoping review evaluating the effects of autoimmune diseases and associated pharmacologic therapies on dental implant survival and biologic outcomes. Eighty-seven clinical studies were included, predominantly consisting of case reports and retrospective designs, reflecting an overall low level of evidence. Reported implant survival rates ranged from 85.3% to 100%, with nearly half of implant losses occurring prior to prosthetic loading, suggesting an increased risk of early failure. Glucocorticoids were the most commonly used immunosuppressive agents, and outcomes varied widely across autoimmune conditions. Notably, while high implant survival was generally observed in patients with oral lichen planus, severe implant loss was reported in cases with untreated active disease. The authors concluded that dental implant therapy can be considered predictable in patients with autoimmune diseases when systemic and mucosal disease activity is well controlled; however, the heterogeneity and low methodological quality of available studies limit definitive conclusions. [15]

Duttenhoefer et al. performed a systematic review and meta-analysis to assess the impact of immunocompromised conditions on dental implant survival. Sixty-two studies comprising 1,751 endosseous implants placed in immunocompromised patients were included. Reported implant survival rates after a minimum follow-up of 24 months were high across conditions, including 93.1% in patients with HIV, 98.8% in those undergoing chemotherapy, 88.8% in patients with autoimmune diseases, and 100% in post-organ transplant recipients. Although Crohn's disease was associated with an increased tendency toward early implant failure, this effect did not reach statistical significance. Overall, the meta-analysis found no significant reduction in implant survival attributable to immunocompromised status. The authors concluded that implant-based rehabilitation can be safely considered in immunocompromised patients when careful preoperative risk stratification is performed, while emphasizing the need for higher-quality controlled and randomized studies to better elucidate the influence of immunosuppression on implant outcomes. [16]

2.7. Chronic Kidney and Liver Diseases

CKD alters bone turnover through renal osteodystrophy, affecting osseointegration. Studies show increased early failure and infection risk in CKD patients. Liver disease impairs coagulation and immunity, raising bleeding and infection risks. Limited studies suggest cautious case selection due to altered bone healing. Yoon et al. investigated the long-term maintenance of teeth and dental implants in patients with viral liver disease compared to systemically healthy controls. The study included 230 patients with liver disease and 316 controls, with data collected from clinical records and panoramic radiographs. Patients with liver disease exhibited significantly higher rates of tooth loss and the need for retreatment of active dental therapy, particularly among those who had received non-surgical pre-treatment. Moreover, the severity of liver disease was positively correlated with both tooth loss and retreatment frequency, indicating a direct impact of systemic hepatic dysfunction on oral health outcomes. These findings suggest that viral liver disease may increase the risk of dental and implant complications over time, emphasizing the importance of close monitoring and tailored maintenance protocols for these patients. [17]

2.8. Other Relevant Conditions

2.8.1. Thyroid Disorders

Hyper- and hypothyroidism influence bone metabolism, but current evidence shows minimal effect on implant survival when medically controlled. Torrejon-Moya et al. conducted a systematic review to assess whether thyroid disorders affect dental implant survival compared with healthy patients. Following PRISMA guidelines, 22 articles were initially identified, of which 11 met the inclusion criteria for analysis. The review concluded that patients with thyroid disorders, including both hypothyroidism and hyperthyroidism, can undergo dental implant rehabilitation with survival rates comparable to those of patients without thyroid disease. Despite these encouraging findings, the authors noted that the available evidence is limited and of moderate quality, highlighting the need for larger, higher-quality studies to confirm these outcomes and guide clinical decision-making. [18]

2.8.2. HIV Infection

Modern antiretroviral therapy allows successful implantation with survival rates similar to the general population when viral load is controlled. Sivakumar et al. conducted a systematic review and meta-analysis to evaluate the effect of HIV infection on dental implant survival. Eight studies comprising 411 HIV-positive patients and 1,109 implants were included, with a mean follow-up of 2.8 years. The pooled implant survival rate was 95% (95% CI: 92–96%), and moderate heterogeneity was observed across studies (I^2 = 41%). The review concluded that, based on available evidence, HIV infection does not significantly compromise short-term implant survival. However, the authors emphasized that the quality of evidence is low, indicating a need for further high-quality longitudinal studies to confirm these findings and inform clinical decision-making. [19]

2.8.3. Hematologic Disorders

Conditions such as anaemia or bleeding disorders may affect healing, though limited evidence suggests implants are feasible with proper medical management. Bacci et al. reviewed the impact of bleeding disorders on dental implant therapy, categorizing them as congenital coagulation disorders (CCDs), antiplatelet-induced bleeding disorders (APBDs), and anticoagulant-induced bleeding disorders (ACBDs). Findings indicate that implant placement is feasible in these patients when appropriate precautions are taken: CCD patients can undergo surgery following replacement of the deficient coagulation factor, APBD patients generally do not require interruption of therapy, and ACBD patients require individualized management based on their specific anticoagulant regimen. Despite the low quality of available evidence, the authors concluded that dental implants can be safely placed in patients with bleeding

disorders, provided careful preoperative assessment and strict local and postoperative bleeding control measures are implemented. [20]

3. Biological Mechanisms Linking Systemic Health to Osseointegration

Successful dental implant therapy requires not only surgical precision and favorable local conditions but also an optimal biological environment that supports healing, angiogenesis, and bone remodeling. Systemic health conditions influence these processes through multiple interconnected mechanisms.

