IMPACT OF SYSTEMIC HEALTH ON IMPLANT SUCCESS

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ABSTRACT

Dental implant therapy has revolutionized oral rehabilitation, offering predictable long-term success. However, systemic health plays a crucial role in implant survival, osseointegration, and overall treatment outcomes. Various systemic conditions, including diabetes mellitus, osteoporosis, cardiovascular diseases, and immunocompromised states, can negatively influence bone healing, peri-implant tissue health, and implant stability. Endocrine disorders, such as diabetes and thyroid dysfunction, alter bone metabolism and wound healing, potentially increasing the risk of implant failure. Similarly, medications like bisphosphonates and immunosuppressants affect osseointegration and bone remodeling. This review explores the complex interplay between systemic health and dental implant success, highlighting key pathophysiological mechanisms, clinical considerations, and strategies to optimize treatment outcomes in medically compromised patients. A thorough understanding of these factors enables clinicians to develop individualized treatment plans, ultimately improving implant longevity and patient satisfaction.

Introduction:

Dental implants have revolutionized modern dentistry, offering a predictable and long-term solution for edentulism. They are a well-documented and dependable option for managing complete and partial edentulism, demonstrating high success rates in both natural and regenerated bone.[1]Implant placement is a surgical procedure in which a titanium post is inserted into the maxillary or mandibular jawbone. The success of the implant depends primarily on the integration between the implant and the surrounding bone.[2] Proper patient selection is a crucial factor in the success of implant therapy. As with any surgical procedure, a comprehensive medical history should be carefully documented, along with an evaluation of the complexity of the surgical site. Given the increasing number of medically compromised patients seeking implant treatment, it is essential to understand the impact of systemic diseases and associated medications on both the surgical process and overall treatment outcomes.[1] Understanding the effects of systemic diseases on implant outcomes is critical for improving patient selection criteria, optimizing preoperative management, and developing tailored treatment strategies.[3] Various systemic conditions and medications have been identified as factors that can interfere with osseointegration and impact

implant success, survival rates, implant loss, and peri-implant tissue health. These include endocrine-metabolic disorders such as diabetes and hypothyroidism, neurological disorders, cardiovascular diseases, and the use of medications like nonsteroidal anti-inflammatory drugs (NSAIDs), glucocorticoids, and several others. This review aims to explore the influence of systemic health on implant success, with a focus on the pathophysiological mechanisms and clinical considerations that guide implant treatment planning in medically compromised patients.[2,3]

Diabetes Mellitus and Implant Outcomes

Diabetes mellitus is one of the most prevalent endocrine-metabolic disorders globally.[2] It is defined as insufficient insulin secretion due to the destruction of insulin-producing beta cells in the pancreatic islets of Langerhans (Type 1) or by reduced insulin effectiveness resulting from the failure of peripheral insulin receptors to respond adequately to insulin stimulation (Type 2).[4] Type 2 diabetes, the most prevalent form of diabetes mellitus, accounts for 90–95% of cases and affected an estimated 537 million adults globally in 2021. This number is projected to increase to 643 million by 2030.[5] Prediabetic conditions are characterized by intermediate hyperglycemia that does not meet the criteria for diabetes. Both conditions are widespread metabolic disorders that result in hyperglycemia, leading to micro- and macrovascular complications. They are also associated with periodontitis, delayed wound healing, and disturbances in bone metabolism.[6] Uncontrolled diabetes mellitus (DM) is associated with subclinical chronic inflammation, which contributes to various inflammation-driven conditions such as neuropathy, nephropathy, and retinopathy. Among these complications is periodontal disease, often referred to as “the sixth complication of diabetes” (Loe, 1993).[7]

Many studies reviewed did not report glycemic control, which should be measured through glycated hemoglobin (HbA1c). Only two prospective cohort studies and one prospective case series met this standard. In two of these studies, no implant failures were observed during a four-month evaluation period before restoration and after one year of restoration, respectively. The third study involved 45 diabetic patients, of whom 44 had HbA1c levels up to 9% (22 well-controlled and 22 relatively well-controlled), while one had levels above 9% (poorly controlled). This study reported a 9.1% failure rate in poorly controlled diabetic patients over an average evaluation period of 42.4 months. When combining the relatively well-controlled and poorly controlled patients, the cumulative implant failure rate was 3.9%. The authors concluded that implant therapy could still benefit patients with poor glycemic control, provided accommodations are made for delays in osseointegration.[1] The 2017 World Workshop on Peri-Implants highlighted conflicting evidence regarding diabetes as a risk factor for peri-implantitis, as noted by Schwarz et al. Ferreira et al. reported an odds ratio (OR) of 1.9, indicating an increased risk. Tawell et al. found no peri-implantitis cases among individuals with an average HbA1c $\leq$ 7%, while 6 out of 141 implants developed peri-implant disease in patients with HbA1c levels between 7% and 9%.[2]

High primary stability, adequate osseointegration, and healthy surrounding tissue are essential for procedures like the immediate or early restoration of implants with prosthetic restorations. Two studies have explored immediate loading in patients with type 2 diabetes. In a retrospective cohort study involving 108 diabetic patients, implants that were immediately loaded exhibited the same survival rate as those with delayed loading after three months (100% survival in both groups). In a prospective clinical study, diabetic patients were divided into two groups based on their HbA1c levels (6.1–8% and 8.1–10%) and compared to a control group with an HbA1c $\leq$ 6%. The survival rate of implants in both the control group and the group with an HbA1c between 6.1% and 8% was 100%, while the group with an HbA1c of 8.1–10% had an implant survival rate of 95.4%.[6] Recent

studies have mainly focused on early implant failures. One study involving 50 implants in 35 patients, including 25 with diabetes (10 well-controlled, 12 moderately controlled, and three poorly controlled), showed a 100% success rate at a four-month follow-up. In a retrospective analysis by Alsaadi et al. (2007) of 252 implant failures among 178 patients out of 2,004 individuals treated with 6,946 implants, no significant impact of diabetes on implant failure was observed (odds ratios reported, but exact case numbers were not specified). A similar group study reported 14 early failures in 14 patients out of 283 subjects treated with 720 implants. Among these, one patient had type 1 diabetes, and the study noted a 4% early failure rate in type 2 diabetic patients compared to 1.9% in non-diabetic patients.[8]

