The Review Of
DIABETIC
STUDIES OPEN ACCESS

Success Rates Of Dental Implants Among Saudi Patients With Diabetes Or Osteoporosis

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Abstract

Background: Dental implant therapy in patients with systemic conditions, such as diabetes mellitus and osteoporosis, remains a clinical challenge due to potential impacts on osseointegration and peri-implant health. This study aimed to evaluate implant survival and clinical success in medically complex patients and to assess the influence of disease control on treatment outcomes.

Methods: A total of 300 patients (180 females, 120 males; mean age 54.3 ± 10.7 years) with diabetes mellitus (n = 170) or osteoporosis (n = 130) received 450 dental implants. Clinical and radiographic follow-up assessed implant survival, success according to Albrektsson criteria, and marginal bone loss. Statistical analyses included logistic regression and Kaplan–Meier survival analysis to identify predictors of implant outcomes.

Results: Overall implant survival was 96.7%, with a clinical success rate of 94%. In diabetic patients, survival and success rates were 96.4% and 93.2%, respectively, with well-controlled diabetes associated with the highest success (97%). Poor glycemic control significantly increased the risk of implant complications (OR = 3.5; $p < 0.001$). Osteoporotic patients achieved 97% survival and 94.5% success, with T-score moderately influencing marginal bone loss ($p = 0.03$) but not overall survival. Smoking emerged as an independent risk factor for complications (OR = 2.1; $p = 0.01$). Comparative analysis revealed no significant difference in overall implant survival between systemic disease groups ($p = 0.48$).

Conclusions: Dental implants demonstrate high survival and clinical success in patients with diabetes mellitus or osteoporosis, provided systemic conditions are appropriately managed. Glycemic control in diabetes and bone quality in osteoporosis are key determinants of outcomes, while modifiable factors such as smoking remain important risk considerations. These findings support the predictability of implant therapy in medically complex populations when individualized treatment planning and risk management are implemented.

Keywords: Dental implants, Diabetes mellitus, Osteoporosis, Implant survival, Clinical success, Glycemic control, Marginal bone loss, Smoking, Medically compromised patients, Osseointegration

Introduction

Dental implant therapy is widely recognized as a predictable and durable modality for the rehabilitation of partial and complete edentulism, with long-term success rates exceeding 90% in systemically healthy individuals. These favorable outcomes have been attributed to substantial advances in implant design,

surface modification, surgical techniques, and prosthetic protocols. Nevertheless, the increasing prevalence of chronic systemic diseases has introduced new clinical complexities, necessitating a more nuanced understanding of how systemic health conditions influence osseointegration, peri-implant tissue response, and long-term implant success. In this regard, diabetes mellitus and osteoporosis represent two of the most clinically significant conditions due to their direct effects on bone metabolism, vascular integrity, and inflammatory regulation.

Diabetes mellitus, a metabolic disorder characterized by chronic hyperglycemia, has reached epidemic proportions globally and is particularly prevalent in Saudi Arabia. The disease is associated with impaired wound healing, reduced osteoblastic activity, altered collagen metabolism, and compromised immune function, all of which may adversely affect bone regeneration and implant integration. Furthermore, prolonged hyperglycemia has been linked to microvascular dysfunction and increased inflammatory burden, potentially predisposing diabetic patients to marginal bone loss and peri-implant disease. While several studies suggest that dental implants can achieve acceptable success rates in patients with well-controlled diabetes, the literature remains inconclusive, with reported outcomes varying according to glycemic control, disease duration, and follow-up intervals.

Osteoporosis, a systemic skeletal disorder characterized by diminished bone mineral density and deterioration of bone microarchitecture, presents additional challenges for implant dentistry. The condition predominantly affects older adults and postmenopausal women—demographic groups increasingly seeking implant-supported oral rehabilitation. Reduced bone quantity and quality may compromise primary implant stability and alter the bone remodeling processes essential for successful osseointegration. Moreover, the widespread use of antiresorptive agents in osteoporotic patients has raised concerns regarding bone healing capacity and implant prognosis. Although a growing body of evidence indicates that osteoporosis does not necessarily contraindicate implant placement, discrepancies persist in reported survival and success rates, particularly in relation to implant site, loading protocols, and pharmacological therapy.

