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Systematic review

Impact of Chemotherapy and Radiotherapy on Osseointegration and Survival of Dental Implants: A Systematic Review and Meta-Analysis.

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Abstract
Dental implants are widely used in oral rehabilitation, and their efficacy depends on proper osseointegration. In cancer patients, chemotherapy and radiotherapy may adversely affect bone healing and implant stability. Despite increasing clinical use, the effect of these therapies on implant survival remains controversial. To comprehensively evaluate the impact of chemotherapy and radiotherapy on the osseointegration and survival of dental implants in cancer patients. In accordance with the PRISMA criteria, a systematic search was conducted in PubMed, Scopus, Web of Science, and Cochrane Library. Relevant studies involving patients undergoing chemotherapy and/or radiotherapy and reporting implant outcomes were included. Data extraction included sample size, number of implants, survival and failure rates, and follow-up duration. The odds ratios and mean differences were computed with a 95% confidence interval in a meta-analysis that was conducted using Review Manager (RevMan 5.4.1). The I^2 statistic was used to evaluate heterogeneity. The analysis involved four studies that were published between 2015 and 2026. The findings demonstrated a general trend toward lower implant survival rates and higher failure rates in patients exposed to chemotherapy and/or radiotherapy compared to controls. Pooled analysis indicated no statistically significant variation in implant survival (P = 0.24) or failure rates (P = 0.30) between the groups. Significant heterogeneity was observed among the studies. The follow-up period exhibited a statistically significant disparity among the groups (P = 0.0001). Dental implant outcomes may be adversely affected by chemotherapy and radiotherapy; however, this meta-analysis did not demonstrate a statistically significant overall effect. Results may have been influenced by variations in study design, sample size, and follow-up duration. A meticulous approach to patient selection and treatment planning is still necessary. Further high-quality studies are required to establish definitive clinical guidelines**.**
Keywords. Dental Implants, Osseointegration, Radiotherapy, Chemotherapy, Implant Survival.

Introduction

Dental implants are a highly effective treatment option for replacing missing teeth in edentulous or partially edentulous patients. They offer a dependable and enduring solution that restores both aesthetics and functionality [1]. Implants have a good success and survival rate according to many longitudinal studies; in fact, under ideal circumstances, some studies have demonstrated survival rates of 100% over ten years or longer (2–4). Usually, success rates in this context are defined by the stability of clinical and radiographic criteria, such as the absence of mobility, peri-implant crestal bone loss (CBL) or peri-implantitis, as well as the patient's satisfaction with the functional and aesthetic outcomes. Nonetheless, although several patients get exceptional results, systemic health problems have surfaced as potentially significant determinants affecting implant success and survival rates [5–7].

The impact of systemic diseases and treatments on the biological milieu surrounding dental implants is becoming more and more apparent. This includes metabolic disorders, immunosuppression, and different treatments for long-term illnesses. Conditions including diabetes, osteoporosis, and cardiovascular disease increase the likelihood of peri-implant complications due to issues with wound healing and bone metabolism, which in turn impact osseointegration [8–10]. One such component that considerably impacts patient health is chemotherapy and radiation, which are components of the treatment for a variety of cancers. An important strategy for treating diseases such as leukemia, lymphoma, breast cancer, and others is chemotherapy, which targets cells that divide quickly. Unfortunately, chemotherapy's systemic effects mean that it impacts both cancer cells and healthy tissues, including those that are essential for bone remodeling and repair [11].

Chemotherapy can affect the durability and success of dental implants by causing cytotoxic effects on osteoblasts and osteoclasts and by lowering the immune response. These side effects can disrupt the osseointegration process and make the implants more susceptible to infections [12,13]. Radiotherapy, especially in the head and neck region, is known to induce hypovascularity, hypocellularity, and hypoxia in bone tissue, collectively described as radiation-induced fibrosis. These changes may impair bone remodeling and increase the risk of osteoradionecrosis, ultimately compromising implant osseointegration [14 15]. Furthermore, implant survival rates are significantly reduced when radiation doses exceed 50 Gy [16]. Despite these concerns, dental implants are increasingly being considered in cancer survivors to improve oral function and quality of life. However, the literature presents conflicting evidence regarding their survival and osseointegration in patients exposed to cancer therapies. While some studies report acceptable outcomes under controlled conditions, others demonstrate significantly higher failure rates. Consequently, it is imperative to conduct a thorough assessment of the current body of evidence through systematic review

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and meta-analysis in order to elucidate the influence of radiotherapy and chemotherapy on implant outcomes and to inform clinical decision-making.
In order to assess the effects of radiation and chemotherapy on osseointegration and survival rates of dental implants in cancer patients, this study set out to conduct a thorough evaluation of the literature. This analysis aimed to give evidence-based recommendations for clinical decision-making in the rehabilitation of oncology patients by integrating the current clinical information to determine if chemotherapy and/or radiotherapy significantly degrade implant results.