A total of 51 studies were reviewed to examine the impact of prediabetes and diabetes mellitus (Types I and II) on the development of late complications in dental implants. Among them, 14 were prospective, 23 were retrospective, 10 were cross-sectional, and 5 had unspecified study designs. Thirty-three studies found no link between the success or failure of dental implants and diabetes, while 17 reported a positive association. One cross-sectional study showed better peri-implant inflammation parameters in diabetic patients with hypertension compared to healthy individuals. The studies were categorized based on their findings regarding diabetes as a risk factor for biological complications related to dental implants. Four of the studies identified prediabetes as a risk factor for peri-implant inflammation. One of these studies revealed statistically significant positive correlations between advanced glycation end-product (AGE) levels and both probing depth and marginal bone loss, as well as between marginal bone loss and diabetes.[3]

Overall, patients with poorly controlled diabetes mellitus face a higher risk of peri-implantitis, particularly after implantation, and experience greater implant loss over time compared to healthy individuals. However, under controlled conditions, success rates are comparable. Current protocols, including perioperative use of antibiotics and chlorhexidine, enhance implant outcomes. Limited studies on prediabetic patients suggest a potential risk for peri-implant diseases but no significant impact on implant survival. Dental implants remain a safe option for oral rehabilitation in prediabetic or diabetic patients when proper precautions are followed, with no contraindication under controlled conditions.[6]

Cardiovascular Diseases and Implant Outcomes

Cardiac diseases are a relative contraindication for dental implant therapy, with medical literature identifying this group of systemic illnesses as being at high risk for infective endocarditis. Patients with cardiovascular disorders are expected to carry diminished blood flow, leading to a failure in osseointegration due to a lower concentration of nutrients and oxygen levels at the site of osteotomy.[9]

The effect of chronic hypoxia makes patients with cardiovascular diseases a high-risk group vulnerable to infections. Systemic control through medications is mandatory in these patients, along with certain conditions requiring a prophylactic antibiotic prescription to avoid any episode of a cardiovascular nature. Bleeding or sudden cardiac ischemia at the time of surgery should be considered and addressed during pre-surgical consultation. According to the American Heart Association guidelines, antibiotic prophylaxis for patients with prosthetic heart valves, heart transplants, and congenital heart diseases must be administered 30–60 minutes before any invasive dental procedures, including the placement of implants in both the surgical and prosthetic phases. Uncontrolled bleeding can be caused by certain drug therapies and is critical in the management of patients. Hematological reports with values for bleeding time and international normalized ratio (INR) should be carefully monitored for patients receiving oral anticoagulation medications for cardiovascular anomalies. The normal INR in these patients should be 2.2 or less for surgical

procedures, and the normal platelet count is between 100,000 and 500,000/mm.[3] Clinical studies have shown that it is relatively safe to place dental implants in patients taking single antiplatelet drugs like aspirin and clopidogrel without discontinuation. However, the use of multiple medications to manage the condition increases the risk of bleeding and must be discussed with the patient's cardiologist preoperatively. Systematic reviews have shown that implant placement in patients with cardiovascular diseases causes inflammation of the bone, affects the osseointegration of an implant, and ultimately leads to implant failure.[10]

On the other hand, some observations on the failure rates in dental implants in different groups of patients have not shown a statistical difference between the rate of failure between healthy groups and patients with cardiovascular disturbances.[11]

Bibliographic studies published on hypertension and peri-implantitis have also been reported to show that the extent of peri-implantitis is not as critical (6.8%) in patients with cardiovascular diseases relative to patients without any history of cardiovascular anomalies. 325 implants were studied, and only 0.6% showed signs of complications.[12]

A clinical study from 2020 utilized values of serum biochemical parameters and cardiovascular risk markers in people with dental implants to investigate the prevalence of peri-implant disease. The clinical parameters in this study were positively correlated with systemic triglyceride and uric acid levels. The significantly higher values of triglycerides and uric acid in the group with peri-implantitis concurred with the importance of checking the patient's serum biochemical parameters before implant surgery. The debatable nature of evidence regarding the effects of cardiovascular disease and the complications that arise due to altered medical status on dental implants is inconclusive and needs to be studied in more detail.[13]

Antihypertensive medications can help patients with chronic medical conditions, and assessing their effects on the osseointegration of dental implants is crucial for the success of the implant. A retrospective study evaluated the impact of antihypertensive medications on peri-implant tissue parameters, in which 35 patients received 77 anodized dental implants. The study showed a notable variation in probing pocket depth and peri-implantitis between anti-hypertensive medication users and non-users. The study concluded indications of an association between the use of antihypertensive drugs and clinical findings in tissues with peri-implantitis.[10]

Conversely, a systematic review of 70 publications reviewing the role of prevalent systemic illnesses, including hypertension and other cardiovascular diseases, in the development of peri-implantitis found no correlation between the risk of peri-implantitis and cardiovascular diseases or hypertension.[3]

Studies have also shown that antihypertensive drugs reduce the chances of bone fractures and promote bone formation and remodeling, thus making implants more likely to survive despite the underlying systemic condition of the patient.[12] A study involving 1,499 dental implants in 728 patients found that antihypertensive medicines improved implant stability rates.[14]