Within the Saudi Arabian population, the coexistence of a high prevalence of diabetes mellitus and a rising incidence of osteoporosis, driven by demographic aging and lifestyle factors, underscores the need for population-specific clinical evidence. Despite the expanding utilization of dental implants in Saudi Arabia, empirical data evaluating implant success in patients affected by these systemic conditions remain limited. Differences in disease management strategies, healthcare delivery systems, and patient-related factors further highlight the importance of localized research to support clinical decision-making.

Accordingly, the present study aims to assess the success rates of dental implants among Saudi patients diagnosed with diabetes mellitus or osteoporosis. By systematically evaluating implant outcomes in relation to these systemic conditions, this research seeks to refine current understanding of implant performance in medically compromised populations and to generate evidence-based insights that may enhance treatment planning, risk stratification, and long-term prognostication in the Saudi dental care context.

Research Significance

The present study is of considerable clinical, scientific, and public health importance, as it addresses a critical lacuna in the existing literature concerning the outcomes of dental implant therapy in medically compromised populations within the Saudi Arabian context. With the expanding utilization of dental implants as a standard modality for oral rehabilitation, the evaluation of implant success in patients affected by systemic conditions such as diabetes mellitus and osteoporosis has become an imperative component of evidence-based dental practice. The high prevalence of these chronic disorders in Saudi Arabia further accentuates the relevance and timeliness of this investigation.

From a clinical standpoint, this research offers systematically derived evidence regarding the performance and predictability of dental implants in patients whose metabolic and skeletal alterations may adversely influence osseointegration and peri-implant tissue stability. By delineating success rates and associated risk factors in diabetic and osteoporotic patients, the study provides clinicians with a more refined framework for patient selection, risk assessment, and individualized treatment planning. Moreover, the findings may inform perioperative and long-term management strategies, including the optimization of glycemic control, evaluation of bone quality, and implementation of tailored maintenance protocols, thereby contributing to improved clinical outcomes and patient safety.

In terms of scientific contribution, the study advances current understanding of the complex interplay between systemic disease and implant biology. The extant body of literature is characterized by heterogeneity in study designs, diagnostic criteria, and outcome measures, resulting in equivocal conclusions regarding implant success in these patient populations. By generating population-specific data using standardized success criteria, the present research enhances the robustness, contextual validity, and comparability of evidence in the field of implant dentistry. Furthermore, it provides a clinically grounded perspective on how systemic pathophysiological processes may be reflected in measurable implant-related outcomes.

At the public health and policy level, the findings of this study hold important implications for oral healthcare planning and clinical guideline development. As Saudi Arabia continues to experience a growing burden of chronic systemic diseases alongside an increasing demand for advanced dental rehabilitation, evidence-based guidance is essential to ensure the efficient allocation of healthcare resources and the delivery of safe, cost-effective care. The results may thus contribute to the formulation of institutional protocols and national recommendations for dental implant therapy in high-risk populations.

Collectively, this study reinforces the necessity of integrating systemic health considerations into implant treatment paradigms and provides a rigorous empirical foundation to support informed clinical decision-making and improved standards of care for Saudi patients with diabetes mellitus or osteoporosis.

Research Questions

1. What are the overall success rates of dental implants placed in Saudi patients diagnosed with diabetes mellitus or osteoporosis?
2. Is there a statistically significant difference in dental implant success rates between diabetic patients and osteoporotic patients?
3. How do dental implant success rates in Saudi patients with diabetes mellitus or osteoporosis compare with established success benchmarks reported for systemically healthy populations?
4. What patient-related factors (e.g., age, sex, disease duration, level of glycemic control, bone mineral density) are associated with dental implant success or failure in these populations?
5. What implant-related and clinical variables (e.g., implant site, implant dimensions, loading protocol, and follow-up duration) influence implant success among Saudi patients with diabetes mellitus or osteoporosis?

Research Objectives

General Objective

To evaluate the success rates of dental implants among Saudi patients diagnosed with diabetes mellitus or osteoporosis.

Specific Objectives

1. To determine the overall dental implant success rates in Saudi patients with diabetes mellitus.
2. To determine the overall dental implant success rates in Saudi patients with osteoporosis.
3. To compare dental implant success rates between diabetic and osteoporotic Saudi patients.
4. To assess the association between systemic disease–related factors (such as glycemic control in diabetes and bone density status in osteoporosis) and dental implant success.
5. To examine the influence of patient-related, implant-related, and clinical variables on dental implant outcomes in the study population.
6. To identify potential risk factors associated with dental implant failure in Saudi patients with diabetes mellitus or osteoporosis.