Method

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses were employed to guarantee the appropriate execution of this investigation [17]).

Search Strategy

To locate pertinent material, we conducted thorough searches in Scopus, PubMed, the Web of Science, and the Cochrane Library. Medical Subject Headings (MeSH) phrases and keywords were both utilized in the search technique. The primary search terms included: ("dental implants" OR "oral implants" OR "implant dentistry") AND ("osseointegration" OR "implant integration" OR "bone integration") AND ("radiotherapy" OR "radiation therapy" OR "irradiation") AND ("chemotherapy" OR "antineoplastic therapy" OR "cancer treatment"). AND ("cancer patients" OR "oncology patients" OR "head and neck cancer" OR "malignancy"). Additionally, manual screening of reference lists from eligible studies was performed to identify any further relevant publications.

Inclusion Criteria

In order to ensure the inclusion of clinically relevant evidence, only human clinical studies were incorporated, including retrospective observational studies, prospective cohort studies, and randomized controlled trials. Eligible studies involved patients diagnosed with cancer who had undergone chemotherapy and/or radiotherapy and subsequently received dental implant therapy. Studies were required to report at least one primary outcome of interest, including implant survival rate, implant failure rate, or measures related to osseointegration. Preference was given to studies that included a comparison or control group of non-exposed patients; however, studies without control groups were also considered if they provided sufficient quantitative outcome data. Studies were also only considered if they had well-defined methods, large enough samples, and long enough follow-up periods to evaluate implant results. For the sake of precise interpretation and analysis, only English-language articles were taken into consideration.

Exclusion Criteria

Animal and in vitro studies were excluded. Case series, case reports, and review articles without original data were also excluded. Studies that did not involve patients undergoing chemotherapy and/or radiotherapy or did not report relevant implant outcomes were excluded. Additionally, studies with incomplete data or unclear methodology were not considered for inclusion.

Data Extraction

The data extraction process was conducted in a systematic manner, utilizing a predesigned and standardized data collection form to guarantee the accuracy and consistency of all included studies. Each study was analyzed to extract pertinent information, such as the author's name, the year of publication, the country of origin, the study design, and the study period. Additionally, participant characteristics such as sample size, age, and gender distribution were recorded. Clinical variables related to implant therapy were also collected, including the total number of implants placed, implant survival and failure rates, and reported complications. Information regarding follow-up duration was documented to assess the adequacy of outcome evaluation. The extracted data were carefully reviewed and verified to minimize errors and ensure reliability before being included in the qualitative and quantitative analyses.

Quality Assessment

Using criteria pertinent to their research designs, the included studies were assessed for methodological quality and bias risk. A variety of biases were investigated, such as reporting bias, performance bias, selection bias, attrition bias, and detection bias. Researchers assigned each study a risk of bias score between low and high.

Statistical Analysis

The Cochrane Collaboration and the Nordic Cochrane Centre in Copenhagen released Review Manager version 5.4.1 in 2014, and all data analyses were conducted using this version. We calculated the ninety-five percent CI and probability ratio for binary outcomes. We determined the mean difference and 95% confidence interval for continuous outcomes. When there was no sign of study heterogeneity, we used a fixed-effect model with the Mantel-Haenszel method to get the overall impact, estimate with 95% CI. The

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remaining instances made use of a random-effects model that was based on the DerSimonian and Laird approach. We used the Q statistic and the I^3 test to determine the proportion of variability in the effect estimates, which allowed us to evaluate the studies' heterogeneity. A P value of below 0.05 was considered statistically significant.

Results

A total of four [18–21] Studies were selected for the current analysis; the publication year varied from 2015 to 2026 (Fig 1).

