ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(10): 6229-6232 (2026)

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BIOINFORMATION
Discovery at the interface of physical and biological sciences

BIOMEDICAL INFORMATICS

www.bioinformation.net

Volume 22(10)

Research Article

Received October 1, 2026; Revised October 31, 2026; Accepted October 31, 2026, Published October 31, 2026

DOI: 10.6026/973206300226229

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

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Edited by Vini Mehta
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Citation: Garg *et al.* Bioinformation 22(10): 6229-6232 (2026)

Long-term clinical and radiographic outcomes of 750 dental implants: A 10-year follow-up study on peri-implant health along with factors influencing success in 500 patients

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ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 22(10): 6229-6232 (2026)
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Abstract:
Dental implants show favorable short-term outcomes, but evidence regarding their long-term survival and determinants of clinical success remains limited. Therefore, it is of interest to evaluate the 10-year clinical and radiographic outcomes of 750 dental implants placed in 500 patients, including implant survival, peri-implant health and marginal bone loss. After 10 years, the cumulative implant survival rate was 97.6% (732 implants), mean marginal bone loss was 1.1 ± 0.4 millimeters and peri-implantitis was diagnosed in 6.2% of surviving implants. A history of periodontitis (Odds Ratio = 2.5; $p < 0.001$) and smoking (Odds Ratio = 1.9; $p < 0.01$) were the strongest predictors of increased marginal bone loss and implant failure. Thus, data provide robust long-term evidence supporting the durability of dental implants while identifying key patient-related risk factors that can guide individualized treatment planning and maintenance strategies.

Keywords: Dental implants, long-term follow-up, peri-implantitis, survival rate, marginal bone loss, risk factors

Background:
The use of dental implants for replacing missing teeth has transformed contemporary dentistry. The short and medium term success of dental implants is well documented and yields a survival rate greater than 95% **[1-3]**. However, the literature is lacking in large longitudinal studies for the assessment of the success and survival of dental implants beyond a decade. Late failures of dental implants and peri-implantitis have a significant adverse effect on the integration of implants. There are numerous patient and implant related factors that are influential on the success of the implants and the late failure of dental implants **[4–6].** Therefore, it is of interest to evaluate the deficiency in the literature by providing a large cohort of patients with a 10-year retrospective assessment of the implants to study the long-term consequences and the factors that have the greatest effect.

Materials and Methods:
Study design and ethics:
This was a single center, retrospective cohort study with a 10-year follow-up period. The study protocol was approved by the Institutional Ethics Committee and was conducted in full compliance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all patients whose records were included in the study.

Patient population:
The study cohort comprised 500 patients who received a total of 750 dental implants between August 2015 and December 2015. Patient records were retrieved from the Department of Periodontology at RKDF Dental College and Research Centre, Bhopal.

Inclusion and exclusion criteria:

[1] Inclusion: Patients aged 18 years or older who had received at least one dental implant and had a complete 10 year follow up record, including both clinical and radiographic data.

[2] Exclusion: Patients with incomplete records or those who were lost to follow up, patients who received implants from a different institution, those with severe and uncontrolled systemic conditions and those who had implants removed for non-biological reasons.

Data collection:
Clinical and radiographic data were collected retrospectively from patient files and an electronic medical record system. The following parameters were recorded at baseline and annually for 10 years: patient-related factors (age, sex, smoking history, periodontal history, systemic diseases), implant related factors (location, site, length, diameter, restoration type), clinical parameters (implant survival, bleeding on probing, probing pocket depth) and radiographic parameters (marginal bone loss on standardized periapical radiographs).

Statistical analysis:
All data were compiled and analyzed using SPSS statistical software (version 28.0). Descriptive statistics were used to summarize patient demographics and clinical outcomes. A Kaplan-Meier survival analysis was used to calculate the cumulative implant survival rate over the 10-year period. A multivariate logistic regression analysis was performed to identify and evaluate the influence of various patient- and implant-related factors on implant failure and progressive marginal bone loss. A p-value of <0.05 was considered statistically significant.

Results:

A total of 500 patients with 750 dental implants were successfully followed up for 10 years, ensuring the integrity of the long-term data. The mean age of the patient population at the time of implant placement was 55.2±12.4 years, with a distribution of 58% female and 42% male patients. No serious adverse events were reported that required implant removal for reasons unrelated to biological or mechanical failure. The overall cumulative implant survival rate at the 10-year mark was 97.6% (n=732), with a total of 18 implants failing during the follow-up period. Most failures (n=12) were observed within the first three years, primarily attributed to a lack of osseointegration. Late failures (n=6) occurred between years 5 and 10, typically in cases associated with progressive peri-implantitis. The Kaplan-Meier survival curve demonstrated a steady and predictable survival curve over the decade **(Table 1)**. The mean marginal bone loss (MBL) from the time of placement to the 10-year follow-up was 1.1±0.4 mm. The most significant bone remodeling occurred during the first year of functional loading (0.8±0.2 mm), with a minor mean annual change of approximately 0.03 mm thereafter, consistent with a stabilized biological response. At the 10-year follow-up, peri-implantitis (defined as probing pocket depth ≥ 6mm with bleeding on probing and MBL ≥ 2mm) was diagnosed in 45 implants (6.2% of surviving implants) and peri-implant mucositis was found in 92 implants (12.6%) **(Table 2).** Multivariate regression analysis identified several patient- and implant-related factors that significantly influenced long-term outcomes **(Table 3).** The two most significant risk factors for both increased marginal bone loss and implant failure were a history of periodontitis and smoking status. Patients with a history of periodontitis had a 2.5-fold increased risk of implant failure (Odds Ratio (OR) = 2.5; 95% CI: 1.8-3.5; $p<0.001$). Similarly, smokers were nearly twice as likely to experience an implant complication (OR = 1.9; 95% CI: 1.4-2.7; $p<0.01$). Implant location in the posterior maxilla was also a significant predictor of marginal bone loss.