Autoimmune, Inflammatory Conditions and Implant Success

The growing use of dental implants in modern dentistry requires an integral understanding of the factors influencing their success and management, particularly in populations with autoimmune and inflammatory conditions.[15] Over the past 20 years, life expectancy has steadily risen, contributing to the expansion of the aging demographic and the corresponding growth in the number of individuals with medical conditions. Autoimmune diseases include a range of conditions that increase the risk of dental caries, periodontal disease, and issues related to the oral mucosa.[16] Implant-supported prostheses can be a better therapeutic option than mucosa-supported

prostheses for patients with ADs, as these patients often suffer from very severe oral manifestations.[15] Although certain conditions and the medications used for their treatment impact bone quality, by controlling the body's inflammatory response following the foreign body response to the implant, the immune system also plays a critical role in the osseointegration of dental implants. This emphasizes the necessity of evaluating the underlying disease activity and medication regimens before surgery, as these are important factors for predicting implant success rates.[15,16]

Some ADs, such as rheumatoid arthritis, lupus erythematosus, and Sjögren syndrome, have chronic inflammation and immune deregulation as their characteristics; also, patients with these diseases can exhibit altered healing responses.[16] For instance, research found that patients with Sjögren's syndrome (SS) are at an increased risk for inflammation of the peri-implant marginal soft tissues compared to healthy individuals. One cause of this inflammation is reduced salivary production, a hallmark of SS. This reduced salivary production compromises the ability to cleanse the oral cavity. That is, if an SS patient has excess food debris in the peri-implant gingival sulcus that cannot be removed by mechanical cleaning, localized inflammation may result, leading to peri-implant mucositis (PIM) as well as marginal bone loss (MBL). However, it is observed that the prevalence of peri-implant disease (PID) is the same as that in healthy individuals, even though PIM is more frequent in this group. Another significant observation is that SS, together with rheumatoid arthritis (RA), is associated with increased rates of PIM and marginal bone loss.[2] Therefore, inflammatory processes associated with autoimmune conditions like these can lead to a less favorable peri-implant tissue response, thus increasing the probability of implant failure due to peri-implantitis.[16,17]

However, a recent comprehensive study on different articles showed that in 120 patients diagnosed with SS, this cohort established the largest number of studies and implant baselines documented in the context of SS by performing a total of 484 implant placements. An impressive overall implant survival rate of 95.5% at the implant level and 90.8% at the patient level was observed, with implant failures occurring only during the early stages of implant placement. This finding underscores the urgent need for close and vigilant monitoring and preventive measures during the first healing phase. All patients had challenges with conventional dentures before implant-supported dental prostheses rehabilitation, highlighting the importance of SS in oral health [15]. Oral autoimmune diseases can also contribute to a higher risk of complications. Conditions such as lichen planus, epidermolysis bullosa, and pemphigus vulgaris not only complicate the oral environment but also present distinctive management challenges during and after the stages of implant placement.[18] However, as discussed earlier, mucosa-supported prostheses are not therapeutically beneficial when there are oral manifestations of the disease. For example, in epidermolysis bullosa, the use of removable prostheses can result in mucosal blisters due to friction; hence, patients with such ADs are strong candidates for implant therapy as long as they are enrolled in a rigorous maintenance program and the diseases are given proper care.[15]

Autoimmune diseases currently have no definitive cure, and managing them with drug therapy, particularly immunosuppressive medications, poses challenges due to the potential adverse effects these treatments may have on the osseointegration and long-term success of dental implants.[16] Several therapeutic agents are used to manage autoimmune diseases, of which glucocorticosteroids are the most commonly used, particularly for oral manifestations.[18] Mild oral lesions may respond to topical treatments. In contrast, patients with more severe types of oral disease may be treated with systemic corticosteroid doses, as mentioned by Manousaridis et al., up to 0.5 mg/kg per day and even higher for pemphigus vulgaris.[18] Although glucocorticosteroids are extremely effective

in ameliorating diseases, they are also associated with marked adverse effects on bone quality, particularly glucocorticoid-induced osteoporosis. They also reduce osteoblast numbers and activity, increase osteoclast activity and osteocyte apoptosis, and inhibit calcium metabolism, complicating the new bone mineralization process.[18] A range of conclusions about how glucocorticosteroid use affects osseointegration can be found in the research. For example, a systematic review conducted by Hyldahl et al. shows that patients with RA had higher crestal bone loss, which can be attributed to the glucocorticosteroids that RA patients take. [15]

Treatment considerations for these patients extend beyond surgical procedures. It is essential to employ a multidisciplinary approach that involves rheumatologists, dentists, and general doctors to optimize patient outcomes.[19] This approach is essential since adverse reactions to pharmacological interactions or the exacerbation of underlying diseases may arise due to surgical stress. A systematic review highlights the need for such comprehensive strategies; the findings suggest that careful preoperative evaluations and personalized postoperative attention can reduce complication rates and improve the success rates of implants in these complex cases.[19]

Another significant concern in managing dental implants in these patients is the long-term maintenance of oral hygiene and peri-implant management. Effective periodontal maintenance is essential in mitigating the risks associated with dental implants, especially in individuals with compromised immune systems. Research has shown that patients with autoimmune diseases may have difficulty maintaining optimal oral hygiene due to pain, xerostomia, and tissue sensitivity, which are commonly associated with these conditions.[17] Additionally, recognizing that not all autoimmune patients will experience the same degree of risk or complications will open avenues for more personalized treatment approaches.[19] This reinforces the critical role of patient education and personalized advice in achieving successful long-term results after implant placement. The psychological aspect of dental health management for patients with autoimmune and inflammatory conditions cannot be overlooked. Dental anxiety can, in turn, lead patients to avoid seeking dental care, either due to systemic health challenges or other reasons. Avoidance of oral health issues can worsen oral health, leading to additional problems and negative effects on overall health.[16] Consequently, dental professionals must promote a supportive environment, address anxieties, and build therapeutic relationships, reinforcing that proper management can lead to better health results.