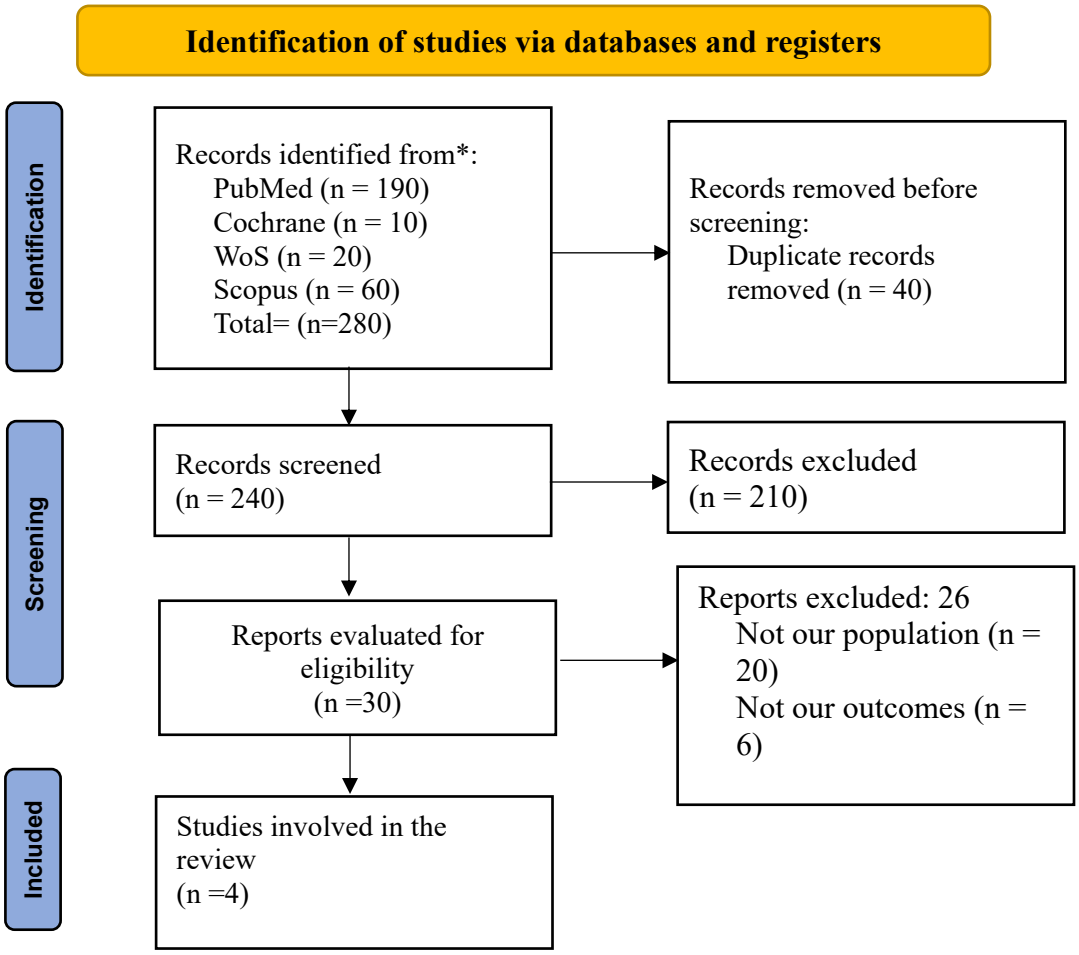

Figure 1. PRISMA flowchart

Table 1. Baseline Characteristics of the Included Studies.

Author, year	year	country	Study period		Study design	Sample Size		
			From	to		Test	Control	Total
Almeslet et al.,2026	2026	Saudi Arabia	2025	2026	RCT	25	28	53
Mertens et al.,2025	2025	USA	2018	2023	A retrospective study	59	32	91
Pompa et al., 2015	2015	Italy	2009	2012	A retrospective study	22	12	34
Sukumaran et al., 2026	2026	India	2025	2026	A retrospective cohort study	98	22	120

The variability of the mean age of participants in the examined groups across the included studies was indicative of the heterogeneous populations, which ranged from pediatric to elderly subjects. (Table 2) displays a generally proportionate representation of males and females in both the test and control groups, as the gender distribution was reported in all included studies.