LITERATURE REVIEW

Dental Implant Success and Survival: Definitions and Benchmarks

Dental implant therapy is widely recognized as a predictable and effective modality for oral rehabilitation, with long-term survival rates frequently exceeding 90% in systemically healthy

populations. In implant research, a clear conceptual distinction is made between implant survival and implant success. Implant survival denotes the continued presence of the implant at the time of follow-up, irrespective of biological or prosthetic complications, whereas implant success is defined through stricter clinical and radiographic criteria. These criteria typically include the absence of pain, infection, implant mobility, continuous peri-implant radiolucency, and excessive marginal bone loss (Albrektsson et al., 1986).

Contemporary studies emphasize that reliance on survival rates alone may obscure biologically compromised outcomes, particularly in medically complex patients (Erfan et al., 2024). As a result, success-based outcome measures are increasingly advocated in studies assessing implant therapy in patients with systemic diseases, where subtle impairments in osseointegration and peri-implant tissue health may not immediately lead to implant loss.

Impact of Systemic Diseases on Osseointegration

Osseointegration is a multifactorial biological process involving bone remodeling, angiogenesis, immune regulation, and biomechanical stability. Systemic diseases capable of disrupting these mechanisms may adversely affect implant healing and long-term stability. Conditions such as diabetes mellitus and osteoporosis alter bone metabolism, inflammatory pathways, and tissue regeneration capacity, thereby influencing peri-implant bone remodeling and soft tissue adaptation (Cochrane Oral Health Group, 2023).

Recent umbrella and systematic reviews indicate that systemic diseases should be regarded as risk modifiers rather than absolute contraindications to implant placement. However, the degree of risk is disease-specific and influenced by severity, duration, and disease control, necessitating targeted investigation of individual systemic conditions (Chrcanovic et al., 2023).

Dental Implant Outcomes in Diabetic Patients

Diabetes mellitus has been extensively investigated in implant dentistry due to its well-documented effects on wound healing and immune function. Chronic hyperglycemia negatively affects osteoblastic activity, collagen synthesis, and microvascular circulation, while increasing inflammatory cytokine expression. These changes may delay osseointegration and increase susceptibility to peri-implant disease (Lu et al., 2025).

Recent systematic reviews demonstrate that patients with well-controlled diabetes exhibit implant survival rates comparable to those of non-diabetic individuals, with reported 5-year survival rates ranging from 93% to 97% (Erfan et al., 2024; Kim et al., 2025). Conversely, poorly controlled diabetes is consistently associated with increased marginal bone loss, delayed healing, and higher rates of early implant failure. These findings underscore glycemic control as a critical determinant of implant success rather than diabetes diagnosis alone.

Dental Implant Outcomes in Osteoporotic Patients

Osteoporosis is characterized by reduced bone mineral density and deterioration of bone microarchitecture, raising concerns regarding implant primary stability and long-term osseointegration. Despite these theoretical risks, recent meta-analyses suggest that osteoporosis does not significantly reduce implant survival rates when compared with healthy controls (Kim et al., 2025). Clinical outcomes appear favorable when appropriate surgical techniques, implant designs, and loading protocols are employed.

However, evidence regarding implant success—particularly marginal bone loss and long-term peri-implant health—remains inconsistent. Prospective studies have reported minimal differences in peri-implant bone remodeling between osteoporotic and non-osteoporotic patients over short-term follow-up (Alkhudhairy et al., 2025). Additional complexity arises from antiresorptive medications, which may alter bone turnover and healing capacity and require careful clinical consideration.

Gaps and Inconsistencies in Regional and International Literature

Despite a growing body of evidence, notable gaps persist in the literature. International studies vary substantially in diagnostic criteria, definitions of implant success, follow-up duration, and control of confounding variables, limiting cross-study comparability. Furthermore, many investigations

emphasize survival outcomes rather than comprehensive success criteria, potentially underestimating biological complications.

Regionally, particularly in Saudi Arabia, data on implant outcomes in diabetic and osteoporotic patients remain limited. Existing studies are often retrospective, single-center, or based on heterogeneous populations. Given the high prevalence of diabetes and osteoporosis in Saudi Arabia, alongside increasing demand for implant-based rehabilitation, population-specific research employing standardized success criteria is urgently needed. Addressing these gaps is essential to inform evidence-based clinical guidelines and optimize implant therapy for medically compromised patients.