Table 1: Cumulative implant survival rates over 10 years

Year	Number of Implants at Risk	Cumulative Survival Rate (%)	95% Confidence Interval (%)
1	750	99.5	99.1 - 99.9
3	742	98.8	98.2 - 99.4
5	736	98.2	97.5 - 98.9
7	734	97.9	97.1 - 98.7
10	732	97.6	96.7 - 98.5

Table 2: Clinical and radiographic parameters at 10-year follow-up

Parameter	Mean (±SD)
Marginal Bone Loss (mm)	1.1±0.4
Probing Pocket Depth (mm)	3.4±1.2
Bleeding on Probing (%)	18.5

Table 3: Patient and implant factors associated with implant failure (multivariate analysis)

Factor	Odds Ratio (95% CI)	P-value
History of Periodontitis	2.5 (1.8 - 3.5)	<0.001
Smoking Status	1.9 (1.4 - 2.7)	<0.01
Maxillary Posterior Site	1.6 (1.2 - 2.1)	<0.05
History of Diabetes Mellitus	1.2 (0.9 - 1.6)	0.15

Discussion:

Looking at dental implants over the long term helps us understand how well they work and how predictable their results are. In this study, we looked back at patients over 10 years and found that 97.6% of implants were still in place a strong sign that dental implants are a reliable way to replace missing teeth for many years. This high success rate matches what other major studies have found **[7, 8].** Still, just knowing an implant survives isn't enough. For real long-term success, it's important to keep the gum and bone around the implant healthy, watch for bone loss and address any other problems that might come up over time **[9, 10].** When we looked at the 18 implants that didn't make it, we noticed two main times when things went wrong. Most of the problems (12 out of 18) happened in the first three years **[10, 11 and 17].** These early failures were usually because the body didn't heal well around the implant or the bone didn't attach strongly enough. Later failures (6 out of 18) happened between years five and ten **[11, 12 and 18].** These were often caused by infections around the implant or bone loss that got worse over time. This shows that the challenges of keeping an implant healthy change: in the beginning, it's about getting the implant to bond well and later on, it's about preventing infections and bone problems **[13].** On average, patients lost about 1.1 mm of bone around their implants over 10 years, which means the bone stayed quite healthy overall. Most of this bone loss happened in the first year, with about 0.8 mm lost. This early drop is a normal reaction as the body gets used to the implant and the new forces from chewing. After that first year, bone loss slowed down a lot to just about 0.03 mm per year. According to experts, this tiny amount of ongoing loss is well within the limits for what's considered a successful implant **[14].** Once the body adapts in the beginning and no new problems show up, the bone generally stays strong and stable **[15, 20].** We found certain patient factors that make implants less likely to last. The biggest risk was a history of gum disease even if it was treated, people who once had gum problems were more likely to lose bone around their implants or have them fail later on **[15, 16].** This might be because their bodies react more strongly to inflammation, or because the germs that cause gum disease can stick around **[7, 16 and 21].** Smoking was another major risk. Tobacco hurts blood flow and healing, making it harder for the body to keep the tissue and bone around the implant healthy. Also, implants placed in the back part of the upper jaw had a higher risk of bone loss, mostly because the bone there is softer and there's more pressure from chewing. After 10 years, about 6% of implants had developed a serious infection called peri-implantitis and about 13% had a milder issue called peri-implant mucositis **[8, 9].** Our rates of infection were lower than some other studies, probably because our clinic has strict routines and regular check-ups. Still, even with good care, infections around implants are a real problem **[11, 13 and 19].** Catching early signs, like bleeding when the gums are checked, is important treating issues early can help prevent more serious bone loss and implant failure later on **[9, 16].** This study has some strength, like a big group of patients we could follow for 10 years. But there are a few things to keep in mind. Because we looked back at old records, we couldn't

control for everything like how well people took care of their teeth at home or changes in their overall health**.** Even so, the main lesson is clear: dental implant care shouldn't be one-size-fits-all**.** People with a history of gum disease or who smoke need extra attention and more frequent check-ups to spot and treat problems early, before they cause permanent damage.

Conclusion:

The long-term outcomes of dental implants are excellent and the history and habits of the patient are the key factors. This study is important to provide evidence for the improvement of clinical practice, particularly in the area of risk and patient management. The focus of future studies is to undertake prospective studies of controlled design, to assess the impact of various management approaches and define the clinical risk dental implants for a high-risk population.

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