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Table 2. Patient's characteristics

Author, year	Age (year)						Sex					
	Test			Control			Test			Control		
	Mean	SD	Total	Mean	SD	Total	Male	Female	total	Male	Female	total
Almeslet et al.,2026	69.6	3.7	25	66.1	4.7	28	14	11	25	15	13	28
Mertens et al.,2025	63	11	59	72	10	32	15	24	59	3	29	32
Pompa et al., 2015	51	19	22	50	10	12	10	12	22	2	10	12
Sukumaran et al., 2026	54.1	12.2	98	37.5	12	22	NR	NR	98	NR	NR	22

This table demonstrates a generally lower implant survival rate in the test group (patients exposed to radiotherapy and/or chemotherapy) compared to the control group. Almeslet et al. reported a markedly reduced survival rate in the test group (60%) compared to 100% in controls, indicating a strong negative impact of cancer therapy on implant outcomes. Similarly, Pompa et al. showed a substantial difference (23% vs. 67%), further supporting this trend.

Table3. Implant survival rate (%)

Author, year	Implant survival rate (%)			
	Test		Control	
	(%)	Total	(%)	Total
Almeslet et al.,2026	60	25	100	28
Mertens et al.,2025	8	59	2	32
Pompa et al., 2015	23	22	67	12
Sukumaran et al., 2026	66	98	89	22

There were three studies that reported the implant survival rate, and all of them are useful. A substantial degree of heterogeneity was identified. Due to this, a random-effect model was implemented for the analysis. 0.07 (-0.05 to 0.19) was the combined mean difference and 95% confidence interval. In terms of the implant survival rate (%), the combined result does not indicate a statistically significant distinction between the groups (Z=1.18, P=0.24).

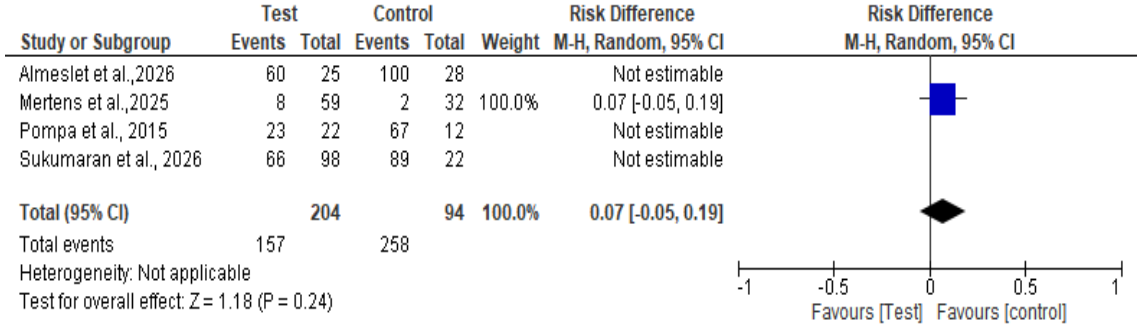

Figure 2. Forest plot of Implant survival rate (%) showed no statistically significant variance between the test and control groups

This table indicates a higher implant failure rate in the test group (patients exposed to radiotherapy and/or chemotherapy) compared to the control group across most included studies. Specifically, Almeslet et al.(18) reported a markedly elevated failure rate in the test group (40%) compared to 0% in controls, suggesting a strong adverse effect of cancer-related therapies on implant outcomes. In Pompa et al.,[19] The failure rate was 10% in the test group versus no reported failures in controls, further supporting the negative impact of these therapies. Meanwhile, Sukumaran et al. demonstrated relatively low failure rates in both groups (34% vs. 11%), indicating that with appropriate clinical management, the risk may be reduced, although it still remains higher than in non-exposed patients.

Three investigations were reported (Implant failure rate (%)), and all are applicable. Heterogeneity was identified to be substantial. Because of this, the analysis was conducted using a fixed-effect model (I^2 = 85%, P=0.001). The 95% CI and combined mean difference were 3.62 (ranging from 0.32 to 41.50). Statistical analysis of the implant failure rate (%) shows no significant distinction between the groups (Z=1.03, P=0.30).

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Table 4. Implant failure rate (%)

Author, year	Implant failure rate (%)			
	Test		Control	
	(%)	Total	(%)	Total
Almeslet et al.,2026	40	25	0	28
Mertens et al.,2025	21	59	2	32
Pompa et al., 2015	10	22	0	12
Sukumaran et al., 2026	34	98	11	22