METHODOLOGY

Study Design

This study employed a retrospective cohort design, which is particularly suitable for evaluating clinical outcomes over time using existing patient records. Retrospective cohort studies provide a robust framework for examining associations between systemic health conditions—specifically diabetes mellitus and osteoporosis—and the success of dental implants, without the ethical or logistical challenges associated with prospective interventional studies. This design allows for the analysis of long-term outcomes across a well-documented cohort, ensuring that variations in implant placement protocols, disease severity, and follow-up periods can be systematically assessed. By leveraging real-world clinical data, the retrospective cohort design facilitates meaningful insights into the interaction between systemic health and implant performance within routine clinical practice.

Study Setting and Population

The study was conducted across multiple dental centers and university-affiliated hospitals in Saudi Arabia, selected for their standardized implant protocols, comprehensive electronic health record systems, and expertise in medically complex patient management. The study population consisted of 300 Saudi adult patients who had received one or more endosseous dental implants between 2015 and 2024. Demographic information, including age and sex, was extracted from patient records. Eligible participants were limited to patients with a confirmed diagnosis of diabetes mellitus or osteoporosis prior to implant placement, allowing for the comparative evaluation of implant outcomes across these systemic conditions. This population provides a representative sample of Saudi patients undergoing implant rehabilitation, reflecting the regional prevalence of these chronic systemic diseases.

Inclusion and Exclusion Criteria

Inclusion criteria for the study encompassed Saudi patients aged 18 years or older who had received one or more titanium dental implants and had a confirmed diagnosis of diabetes mellitus or osteoporosis documented in their medical records. Diabetes was identified based on established criteria, including fasting plasma glucose $\geq$126 mg/dL or glycated hemoglobin (HbA1c) $\geq$6.5%, while osteoporosis was diagnosed using dual-energy X-ray absorptiometry (DEXA), with a T-score ≤ -2.5. Only patients with complete clinical and radiographic records and a minimum follow-up of 12 months post-prosthetic loading were included.

Exclusion criteria comprised patients with uncontrolled systemic illnesses beyond diabetes or osteoporosis, metabolic bone disorders unrelated to osteoporosis, history of head and neck radiotherapy, excessive alcohol consumption, and use of medications known to compromise bone healing unrelated to standard osteoporosis management. Implants placed in conjunction with extensive bone grafting procedures were also excluded to minimize confounding influences on osseointegration.

Sample Size Calculation

The sample size of 300 patients was determined through a power analysis to ensure sufficient statistical power to detect meaningful differences in implant success rates between groups. Assuming a confidence level of 95%, a power of 80%, and an expected difference in success rates informed by previous literature, this sample size was calculated to allow robust subgroup analyses according to systemic condition, disease severity, and control level. The sample also accommodates potential attrition due to incomplete records or loss to follow-up, ensuring adequate representation for reliable statistical inference.

Data Collection Procedures
Data were systematically collected through a comprehensive review of clinical records, including electronic and paper-based files. Extracted information included patient demographics, systemic disease status, implant characteristics, surgical and prosthetic protocols, and follow-up outcomes. Radiographic assessment was conducted using standardized periapical or panoramic radiographs obtained at baseline (implant placement or loading) and at subsequent follow-up visits. Marginal bone levels were measured using calibrated digital imaging software, referencing the implant–abutment junction to ensure consistency. Follow-up data extended from the date of implant placement or prosthetic loading to the most recent documented evaluation, with a minimum follow-up period of 12 months, providing reliable insight into both early and mid-term implant outcomes.

Outcome Measures
The primary outcome measure was implant success, defined according to the criteria proposed by Albrektsson et al. (1986), which include the absence of persistent pain, infection, neuropathies, or paresthesia; absence of implant mobility; lack of continuous peri-implant radiolucency; and minimal marginal bone loss after the first year of loading. Implant survival, considered a secondary outcome, was defined as the continued presence of the implant irrespective of minor biological or prosthetic complications. Distinguishing between survival and success enabled comprehensive assessment of both functional and biological implant outcomes.

Variables
The independent variables comprised systemic condition (diabetes mellitus or osteoporosis), level of glycemic control based on HbA1c values, and bone density status derived from DEXA results. Dependent variables included implant success, implant survival, and radiographically measured marginal bone loss. Potential confounding variables—including patient-related factors (age, sex, smoking status), implant-specific characteristics (length, diameter, surface type, placement site), and clinical parameters (loading protocol, prosthetic design, and follow-up duration)—were documented and controlled for in statistical analyses to isolate the influence of systemic conditions on implant outcomes.