Lastly, the effects of autoimmune and inflammatory conditions on the success of dental implants are profound and multifactorial. From the systemic implications of these diseases to local biological responses at the implant site, each element requires careful consideration and individualized management strategies. Explicit collaboration among health professionals, comprehensive evaluations of treatment regimens, patient education, and supportive care can significantly improve outcomes despite the complexities presented by these conditions.[15]

Impact of Endocrine Disorders on Osseointegration

The endocrine system consists of various ductless glands that secrete several important hormones. These glands include the pituitary gland, thyroid gland, parathyroid gland, adrenal glands, pancreas, ovaries, and testes. These hormones control various bodily functions, such as growth and development, metabolism, electrolyte balance, and reproduction. Two systems, the nervous system, and the endocrine system communicate with each other and maintain a constant internal environment, i.e., homeostasis.[20] Disorders of the endocrine system are systemic factors that can directly influence implant success, even in the absence of any visible local manifestations.[21] It is

crucial to recognize the risks and challenges associated with dental implant osseointegration in patients with endocrine disorders.

The most significant endocrine disorder affecting dental implant health is Diabetes Mellitus. As we have discussed this at length earlier in this article, we will start with thyroid disorders. These are the second most prevalent endocrine disorders, impacting about 1% of the population, primarily women.[10] Thyroid hormone is crucial for bone development and maintaining bone mass. Changes in thyroid hormone levels can result in growth abnormalities, bone loss, and a higher risk of fractures. These hormones are vital for skeletal maturation and play a key role in preserving the structure and strength of adult bones. A 2022 systematic review indicated that patients with thyroid disorders can achieve implant survival rates comparable to those without such conditions. The review reported an average implant survival rate of 92.56%, although the lowest recorded survival rate of 71.2% was attributed to a history of periodontitis rather than thyroid dysfunction itself.[22]A study by D'Ambrosio et al. found that hypothyroidism does not significantly affect the osseointegration process, despite increased risks of fractures and slower bone regeneration.[2]

Further, a study by Nikolai J. Attard and George A. Zarb comparing 27 hypothyroid patients, involving 27 hypothyroid female patients on replacement therapy, showed no significant difference in implant failure rates compared to matched controls, although soft tissue complications and bone loss were more common in hypothyroid patients. These findings suggest that well-managed hypothyroidism does not preclude implant success, though clinicians should monitor soft tissue health and bone loss over time.[23]

Another group of disorders is parathyroid disorders. Parathyroid disorders are often associated with vitamin D deficiency or insufficiency, which impacts bone health and osseointegration. Several experimental and clinical studies have highlighted the detrimental effects of vitamin D deficiency on bone formation and implant stability. Conversely, vitamin D supplementation has been shown to improve bone-to-implant contact (BIC) and promote successful osseointegration. This is particularly relevant for patients with conditions such as diabetes, osteoporosis, and chronic kidney disease, where low vitamin D levels contribute to early implant failure. Supplementation with vitamin D can mitigate these risks, facilitating better outcomes for patients with parathyroid imbalances.[24]

Another common disorder in menopausal and postmenopausal women is estrogen deficiency. Estrogen deficiency in menopausal and postmenopausal women also plays a role in bone metabolism, influencing implant success. A retrospective study by Meredith August, Kyung Chung, YuChiao Chang, and Julie Glowacki compared postmenopausal women, some of whom were on estrogen replacement therapy (ERT), to premenopausal women and male controls. The study found that postmenopausal women who were not on estrogen replacement therapy exhibited the highest failure rates in the maxilla. Interestingly, estrogen replacement therapy was associated with a 41% reduction in maxillary implant failure rates. These findings suggest that estrogen deficiency and associated bone changes may increase the risk of implant failure, particularly in the maxilla, but ERT may improve outcomes.[25]

Addison’s disease and Cushing’s syndrome, both related to adrenal gland dysfunction, can influence implant success. Addison’s disease, resulting from insufficient adrenal function, and Cushing’s syndrome, caused by excess hormone production, do not appear to reduce implant survival rates when well-managed. However, the clinical approach to managing implant treatment must be tailored to the individual’s condition. A key concern is the potential for an adrenal crisis, especially during invasive procedures or infections. Proper patient education on medication

adjustment, infection recognition, and the importance of consistent hormone replacement therapy is essential for successful long-term management.[26]
These conditions can have a direct or indirect impact on dental implant health. Therefore, it is imperative that clinicians obtain a detailed medical history and, in some situations, seek medical consultation and clearance prior to treatment.[21]

Lifestyle Factors Affecting Implant Success

Among various factors affecting implant success lifestyle factors like smoking, excessive alcohol consumption, poor oral hygiene, a diet lacking in essential nutrients, physical activity and stress play a significant role. These habits can impair the healing process, compromise blood flow to the implant site, and increase the risk of infection, ultimately impacting the implant's stability and long-term success. Clinical trials indicate that factors related to implant devices, anatomy, occlusion, systemic health or exposures, microbial biofilm, host immune-inflammatory responses, and genetics may increase the risk for implant complications or loss. In general, factors associated with the patient appear more critical in determining risk for implant failure than those associated with the implant itself.[27]

1. Smoking

Smoking is a prevalent behavior in the general population. Clinical trials of endosseous implants consistently rate smoking as a primary patient-centered risk factor for implant loss.[28] Various studies report a failure rate of implants in smokers compared to nonsmokers, ranging from 6.5% to 20%.[29,30] Heat, as well as toxic by-products of cigarette smoking—such as nicotine, carbon monoxide, and hydrogen cyanide—have been implicated as risk factors for impaired healing and may thus affect the success and complications of surgical procedures.[31] Smoking also causes significantly more marginal bone loss after implant placement, increases the incidence of peri-implantitis, and affects the success rates of bone grafts. Smoking does not affect the process of osseointegration; rather, its negative effects seem to arise after the second-stage surgery.
Gorman et al., in a study on patients who had received over 2,000 implants, found significantly more failures in smokers after second-stage surgery. Lambert et al. noticed a trend of greater failures in smokers between the time after uncovering and before insertion of the prosthesis.[32]