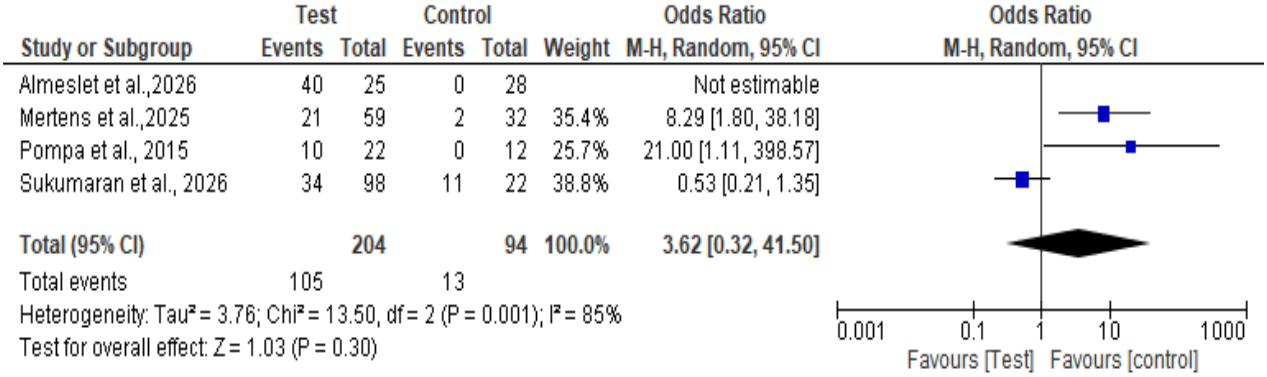

Figure 3. Forest plot of Implant failure rate (%) showed no significant variation between the test and control groups

The follow-up periods reported in this table show variability between studies and between test and control groups, which may influence the interpretation of implant outcomes. Across most studies, the test group had shorter follow-up durations compared to controls. For instance, Almeslet et al.,[18] Mertens et al.,[21] et Pompa et al. [19] All reported follow-up periods of 3 months in the test group versus 6 months in the control group. This discrepancy may lead to underestimation of long-term implant failure in the test group, as some complications, particularly late failures, may not yet have occurred within the shorter observation period.

Table 5. Follow up (month)

Author, year	Follow up (month)			
	Test		Control	
	(n)	Total	(n)	Total
Almeslet et al.,2026	3	25	6	28
Mertens et al.,2025	15	59	28	32
Pompa et al., 2015	3	22	6	12
Sukumaran et al., 2026	3	98	6	22

Three investigations were reported (Follow-up (month)), and all are applicable. Heterogeneity was not identified as significant. Therefore, the analysis was conducted using a fixed-effect model (I^2 = 49%, P=0.11). With a 95% CI ranging from 0.06 to 0.24, the total mean difference was 0.12. When looking at the groups as a whole, there is a significant disparity in terms of (Follow-up (month)) (Z=5.97, P=0.0001).

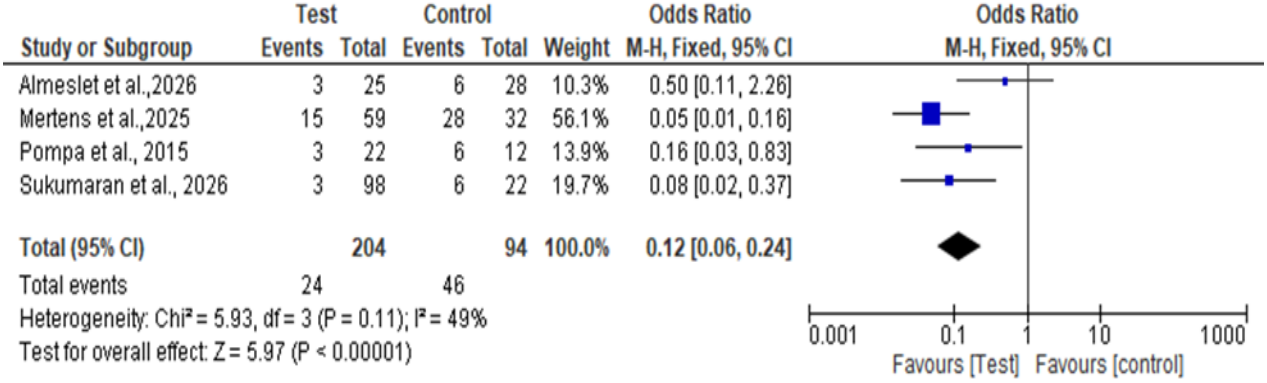

Figure 4. Forest plot of follow-up (month) showed a statistically significant difference between the test and control groups

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Table5. Risk of Bias Assessment