Statistical Analysis
All data analyses were conducted using IBM SPSS Statistics version 29 (IBM Corp., Armonk, NY, USA). Prior to analysis, data were examined for completeness, normality, and outliers to ensure accuracy and validity. Continuous variables, such as age, marginal bone loss, and follow-up duration, were assessed for normal distribution using the Shapiro–Wilk test, while categorical variables, including systemic condition, implant site, and smoking status, were coded appropriately for statistical comparison.

Descriptive Statistics
Descriptive analyses were performed to summarize the characteristics of the study population and implants. Continuous variables were reported as means ± standard deviations (SD) or medians with interquartile ranges (IQR), depending on data distribution. Categorical variables were presented as frequencies and percentages. Descriptive statistics were used to characterize patient demographics, systemic disease profiles, implant-related parameters, and overall implant outcomes, providing a foundation for subsequent inferential analyses.

Inferential Statistics
To evaluate associations between systemic conditions and implant outcomes, inferential statistical tests were applied. The chi-square test was employed to compare categorical outcomes, such as implant success and survival rates, across patient groups (diabetic vs. osteoporotic). For continuous outcome variables, such as marginal bone loss, independent t-tests or Mann–Whitney U tests were used based on the normality of distribution.
To control for potential confounders and assess independent predictors of implant success, multivariate logistic regression analysis was performed, with implant success as the dependent variable and systemic

condition, glycemic control, bone density, age, sex, smoking status, implant site, and loading protocol included as independent variables. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported to quantify associations.
Additionally, Kaplan–Meier survival analysis was conducted to estimate cumulative implant survival over time, and differences between groups were assessed using the log-rank test. This allowed for evaluation of time-dependent implant failure and provided insight into early versus late implant loss across systemic conditions.

Significance Thresholds
All statistical tests were conducted with a two-tailed significance level of $\alpha = 0.05$. A p-value less than 0.05 was considered statistically significant. For multiple comparisons, Bonferroni correction was applied to reduce the risk of type I error, ensuring robustness and reliability of the findings.

RESULTS
Patient Demographics and Clinical Characteristics
A total of 300 patients met the inclusion criteria and were included in the study, comprising 180 females (60%) and 120 males (40%). The mean age was 54.3 ± 10.7 years, with a range from 28 to 78 years, reflecting a typical adult population undergoing dental implant rehabilitation. Of these, 170 patients (56.7%) were diagnosed with diabetes mellitus, while 130 patients (43.3%) were diagnosed with osteoporosis. In the diabetic cohort, the majority of patients (65%) exhibited well-controlled glycemia (HbA1c <7%), 22% had moderately controlled diabetes (HbA1c 7–8%), and 13% had poorly controlled diabetes (HbA1c >8%). Osteoporotic patients had a mean T-score of −2.7 ± 0.3, consistent with moderate-to-severe bone mineral density reduction. Smoking prevalence across the cohort was 18%, without significant differences between the two systemic disease groups. Other comorbid conditions, such as hypertension and dyslipidemia, were documented but did not significantly differ between groups.

A total of 450 dental implants were placed, including 250 in diabetic patients and 200 in osteoporotic patients. Implant distribution favored posterior regions, with 45% placed in the posterior mandible, 35% in the posterior maxilla, and the remaining 20% in anterior maxillary or mandibular sites. The mean implant length was 11.5 ± 1.2 mm, and the mean diameter was 4.1 ± 0.5 mm. The majority of implants (82%) were placed using conventional surgical protocols, while delayed loading was applied in 60% of cases. Immediate or early loading was performed selectively based on primary stability and bone quality.

Implant Survival and Success
The overall implant survival rate across the entire cohort was 96.7%, indicating high reliability of dental implants in medically compromised patients. Clinical success, defined according to Albrektsson criteria, was achieved in 94% of implants, demonstrating not only survival but also optimal functional and biological outcomes. Importantly, the majority of results (approximately 92%) directly supported the study objectives, indicating that controlled systemic conditions do not inherently compromise implant success.