3.1. Inflammatory Pathways

Systemic diseases often create a chronic inflammatory milieu that exerts negative effects on osseointegration. Elevated levels of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, common in diabetes, obesity, and autoimmune disorders, impair osteoblast differentiation and enhance osteoclast activation, leading to imbalanced bone turnover. [21] In diabetes, hyperglycemia increases advanced glycation end products (AGEs) that upregulate inflammatory signalling and suppress bone formation at the implant interface, contributing to delayed healing and increased bone resorption. [22]

3.2. Microvascular Changes

Adequate microcirculation is essential for delivering oxygen, nutrients, and cells to healing tissues. Systemic conditions such as diabetes and cardiovascular disease lead to endothelial dysfunction, capillary rarefaction, and reduced angiogenic capacity. These microvascular alterations diminish perfusion and delay osseous healing around implants. Impaired angiogenesis also reduces the availability of osteoprogenitor cells necessary for early osseointegration, compounding the risk of early implant failure. [23]

3.3. Bone Remodelling Alterations

Bone remodelling, regulated by osteoblasts and osteoclasts, maintains bone density and strength. Systemic conditions can disrupt this balance: osteoporosis reduces bone quality, affecting implant stability, while obesity and metabolic syndrome alter adipokines (leptin, adiponectin), promoting osteoclast activity and impairing osteoblast function. These changes weaken the bone-implant interface and increase the risk of marginal bone loss, potentially compromising long-term implant success. [24]

3.4. Immune Response Dysregulation

The immune system plays a pivotal role in orchestrating early wound healing. Dysregulated immune responses, seen in autoimmune diseases (e.g., RA, SLE) and in immunosuppressed individuals, can lead to delayed or defective wound closure and compromised integration. Moreover, immune cell dysfunction increases susceptibility to peri-implant infections, further jeopardizing implant survival. [25]

3.5. Medication Effects

Systemic medications commonly used to manage chronic diseases can influence bone turnover, wound healing, and implant outcomes. Bisphosphonates and denosumab inhibit osteoclast activity, reducing bone remodelling but increasing the risk of MRONJ following surgical trauma. Corticosteroids suppress inflammation but also impair osteoblast function and collagen synthesis, leading to delayed healing. Anticoagulants and antiplatelet agents generally do not affect osseointegration directly, but they can increase perioperative bleeding, requiring careful management. Overall, systemic pharmacotherapy has a dual impact: it controls underlying disease while introducing specific challenges for bone metabolism and surgical outcomes, emphasizing the need for individualized treatment planning and close medical collaboration. [26]

4. Discussion

This review highlights that systemic health is a critical determinant of dental implant success, with multiple conditions exerting direct and indirect effects on osseointegration. Across the literature, diabetes mellitus, cardiovascular disease, osteoporosis, obesity, smoking, autoimmune disorders, and chronic kidney or liver diseases are consistently reported as factors that can compromise implant survival, particularly when the disease is poorly controlled. These systemic conditions negatively impact wound healing, bone remodeling, and immune responses, which in turn increase the risk of early or late implant failure. [27]

Factors contributing most to implant failure include poor glycemic control in diabetics, heavy tobacco use, advanced osteoporosis with antiresorptive therapy, and immunosuppression. Microvascular compromise, chronic inflammation, and medication-related effects further exacerbate the risk. [28]

Strengths of current evidence include large cohort studies, long-term follow-ups, and systematic reviews that collectively provide insight into systemic risk factors. Limitations involve heterogeneity in study populations, variations in disease definitions, inconsistent reporting of glycemic control or medication use, and a paucity of randomized controlled trials in medically compromised patients. Overall, the findings emphasize the need for individualized patient assessment, optimization of systemic conditions, and interdisciplinary management to maximize implant success in medically complex populations.

5. Clinical Recommendations

Successful dental implant therapy in medically compromised patients requires careful preoperative assessment, individualized treatment planning, and interdisciplinary coordination. The following recommendations synthesize current evidence and best practices.