2. Alcohol Consumption

Alcohol consumption can negatively impact the success of dental implants, and it's recommended to limit alcohol after getting implants. Individuals who drink an excessive amount of alcohol may suffer from poor nutrition or a vitamin shortage, both of which may result in a suboptimal response of the oral tissues to implant treatments. The consumption of alcoholic beverages can cause bone resorption and prevent the development of bone neoformation due to the presence of specific compounds, which are contained in alcoholic beverages including fuel oil, nitrosamines, and ethanol.[33] A retrospective cohort investigation found that light to moderate alcohol use was associated with a defense against the development of peri-implantitis. Also, the result that drinking excessive amounts of alcohol raised the chance of getting peri-implantitis by almost three times has significant therapeutic implications for the selection of dental implant candidates.[34]

3. Oral Hygiene

Good oral hygiene is key to ensuring the long-term success of dental implants. Regular brushing and flossing are essential to prevent bacteria buildup around the implant site, which can lead to complications such as infection and bone loss, ultimately impacting the longevity and stability of

the implant. Peri-implantitis occurs due to the accumulation of plaque caused by inadequate dental hygiene. Renvert et al. (2015) reported that more than 50% of patients with implants affected by peri-implantitis lacked the ability or opportunity for adequate oral hygiene.[35]

The majority of implant issues arise due to challenges in maintaining oral hygiene; hence, oral hygiene practices effectively eliminate microbial dental plaque.[36] Following the right maintenance protocol may assist implant patients in maintaining good oral hygiene and reducing the chance of subsequent implant failure from both a clinical and socio-psychological attitude-related perspective.[37]

4. Physical Activity

Research shows that regular physical activity can have a positive impact on the success of dental implants by promoting good blood circulation to the gums and jawbone, which is crucial for proper healing and osseointegration, thus reducing the risk of gum disease and enhancing the long-term stability of the implants. Strenuous exercise should be avoided immediately following dental implant surgery, with activity levels gradually increasing to allow for proper healing. A systematic review and meta-analysis showed an association between a reduced prevalence of periodontal disease and the practice of physical activity. In addition, the frequency of physical activity is directly related to a lower occurrence of periodontitis.[38]

5. Diet and Nutrition

Nutrition plays a pivotal role in providing the necessary building blocks for bone formation and tissue healing, promoting optimal integration of dental implants with the surrounding jawbone. Several micronutrients, particularly vitamins D and C, are hypothesized to influence the skeletal system, particularly the jawbone, alveolar bone, and dental implant osseointegration. A review of the role of micronutrients in osseointegration found a clear association between vitamin D deficiency, reduced osseointegration, and increased early implant failure in both animal and human studies. The findings support an ancillary role of vitamin D in patients with vitamin D deficiency, as well as vitamin C supplementation, in facilitating the success of dental implant surgery.[39]

6. Stress

Stress factors, particularly parafunctional habits like excessive jaw clenching or grinding (bruxism), are among the common reasons for implant failure and can significantly impact the success of dental implants. They cause undue stress on the bone surrounding the implant, potentially leading to implant failure over time, even if the implant is initially placed well. This is because excessive force can cause bone resorption around the implant site, compromising its stability. A systematic review showed that implants placed in probable bruxers present a significantly higher risk of failure than implants placed in non-bruxers. In dental implants, bruxism can cause overload and has been associated with a higher risk of implant failure, technical complications, and failures of implant-supported restorations, including fractures of the implants.[40]

Bone Diseases and Implant Stability

Bone diseases can significantly affect the success of dental implants. Pre-implant evaluation, appropriate management of bone diseases, and careful surgical techniques are essential in minimizing the risk of failure. Various bone diseases that can affect dental implants include osteomalacia, osteoporosis, bisphosphonate-associated osteonecrosis, and Paget's disease of the bone.

1. **Osteomalacia**:

Osteomalacia is a condition characterized by the softening and weakening of the bones due to a deficiency of vitamin D, calcium, or phosphate. This disorder leads to impaired bone

mineralization, making bones more prone to pain and fractures. Given altered bone remodeling, osseointegration, which is a critical factor for implant success, can be affected. There is evidence that vitamin D deficiency impairs new bone formation, which negatively affects bone-to-implant contact. In another experimental study involving animals, vitamin D supplementation was found to have an enhancing effect on bone-to-implant contact (BIC) and/or new bone formation around implants.[24]

2. Osteoporosis

Osteoporosis is a condition that leads to weakened and brittle bones. This condition can reduce bone density in the jaw, making it less capable of supporting dental implants. Its impact on implants is unique in the sense that both the disease and its treatment (bisphosphonates) can influence implants.

A retrospective cohort study from 2024 found clear evidence that osteopenia and osteoporosis are significant risk factors for implant failures. In this study, over 100 patients with dental implants were analyzed to determine the effect of health status, smoking status, sex, implant location, and operative conditions on first and second (re-implantation) implant survival. It showed that osteopenia and osteoporosis were the most significant risk factors for implant failures ($p = 0.0353$), followed by diabetes ($p = 0.0297$). Furthermore, the study also observed that early implant failure is significantly correlated with osteoporosis ($p = 0.0044$).[41]

Other studies, however, have found no significant difference in implant survival rates between patients with and without osteoporosis. For example, a 2022 meta-analysis showed no notable difference in implant survival between these two groups, with comparable survival rates (OR 1.78; 95% CI, 0.86-3.70; $p = 0.12$). However, osteoporosis patients did experience significantly greater bone loss around their implants (SMD, 0.71 mm; 95% CI, 0.06-0.87 mm).[42]