Author, year	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Overall Risk
Almeslet et al.,2026	Unclear (randomization not well described)	High (no blinding reported)	Unclear (no blinded assessment)	Low (complete data reported)	Low (outcomes reported)	Moderate
Mertens et al.,2025	Unclear (small sample, unclear allocation)	High (no blinding)	Unclear	Low (limited but complete data)	Low	Moderate
Pompa et al., 2015	High (retrospective design)	High (no blinding)	Unclear	Low	Unclear (possible selective reporting)	Moderate-High
Sukumaran et al., 2026	Moderate (prospective but non-randomized)	High (no blinding)	Unclear	Low (large sample, adequate follow-up)	Low	Moderate

Discussion

Results from four published studies evaluating the impact of radiation and chemotherapy on dental implant results were pooled in our current meta-analysis and systematic review. There was no statistically significant distinction in implant survival or failure rates between the test and control groups, even though individual studies indicated a trend toward lower implant survival and higher failure rates in patients exposed to cancer therapy. This is because there was a great deal of variation among the studies that were considered, especially when looking at the patient populations, cancer types, radiation doses, implantation timing, and follow-up durations. As shown in the results, variability in follow-up periods, often shorter in the test group, may have led to underreporting of late implant failures, which are especially relevant in irradiated bone. Our results are in line with those of a previous meta-analysis by Chrcanovic et al. [22] that examined the rates of marginal bone loss, postoperative infections, and dental implant survival in patients receiving chemotherapy vs those who were not.

Dental implant implantation did not affect implant failure rates (risk ratio 1.02, 95% CI 0.56-1.85; P = 0.95) in patients whose chemotherapy status was not known. Their results do not suggest whether the placement of dental implants in chemotherapy patients affects implant failure rates. This is due to the scarcity of published studies, the majority of which have low specificity and involve a limited number of cases without a control group. The long-term viability of dental implants in cancer patients treated with chemotherapy was studied by Almeslet et al. [18].

Patients undergoing chemotherapy for systemic cancers who had previously had dental implant placement made up the Test Group, while individuals with no such cancers and who had previously had dental implant therapy (DAT) made up the Control Group. Implant survival rates were 100% in the control group that underwent testing and 60% in the experimental group. Although they did find that chemotherapy did not rule out dental implant therapy entirely, they did note that the patients' implants may not have a chance of survival in the long run. In addition, a seven-year study by Brauner et al. [23] looked at the results of dental implant rehabilitation for patients who had undergone cancer treatment. Out of 42 individuals who received dental implants, 4.5% experienced implant failure [23].

Despite the difficulties of cancer treatments like chemotherapy, implant-supported rehabilitation appears to be an option for post-oncological patients who are well-selected and follow a structured decision-making protocol, with an acceptable implant survival rate. Toneatti et al. [24] conducted a previous systematic review that looked at risk factors in irradiated head and neck cancer patients, the incidence rate of osteoradionecrosis, and the survival of dental implants. We found that implant survival after an average of 37.7 months in non-irradiated persons was 97% (5 percent confidence interval, CI 95.2%, 95 percent CI 98.3%), and after an average of 39.8 months in irradiated patients, it was 91.9% (5 percent CI 87.7 percent, 95 percent CI 95.3%). Although osteoradionecrosis is a rare but serious problem, every oral and maxillofacial surgeon should be prepared for it, and their research shows that irradiated patients have shorter implant lifespans than non-irradiated persons. Improving service quality, reducing risks, and shortening treatment times may necessitate standardized patient selection and treatments. Their findings provide more support for the idea that implant insertion can be a good treatment choice for patients with irradiated head and neck cancer who have impaired oral function and a good prognosis for the long run.

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Conclusion

The results of this systematic review and meta-analysis indicated that dental implant outcomes may be negatively impacted by chemotherapy and radiotherapy, as evidenced by clinically reduced survival rates and higher failure rates in exposed patients. Nevertheless, the aggregated statistical analysis did not reveal a substantial distinction between the exposed and non-exposed groups, which is likely attributable to the heterogeneity of study designs, the small sample sizes, and the variations in follow-up duration of the samples. Despite its detrimental effects on bone vascularity and remodeling capacity, radiotherapy remains a critical risk factor that influences osseointegration, particularly at higher dosages. Consequently, the successful implementation of implant therapy in cancer patients necessitates the cautious selection of the appropriate case, the timing of implant placement, and the consideration of adjunctive measures to facilitate healing. In order to optimize treatment outcomes and establish definitive clinical guidelines in this patient population, additional well-designed, large-scale randomized controlled trials are required.

Conflict of interest. Nil

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