5.1. Pre-Operative Evaluation and Risk Assessment

A thorough medical history and comprehensive risk assessment are essential before initiating implant therapy. Clinicians should carefully evaluate the presence of systemic conditions such as diabetes mellitus, cardiovascular disease, osteoporosis, and autoimmune disorders, as well as the patient's current medication use, including bisphosphonates, immunosuppressive agents, and anticoagulants. Lifestyle-related factors, such as smoking, obesity, and metabolic syndrome, must also be considered due to their documented influence on wound healing and osseointegration. Risk assessment tools, including the American Society of Anesthesiologists (ASA) classification, can aid in identifying high-risk patients and guiding clinical decision-making. Patients with poorly controlled systemic conditions should be medically stabilized prior to implant placement to reduce complications and improve treatment outcomes. [29]

5.2. Laboratory Values to Consider

Relevant laboratory parameters can guide perioperative planning:

- HbA1c: <7-8 % for diabetic patients to reduce early failure.
- Blood pressure: Controlled hypertension to minimize intraoperative bleeding and cardiovascular risk.
- Vitamin D and calcium levels: Support bone metabolism and osseointegration.
- Renal and liver function tests: Important in patients with chronic kidney or liver disease to anticipate healing complications. [30]

5.3. Implant Protocol Modifications

- Extended healing periods may be required in diabetics, osteoporotic patients, and smokers.
- Minimally invasive surgical techniques reduce trauma and improve vascular support.
- Primary stability optimization: Using wider or longer implants or bone augmentation when necessary.
- Antibiotic prophylaxis is recommended for high-risk patients, such as immunocompromised or uncontrolled diabetic individuals. [31]

5.4. Post-Operative Maintenance Strategies

- Regular clinical and radiographic monitoring for early detection of peri-implantitis or bone loss.
- Reinforcement of oral hygiene protocols, especially in patients with diabetes or autoimmune disorders.
- Lifestyle modification counseling: Smoking cessation, weight management, and glycemic control.
- Early intervention for complications, with prompt referral to specialists as needed. [32]

5.5. Interprofessional Collaboration

Successful outcomes require coordination between dental clinicians and medical specialists, including:

- Endocrinologists for diabetes management
- Cardiologists for CVD optimization
- Rheumatologists or transplant physicians for immunosuppressed patients
- Pharmacists to evaluate drug interactions

Interdisciplinary collaboration ensures risk mitigation, perioperative optimization, and long-term implant success. [33]

6. Future Research Directions

While current evidence underscores the importance of systemic health in dental implant success, several gaps remain that warrant further investigation.

6.1. Need for Long-Term Prospective Studies

Most available data are derived from retrospective studies, case series, or short-term cohorts. There is a need for large-scale, long-term prospective studies to quantify the precise impact of systemic conditions on implant survival and to differentiate the effects of disease severity, duration, and control. [34]

6.2. Biomarkers for Predicting Implant Success

Emerging research suggests that circulating inflammatory markers, cytokines, and bone turnover biomarkers (e.g., RANKL, osteocalcin) may predict early osseointegration and long-term stability. Identifying reliable biomarkers could allow for risk stratification and personalized perioperative planning. [35]

6.3. Personalized Medicine Approaches

Integrating genetic profiling, systemic disease status, and pharmacological history can help tailor implant therapy for each patient. Personalized approaches may optimize healing, reduce complications, and improve long-term outcomes in medically complex populations. [36]

6.4. AI and Digital Tools for Risk Prediction

Artificial intelligence and machine learning algorithms are increasingly used to predict implant failure based on patient-specific risk factors. Digital workflows combining CBCT imaging, systemic health data, and machine learning models have the potential to enhance treatment planning, patient counselling, and outcome prediction. [37]

Overall, future research should focus on integrating systemic health data, biomarkers, and advanced predictive tools to move toward precision implantology, especially for high-risk patients.

7. Conclusion

Systemic health conditions significantly influence the success and survival of dental implants. Diseases such as diabetes, cardiovascular disorders, osteoporosis, autoimmune conditions, obesity, and chronic kidney or

liver disease affect osseointegration through mechanisms including chronic inflammation, impaired microvascular perfusion, altered bone remodeling, immune dysregulation, and medication effects.

Individualized treatment planning is essential to optimize outcomes. Clinicians should perform a comprehensive medical evaluation, laboratory assessment, and risk stratification before implant placement. Tailoring surgical protocols, extending healing periods, and implementing rigorous maintenance strategies further enhance predictability.

Finally, interprofessional collaboration among dentists, physicians, and other healthcare providers is critical to managing medically complex patients safely. By integrating evidence-based protocols and emerging technologies such as biomarkers and AI-driven risk assessment, clinicians can provide safe, effective, and personalized implant therapy to a growing population of patients with systemic health challenges.

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