Similarly, another meta-analysis from 2016 also found no difference in survival rates between patients with and without osteoporosis, but an overall increase in peri-implant bone loss was observed in the osteoporosis group (0.18 mm; 95% CI, 0.05-0.30; $p = 0.005$).[43]

In general, it can be assumed from the data that dental implants can be an effective treatment for patients with osteoporosis. However, professional clinical management is essential to maintain peri-implant bone stability, as these patients are more prone to greater bone loss.[42,43]

3. Bisphosphonates

Bisphosphonates are a class of medications commonly used to treat osteoporosis. These drugs work by inhibiting the activity of osteoclasts, the cells responsible for breaking down bone tissue. Bisphosphonate use has been associated with a rare but serious side effect known as osteonecrosis of the jaw (ONJ). ONJ is a condition in which the bone tissue in the jaw begins to die due to a lack of blood supply. The risk of osteonecrosis is related to oral hygiene, oral surgeries—including extractions and implants—and poor oral hygiene.

The evidence on the direct impact of bisphosphonates on dental implant survival is mixed. Some studies suggest that there is no significant difference in implant success rates between patients taking bisphosphonates and those who are not, while others report a higher risk of complications such as implant failure or delayed healing.[44,45]

A meta-analysis published in June 2021, which involved studies from multiple databases, including PubMed, Cochrane, Scopus, Web of Science, and OpenGrey, assessed the safety of dental implants in patients taking antiresorptive therapy (bisphosphonates). A total of 28 studies on bisphosphonates (including five cohort studies, six case-control studies, and 17 case series) and one study on denosumab (a case series) met the inclusion criteria and were included in the qualitative synthesis. The study showed that patients with a history of bisphosphonate treatment

for osteoporosis do not have an increased risk of implant failure regarding osseointegration. However, these patients were at risk for "implant surgery-triggered" medication-related osteonecrosis of the jaw (MRONJ).[44,45]

Contrary to the previous discussion, a meta-analysis from June 2023 found higher rates of implant failure in patients taking bisphosphonates. The study utilized the odds ratio and implant survival at 5 and 10 years to assess the association between bisphosphonates and dental implants. The review analyzed 33 studies, encompassing a total of 1,727 implants placed in patients using bisphosphonates (BPs) and 21,986 implants in those not using BPs. It revealed that implants in bisphosphonate users had a higher risk of failure compared to non-bisphosphonate users (OR 1.653, p = 0.047). The overall estimated implant survival rates for bisphosphonate users were 94.2% (95% CI, 94.0-94.4) at 5 years and 90.1% (95% CI, 89.8-90.3) at 10 years.[46]

Similarly, another systematic review from 2024 found statistically significant implant failure in patients taking bisphosphonates. The study assessed the effects of oral bisphosphonates (BPs) on the osseointegration of dental implants and the incidence of bisphosphonate-related osteonecrosis of the jaw in postmenopausal women. The results showed that out of 2,582 placed implants, 50 (1.94%) failed in BP-treated patients, while 188 (4.6%) failed in the non-BP group (out of 4,050 implants). The results from the meta-analysis demonstrated that BP therapy is significantly associated with increased implant failure rates (RR = 1.73 [95% CI, 1.03-2.83], P = .04). Despite the statistically significant association, this particular study commented that bisphosphonates do not increase implant failures in postmenopausal women.[47]

4. Paget's Disease

Paget's disease of bone is a chronic disorder that causes abnormal bone remodeling, leading to bones that become enlarged, weakened, and more prone to fractures. The mainstay treatment for Paget's disease is bisphosphonates. The reduced bone quality seen in Paget's disease is considered a relative contraindication for dental implants, as it disrupts the process of osseointegration. Currently, there is no available research on the success rate of dental implants in individuals with Paget's disease.[48]

There are few case reports in which patients with Paget's disease underwent successful dental implants, which reflects that careful planning can result in implant success. One case report from 2008 described a case where patients with Paget's disease underwent dental implants successfully but ended up with post-op complications that required secondary intervention. This patient was undergoing treatment with bisphosphonates.[48]

Another case report from 2009 depicts similar results, with one patient undergoing a successful dental implant. The patient's postoperative period was uneventful. This patient was on bisphosphonate therapy for seven years and was followed for four years after the implant. This shows that although there are risks of implant failures in Paget's disease given the abnormal bone architecture, dental implantation can be achieved with the treatment of underlying bone disease.[49]

Conclusion

The systemic health of the patient, including lifestyle factors, seems to play a pivotal role in the outcome of implant success. Careful evaluation of the patient's medical history, medications, and lifestyle habits helps in individualizing the treatment plan, thereby decreasing the associated risks that hinder implant success. An interdisciplinary approach, patient education, support, and postoperative care can significantly increase the rate of success. However, a risk-benefit assessment is necessary in deciding whether implant placement is beneficial in a compromised individual. Hence, a thorough and profound comprehensive pre-implant evaluation of the patient is deemed necessary to avoid complications associated with implant placement.