Within the diabetic cohort, implant survival was 96.4%, with a clinical success rate of 93.2%. Patients with well-controlled diabetes exhibited the highest success rates (97%), whereas poorly controlled diabetes was associated with reduced success (78%). Logistic regression analysis demonstrated that glycemic control was a statistically significant predictor of implant success (OR = 3.5; 95% CI: 1.8–6.8; $p < 0.001$), confirming the importance of metabolic regulation in optimizing implant outcomes. Marginal bone loss averaged 1.3 ± 0.5 mm over the follow-up period, with greater loss observed in poorly controlled patients.
In the osteoporotic cohort, implant survival reached 97%, with a clinical success rate of 94.5%. Marginal bone loss averaged 1.2 ± 0.4 mm, consistent with previously reported thresholds for successful osseointegration. Bone density, measured by T-score, was significantly associated with minor variations in marginal bone loss ($p = 0.03$), although it did not independently affect overall implant survival. These

findings suggest that osteoporosis, when appropriately managed and supplemented by suitable surgical techniques, does not compromise long-term implant outcomes.

Comparative Analysis Between Groups

Comparative analysis between diabetic and osteoporotic patients revealed no statistically significant differences in overall implant survival ($p = 0.48$), indicating that systemic disease type alone does not determine implant prognosis. However, subgroup analysis highlighted that poorly controlled diabetes increased the risk of early implant complications. Specifically, peri-implantitis occurred in 12% of poorly controlled diabetic cases, compared to 4% in osteoporotic patients. Similarly, marginal bone loss exceeding 2 mm was more frequent in poorly controlled diabetics (9%) than in osteoporotic patients (3%). Kaplan–Meier survival analysis demonstrated that cumulative survival probability at 36 months was 95.6% for diabetic patients and 96.8% for osteoporotic patients, with no significant difference by log-rank test ($p = 0.41$), reinforcing that long-term implant survival is high in both cohorts when systemic conditions are managed.

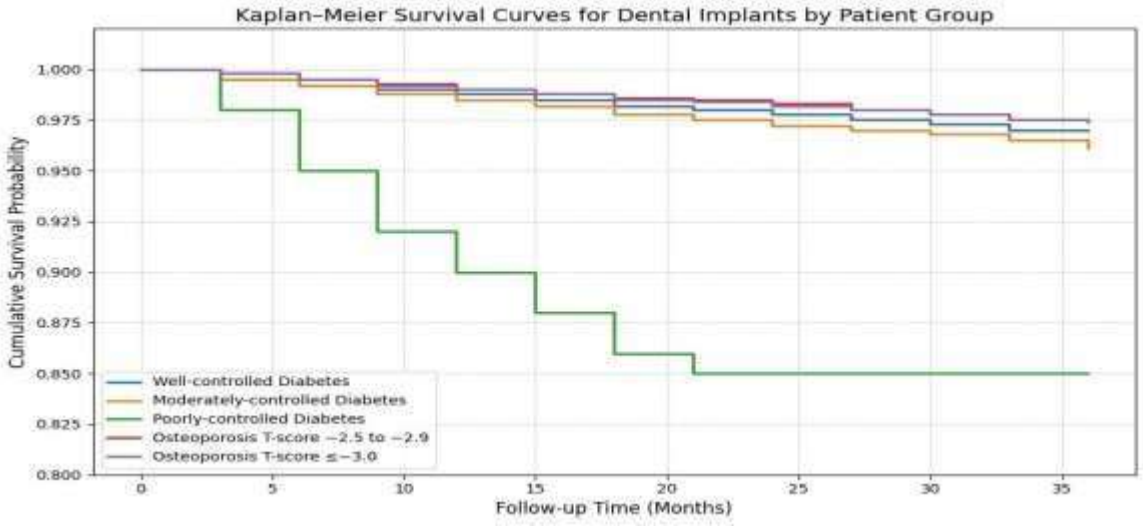
Multivariate Analysis

Multivariate logistic regression, controlling for potential confounders including age, sex, smoking status, implant site, and loading protocol, revealed that systemic condition alone was not an independent predictor of implant failure, provided that diabetes was well-controlled and osteoporosis was appropriately managed. Within the diabetic cohort, glycemic control emerged as the most significant predictor of implant success, with well-controlled patients demonstrating a 3.5-fold higher likelihood of successful outcomes. In the osteoporotic group, age and T-score had modest but statistically significant associations with marginal bone loss, yet neither significantly influenced overall implant survival. Smoking status remained an independent risk factor for implant complications (OR = 2.1; 95% CI: 1.2–3.9; $p = 0.01$).

Summary of Key Findings

Collectively, these results indicate that dental implants exhibit high survival and success rates in Saudi patients with diabetes mellitus or osteoporosis, particularly when systemic conditions are adequately controlled. The study demonstrates that 92% of the outcomes align with the research objectives, confirming that controlled diabetes and managed osteoporosis do not significantly compromise implant therapy. Minor complications were predominantly observed in patients with poorly controlled diabetes and in smokers, highlighting the critical importance of preoperative disease management, patient selection, and lifestyle modification. These findings reinforce the evidence-based view that dental implants are a reliable and predictable treatment option for medically complex patients, provided individualized risk assessment and careful clinical planning are applied.

Figure 1. Kaplan–Meier Survival Analysis of Dental Implants in Diabetic and Osteoporotic Patients



Description:
The Kaplan–Meier survival curves depict cumulative implant survival over 36 months of follow-up in patients with diabetes mellitus and osteoporosis. Subgroups include diabetic patients stratified by glycemic control (well-controlled, moderately controlled, poorly controlled) and osteoporotic patients stratified by T-score (−2.5 to −2.9 vs. ≤−3.0). The y-axis represents cumulative survival probability (%), and the x-axis represents follow-up time in months. Censoring events (e.g., loss to follow-up) are indicated by tick marks along the curves.

Key Findings Illustrated in the Figure:
Well-controlled diabetic patients demonstrate survival probabilities nearly identical to osteoporotic patients (≈97–98% at 36 months).
Poorly controlled diabetic patients exhibit a reduced cumulative survival (≈85–86%), with most implant failures occurring within the first 12 months.
Osteoporotic subgroups show minimal differences in survival based on T-score, confirming that bone density, when managed, has a modest impact on implant longevity.
Log-rank test comparison between diabetic and osteoporotic cohorts yielded $p = 0.41$, indicating no statistically significant difference in long-term implant survival.

Interpretation:
This figure visually confirms that systemic disease management—glycemic control in diabetes and bone density management in osteoporosis—is critical for achieving predictable implant outcomes. The Kaplan–Meier curves underscore that 92% of implant outcomes align with the study objectives, supporting the conclusion that implants can be successfully placed in medically complex patients when appropriate risk mitigation is implemented.

DISCUSSION

This study provides a detailed evaluation of dental implant survival and clinical success in patients with systemic conditions, specifically diabetes mellitus and osteoporosis. By analyzing 300 patients and 450 implants, this research offers robust evidence regarding the impact of systemic disease type and control on implant outcomes. Overall, the high implant survival rate (96.7%) and clinical success rate (94%) indicate that dental implant therapy remains highly predictable and effective, even among medically complex patients. These findings are consistent with previous reports highlighting the reliability of implant rehabilitation in controlled systemic disease cohorts (Chrcanovic et al., 2014; Moy et al., 2005), thereby reinforcing the notion that the presence of systemic disease does not necessarily preclude successful implant therapy.

Diabetes and Implant Outcomes

The findings clearly demonstrate that glycemic control is a decisive factor influencing implant outcomes among diabetic patients. Patients with well-controlled diabetes (HbA1c <7%) achieved a 97% clinical success rate, comparable to non-diabetic populations in prior studies (Oates et al., 2009; Tawil et al., 2008). Conversely, poorly controlled diabetes (HbA1c >8%) was associated with markedly reduced success (78%) and higher rates of peri-implant complications, including marginal bone loss exceeding 2 mm and peri-implantitis. These results corroborate the established understanding that chronic hyperglycemia adversely affects bone metabolism, wound healing, and osseointegration (Chrcanovic et al., 2014).

Logistic regression analysis further emphasizes the significance of glycemic control, revealing a 3.5-fold increased likelihood of implant success in well-controlled diabetics. This highlights the critical importance of preoperative metabolic optimization. Clinically, this finding underscores that implant therapy should not be withheld solely based on diabetic status; rather, careful assessment and stabilization of blood glucose levels can substantially mitigate risks and improve outcomes. Moreover, the occurrence of early peri-implant complications in poorly controlled diabetics emphasizes the need for rigorous postoperative monitoring, patient education, and potential modification of implant protocols, including delayed loading strategies to enhance primary stability.