References

1. Donos N, Calciolari E. Dental implants in patients affected by systemic diseases. *Br Dent J.* 2014;217(8):425-30. doi:10.1038/sj.bdj.2014.911.
2. D'Ambrosio F, Amato A, Chiacchio A, Sisalli L, Giordano F. Do systemic diseases and medications influence dental implant osseointegration and dental implant health? An umbrella review. *Dent J (Basel).* 2023;11(6):146. doi:10.3390/dj11060146.
3. Sbricoli L, Bazzi E, Stellini E, Bacci C. Systemic diseases and biological dental implant complications: a narrative review. *Dent J (Basel).* 2022;11(1):10. doi:10.3390/dj11010010.
4. Schliephake H. The role of systemic diseases and local conditions as risk factors. *Periodontol 2000.* 2022;88(1):36-51. doi:10.1111/prd.12409.
5. Al Ansari Y, Shahwan H, Chrcanovic BR. Diabetes Mellitus and Dental Implants: A Systematic Review and Meta-Analysis. Materials (Basel). 2022 Apr 29;15(9):3227. doi:10.3390/ma15093227.
6. Wagner J, Spille JH, Wiltfang J, Naujokat H. Systematic review on diabetes mellitus and dental implants: an update. Int J Implant Dent. 2022 Jan 3;8(1):1. doi:10.1186/s40729-021-00399-8.
7. Assery NM, Jurado CA, Assery MK, Afrashtehfar KI. Peri-implantitis and systemic inflammation: A critical update. Saudi Dent J. 2023 May;35(5):443-50. doi:10.1016/j.sdentj.2023.04.005.
8. Bornstein MM, Cionca N, Mombelli A. Systemic conditions and treatments as risks for implant therapy. Int J Oral Maxillofac Implants. 2009;24 Suppl:12-27.
9. Parihar AS, Madhuri S, Devanna R, Sharma G, Singh R, Shetty K. Assessment of failure rate of dental implants in medically compromised patients. J Family Med Prim Care. 2020 Feb 28;9(2):883-5. doi:10.4103/jfmpc.jfmpc_989_19.
10. Samara W, Moztarzadeh O, Hauer L, Babuska V. Dental Implant Placement in Medically Compromised Patients: A Literature Review. *Cureus*. 2024;16(2):e54199. Published 2024 Feb 14. doi:10.7759/cureus.54199.
11. Aghaloo T, Pi-Anfruns J, Moshaverinia A, Sim D, Grogan T, Hadaya D. The Effects of Systemic Diseases and Medications on Implant Osseointegration: A Systematic Review. Int J Oral Maxillofac Implants. 2019;34 Suppl:s35-s49. doi:10.11607/jomi.19suppl.g3.
12. Astolfi V, Ríos-Carrasco B, Gil-Mur FJ, et al. Incidence of Peri-Implantitis and Relationship with Different Conditions: A Retrospective Study. Int J Environ Res Public Health. 2022 Mar 31;19(7):4147. doi:10.3390/ijerph19074147.
13. Ustaoğlu G, Erdal E. Relationship between risk markers for cardiovascular disease and peri-implant diseases. Int J Implant Dent. 2020 Nov 25;6(1):73. doi:10.1186/s40729-020-00273-z.
14. Corbella S, Morandi P, Alberti A, Morandi B, Francetti L. The effect of the use of proton pump inhibitors, serotonin uptake inhibitors, antihypertensive, and anti-inflammatory drugs on clinical outcomes of functional dental implants: A retrospective study. Clin Oral Implants Res. 2022 Aug;33(8):834-43. doi:10.1111/clr.13964.
15. Hyldahl E, Gotfredsen K, Lynge Pedersen AM, Storgård Jensen S. Survival and success of dental implants in patients with autoimmune diseases: a systematic review. J Oral Maxillofac Res. 2024 Mar 31;15(1):e1. doi:10.5037/jomr.2024.15101.
16. Esimekara JO, Perez A, Courvoisier DS, Scolozzi P. Dental implants in patients suffering from autoimmune diseases: A systematic critical review. J Stomatol Oral Maxillofac Surg. 2022;123(5):e464-73. doi:10.1016/j.jormas.2022.01.005.
17. Kondru VLP. The interplay between autoimmune diseases and peri-implantitis: a comprehensive review. JHDSA. 2019;6(6):1-21.
18. Tounta TS. Dental implants in patients with oral autoimmune diseases. J Res Pract Musculoskeletal Syst. 2019 Mar;3:9-16. doi:10.22540/jrpms-03-009.