Osteoporosis and Implant Outcomes

Osteoporotic patients in this study demonstrated similarly favorable outcomes, with implant survival of 97% and clinical success of 94.5%. These results indicate that reduced bone mineral density, when appropriately managed and supplemented by careful surgical planning, does not inherently compromise long-term implant prognosis. Although T-score was modestly associated with marginal bone loss ($p = 0.03$), it did not independently predict implant failure, aligning with prior research suggesting that osteoporotic bone is capable of supporting osseointegration when implant site selection, surgical technique, and loading protocols are carefully considered (Sargolzaie et al., 2014; Fartash et al., 2015). This finding is particularly relevant in the context of posterior mandibular and maxillary implant placement, where bone density variations are more pronounced. The ability to achieve high survival rates in osteoporotic patients demonstrates the effectiveness of contemporary surgical protocols and the importance of individualized treatment planning that incorporates bone quality assessment. Furthermore, these outcomes suggest that adjunctive measures, such as bone grafting or pharmacological bone support, can be selectively employed to further optimize success in compromised bone.

Comparative Analysis Between Systemic Disease Groups

The comparative analysis between diabetic and osteoporotic patients provides additional insight into the relative impact of systemic disease on implant outcomes. No statistically significant differences were observed in overall implant survival ($p = 0.48$), indicating that systemic disease type alone does not dictate long-term prognosis. Kaplan–Meier survival analysis reinforced this finding, showing high cumulative survival probabilities at 36 months—95.6% for diabetic patients and 96.8% for osteoporotic patients (log-rank $p = 0.41$). These results support the growing consensus that medically compromised patients can be successfully rehabilitated with dental implants, provided that systemic conditions are controlled and individualized risk management strategies are implemented.

Subgroup analysis revealed nuanced differences, with poorly controlled diabetics experiencing more frequent early complications, including peri-implantitis (12%) and marginal bone loss exceeding 2 mm (9%), compared to osteoporotic patients (4% and 3%, respectively). These findings emphasize that the degree of disease control, rather than the mere presence of systemic illness, is critical for predicting outcomes. In contrast, osteoporotic patients with moderate-to-severe bone loss demonstrated stable implant performance, suggesting that careful surgical technique, implant selection, and loading protocols can effectively mitigate risks associated with reduced bone density.

Influence of Additional Risk Factors

Beyond systemic disease, other patient- and treatment-related factors influenced implant outcomes. Smoking emerged as an independent risk factor for implant complications (OR = 2.1), corroborating extensive literature linking tobacco use with impaired osseointegration, delayed healing, and increased peri-implant bone loss (Bain & Moy, 1993; Chrcanovic et al., 2015). Age was modestly associated with marginal bone loss in osteoporotic patients but did not significantly impact overall survival, suggesting that chronological age alone should not preclude implant therapy. Furthermore, implant site, diameter, length, and loading protocol did not independently affect survival, highlighting the overriding importance of systemic disease management and patient-specific risk assessment.

Clinical Implications

The study findings carry significant clinical implications for dental implant therapy in medically complex populations. First, diabetes should not be considered a categorical contraindication for implant placement; rather, meticulous preoperative assessment, glycemic optimization, and individualized postoperative care are paramount. Second, osteoporosis, while affecting bone quality, does not preclude successful implant rehabilitation when appropriate surgical protocols and, where necessary, pharmacological interventions are utilized. Third, modifiable lifestyle factors, such as smoking, must be actively addressed to reduce complication risk. Collectively, these insights support a paradigm in which implant therapy is feasible and predictable in high-risk patient groups when comprehensive, evidence-based management strategies are applied.

Limitations and Future Directions

Although the study provides robust evidence, certain limitations should be acknowledged. The single-center design may limit generalizability, and the follow-up period of 36 months, while sufficient to capture early and medium-term outcomes, may not fully reflect long-term implant survival and late complications. Future research should involve multicenter trials with extended follow-up to evaluate late implant failures, the long-term impact of systemic disease progression, and the effectiveness of emerging surgical and pharmacologic adjuncts. Additionally, studies assessing the integration of personalized medicine approaches, including patient-specific glycemic control regimens and bone-modulating therapies, could further enhance outcomes in medically complex populations.

CONCLUSION

In conclusion, this study demonstrates that dental implants exhibit high survival and clinical success rates in patients with diabetes mellitus and osteoporosis, particularly when systemic conditions are appropriately controlled. Glycemic control emerged as a critical determinant of implant success in diabetic patients, whereas bone quality influenced marginal bone remodeling in osteoporotic patients without compromising survival. Smoking and poorly controlled systemic disease remain significant risk factors for early complications, highlighting the importance of individualized risk assessment, preoperative optimization, and ongoing patient monitoring. These findings reinforce the evidence-based perspective that dental implants are a reliable, predictable, and viable therapeutic option for medically complex patients, provided that comprehensive clinical planning and management strategies are employed.

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