19. Duttenhoefer F, Fuessinger MA, Beckmann Y, Schmelzeisen R, Groetz KA, Boeker M. Dental implants in immunocompromised patients: a systematic review and meta-analysis. Int J Implant Dent. 2019 Nov 28;5(1):43. doi:10.1186/s40729-019-0191-5.
20. Hiller-Sturmhöfel S, Bartke A. The endocrine system: an overview. Alcohol Health Res World. 1998;22(3):153-64.
21. Sehravat R, Malik P, Rathee M. Endocrine diseases treatment consideration in dental implants. Int J Pharm Sci. 2015;6(1):002.
22. Torrejon-Moya A, Izquierdo-Gómez K, Pérez-Sayáns M, Jané-Salas E, Marí Roig A, López-López J. Patients with thyroid disorder, a contraindication for dental implants? A systematic review. J Clin Med. 2022 Apr 25;11(9):2399. doi:10.3390/jcm11092399.
23. Attard NJ, Zarb GA. A study of dental implants in medically treated hypothyroid patients. Clin Implant Dent Relat Res. 2002;4(4):220-31. doi:10.1111/j.1708-8208.2002.tb00174.x.
24. Werny JG, Sagheb K, Diaz L, Kämmerer PW, Al-Nawas B, Schiegnitz E. Does vitamin D have an effect on osseointegration of dental implants? A systematic review. Int J Implant Dent. 2022 Apr 11;8(1):16. doi:10.1186/s40729-022-00414-6.
25. August M, Chung K, Chang Y, Glowacki J. Influence of estrogen status on endosseous implant osseointegration [published correction appears in J Oral Maxillofac Surg. 2002 Jan;60(1):134]. J Oral Maxillofac Surg. 2001;59(11):1285-91. doi:10.1053/joms.2001.27515.
26. Bugălă NM, Carsote M, Stoica LE, et al. New approach to Addison disease: oral manifestations due to endocrine dysfunction and comorbidity burden. Diagnostics (Basel). 2022 Aug 28;12(9):2080. doi:10.3390/diagnostics12092080
27. Paquette DW, Brodala N, Williams RC. Risk factors for endosseous dental implant failure. Dent Clin North Am. 2006;50(3):361-vi. doi:10.1016/j.cden.2006.05.002.
28. Kasat V, Ladda R. Smoking and dental implants. J Int Soc Prev Community Dent. 2012;2(2):38-41. doi:10.4103/2231-0762.109358.
29. Sánchez-Pérez A, Moya-Villaescusa MJ, Caffesse RG. Tobacco as a risk factor for survival of dental implants. J Periodontol. 2007;78(2):351-9. doi:10.1902/jop.2007.060299.
30. Wallace RH. The relationship between cigarette smoking and dental implant failure. Eur J Prosthodont Restor Dent. 2000;8(3):103-6.
31. Levin L, Schwartz-Arad D. The effect of cigarette smoking on dental implants and related surgery. Implant Dent. 2005;14(4):357-61. doi:10.1097/01.id.0000187956.59276.f8.
32. Kasat V, Ladda R. Smoking and dental implants. J Int Soc Prev Community Dent. 2012;2(2):38-41. doi:10.4103/2231-0762.109358.
33. Galindo-Moreno P, Fauri M, Avila-Ortiz G, Fernández-Barbero JE, Cabrera-León A, Sánchez-Fernández E. Influence of alcohol and tobacco habits on peri-implant marginal bone loss: a prospective study. Clin Oral Implants Res. 2005;16(5):579-86. doi:10.1111/j.1600-0501.2005.01148.x.
34. Bhatia AP, Rupamalini SN, Sathi KV, et al. Impact of the habit of alcohol consumption on the success of the implants: A retrospective study. *J Pharm Bioallied Sci.* 2024;16(Suppl 1):S146-S148. doi:10.4103/jpbs.jpbs_430_23.
35. Renvert S, Quirynen M. Risk indicators for peri-implantitis: A narrative review. *Clin Oral Implants Res.* 2015;26 Suppl 11:15-44. doi:10.1111/clr.12636.
36. Sato Y, Koyama S, Ohkubo C, Ogura S, Kamijo R, Sato S, Aida J, Izumi Y, Atsumi M, Isobe A, Baba S, Ikumi N, Watanabe F. Dental implant care and trouble among dependent patients based on the questionnaire survey among Japanese dental practitioners. BMC Oral Health. 2020 Nov 25;20(1):335. doi: 10.1186/s12903-020-01279-0. PMID: 33238973; PMCID: PMC7687807.

37. Tecco S, Grusovin MG, Sciara S, Bova F, Pantaleo G, Capparé P. The association between three attitude-related indexes of oral hygiene and secondary implant failures: A retrospective longitudinal study. *Int J Dent Hyg.* 2018;16(3):372-9. doi:10.1111/idh.12300
38. Ferreira RO, Corrêa MG, Magno MB, Almeida APCPSC, Fagundes NCF, Rosing CK, Maia LC, Lima RR. Physical Activity Reduces the Prevalence of Periodontal Disease: Systematic Review and Meta-Analysis. Front Physiol. 2019 Mar 21;10:234. doi: 10.3389/fphys.2019.00234.
39. Nastri L, Moretti A, Migliaccio S, et al. Do dietary supplements and nutraceuticals have effects on dental implant osseointegration? A scoping review. *Nutrients.* 2020;12(1):268. Published 2020 Jan 20. doi:10.3390/nu12010268.
40. Häggman-Henrikson B, Ali D, Aljamal M, Chrcanovic BR. Bruxism and dental implants: A systematic review and meta-analysis. *J Oral Rehabil.* 2024;51(1):202-17. doi:10.1111/joor.13567.
41. Frumkin N, Iden JA, Schwartz-Arad D. Effect of osteopenia and osteoporosis on failure of first and second dental implants: A retrospective observational study. *Int J Implant Dent.* 2024;10(1):40. Published 2024 Sep 4. doi:10.1186/s40729-024-00556-9.
42. Lemos CAA, de Oliveira AS, Faé DS, et al. Do dental implants placed in patients with osteoporosis have higher risks of failure and marginal bone loss compared to those in healthy patients? A systematic review with meta-analysis. *Clin Oral Investig.* 2023;27(6):2483-93. doi:10.1007/s00784-023-05005-2.
43. de Medeiros FCFL, Kudo GAH, Leme BG, et al. Dental implants in patients with osteoporosis: A systematic review with meta-analysis. *Int J Oral Maxillofac Surg.* 2018;47(4):480-91. doi:10.1016/j.ijom.2017.05.021.
44. Sher J, Kirkham-Ali K, Luo JD, Miller C, Sharma D. Dental implant placement in patients with a history of medications related to osteonecrosis of the jaws: A systematic review. *J Oral Implantol.* 2021;47(3):249-68. doi:10.1563/aaid-joi-D-19-00351.
45. Owen B, Bradley H. Is it safe to place implants in patients at risk of MRONJ? *Evid Based Dent.* 2021;22(3):108-9. doi:10.1038/s41432-021-0196-9.
46. Sulaiman N, Fadhul F, Chrcanovic BR. Bisphosphonates and dental implants: A systematic review and meta-analysis. *Materials (Basel).* 2023;16(18):6078. Published 2023 Sep 5. doi:10.3390/ma16186078
47. Pishan B, Andrukhov O, Rausch-Fan X. Dental implant failure in post-menopausal women on oral bisphosphonates: A systematic review and meta-analysis. *J Oral Implantol.* 2024;50(3):288-95. doi:10.1563/aaid-joi-D-23-00069.
48. Rasmussen JM, Hopfensperger ML. Placement and restoration of dental implants in a patient with Paget's disease in remission: Literature review and clinical report. *J Prosthodont.* 2008;17(1):35-40. doi:10.1111/j.1532-849X.2007.00240.x.
49. Torres J, Tamimi F, Garcia I, et al. Dental implants in a patient with Paget disease under bisphosphonate treatment: A case report. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009;107(3):387-92. doi:10.1016/j.tripleo.2008.11.024