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IMPLANTES DENTÁRIOS EM MAXILARES IRRADIADOS: OSSEOINTEGRAÇÃO, OSTEORRADIONECROSE E TOMADA DE DECISÃO CLÍNICA

DENTAL IMPLANTS IN IRRADIATED JAWS: OSSEOINTEGRATION, OSTEORADIONECROSIS, AND CLINICAL DECISION-MAKING

IMPLANTES DENTALES EN MAXILARES IRRADIADOS: OSTEOINTEGRACIÓN, OSTEORRADIONECROSIS Y TOMA DE DECISIONES CLÍNICAS

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RESUMO

A radioterapia para tumores de cabeça e pescoço pode produzir alterações persistentes nos tecidos orais e maxilofaciais, incluindo comprometimento vascular, fibrose e alterações no metabolismo e remodelação óssea. Essas modificações representam desafios importantes para a reabilitação com implantes dentários, especialmente devido ao potencial impacto sobre a osseointegração e ao risco de osteorradionecrose. Embora a radioterapia tenha sido historicamente considerada um importante fator de risco para a terapia com implantes, evidências recentes demonstram que a reabilitação implantossuportada pode ser viável em pacientes cuidadosamente selecionados. Esta revisão narrativa teve como objetivo examinar as evidências atuais sobre implantes dentários em maxilares irradiados, com ênfase nas alterações biológicas induzidas pela radiação, osseointegração, sobrevida dos implantes, osteorradionecrose, dose de radiação, considerações anatômicas, momento da instalação dos implantes e tomada de decisão clínica. Foi realizada uma busca não sistemática nas bases PubMed/MEDLINE, Scopus e Web of Science, priorizando diretrizes clínicas, revisões sistemáticas, meta-análises, umbrella reviews e estudos

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clínicos relevantes. Os achados indicam que a radioterapia não deve ser considerada uma contraindicação absoluta à terapia com implantes; entretanto, os resultados são heterogêneos e dependem de fatores relacionados ao paciente, à exposição à radiação e ao sítio cirúrgico. Não há, atualmente, um limiar universal de dose de radiação ou período de espera capaz de determinar, isoladamente, a segurança da instalação de implantes. Assim, o planejamento deve considerar a dose recebida pelo sítio específico, as condições locais dos tecidos, a localização anatômica, o estado oncológico e os benefícios funcionais esperados. Conclui-se que a terapia com implantes em maxilares irradiados requer uma abordagem individualizada, sítio-específica e multidisciplinar, na qual os benefícios da reabilitação sejam cuidadosamente equilibrados com os riscos biológicos e cirúrgicos.

Palavras-chave: Implantes dentários; Radioterapia; Osseointegração; Osteorradionecrose; Neoplasias de cabeça e pescoço.

ABSTRACT

Radiotherapy for head and neck tumors may produce persistent changes in oral and maxillofacial tissues, including vascular impairment, fibrosis, and alterations in bone metabolism and remodeling. These changes represent important challenges for dental implant rehabilitation, particularly because of their potential effects on osseointegration and the risk of osteoradionecrosis. Although radiotherapy has historically been considered a major risk factor for implant therapy, recent evidence indicates that implant-supported rehabilitation may be feasible in carefully selected patients. Quantitative syntheses indicate that implant survival is generally lower in irradiated than non-irradiated bone; one meta-analysis reported 91.9% survival after radiotherapy versus 97% in non-irradiated patients, while osteoradionecrosis occurred in approximately 3% of irradiated patients. This narrative review aimed to examine the current evidence regarding dental implants in irradiated jaws, with emphasis on radiation-induced biological changes, osseointegration, implant survival, osteoradionecrosis, radiation dose, anatomical considerations, timing of implant placement, and clinical decision-making. A non-systematic literature search was conducted in PubMed/MEDLINE, Scopus, and Web of Science, prioritizing clinical guidelines, systematic reviews, meta-analyses, umbrella reviews, and relevant clinical studies. The findings indicate that radiotherapy should not be considered an absolute contraindication to implant therapy; however, clinical outcomes are heterogeneous and depend on patient-related factors, radiation exposure, and characteristics of the surgical site. Currently, no universally applicable radiation-dose threshold or waiting period can independently determine the safety of implant placement. Therefore, treatment planning should consider the dose delivered to the specific implant site, local tissue conditions, anatomical location, oncological status, and the expected functional benefits of rehabilitation. In conclusion, implant therapy in irradiated jaws requires an individualized, site-specific, and multidisciplinary approach in which the benefits of rehabilitation are carefully balanced against biological and surgical risks.

Keywords: Dental Implants; Radiotherapy; Osseointegration; Osteoradionecrosis; Head and Neck Neoplasms.

RESUMEN

La radioterapia para tumores de cabeza y cuello puede producir alteraciones persistentes en los

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tejidos orales y maxilofaciales, incluyendo compromiso vascular, fibrosis y cambios en el metabolismo y la remodelación ósea. Estas modificaciones representan desafíos importantes para la rehabilitación con implantes dentales, especialmente debido a su posible impacto sobre la osteointegración y al riesgo de osteorradionecrosis. Aunque la radioterapia ha sido históricamente considerada un importante factor de riesgo para la terapia con implantes, la evidencia reciente demuestra que la rehabilitación implantosoportada puede ser viable en pacientes cuidadosamente seleccionados. Esta revisión narrativa tuvo como objetivo examinar la evidencia actual sobre implantes dentales en maxilares irradiados, con énfasis en las alteraciones biológicas inducidas por la radiación, la osteointegración, la supervivencia de los implantes, la osteorradionecrosis, la dosis de radiación, las consideraciones anatómicas, el momento de la colocación de los implantes y la toma de decisiones clínicas. Se realizó una búsqueda no sistemática en las bases de datos PubMed/MEDLINE, Scopus y Web of Science, priorizando guías clínicas, revisiones sistemáticas, metaanálisis, revisiones paraguas (*umbrella reviews*) y estudios clínicos relevantes. Los hallazgos indican que la radioterapia no debe considerarse una contraindicación absoluta para la terapia con implantes; sin embargo, los resultados son heterogéneos y dependen de factores relacionados con el paciente, la exposición a la radiación y el sitio quirúrgico. Actualmente, no existe un umbral universal de dosis de radiación ni un período de espera capaz de determinar, por sí solo, la seguridad de la colocación de implantes. Por lo tanto, la planificación debe considerar la dosis recibida por el sitio específico, las condiciones locales de los tejidos, la localización anatómica, el estado oncológico y los beneficios funcionales esperados. Se concluye que la terapia con implantes en maxilares irradiados requiere un enfoque individualizado, específico para el sitio y multidisciplinario, en el que los beneficios de la rehabilitación se equilibren cuidadosamente con los riesgos biológicos y quirúrgicos.

Palabras clave: Implantes dentales; Radioterapia; Osteointegración; Osteorradionecrosis; Neoplasias de cabeza y cuello.

INTRODUCTION

Head and neck cancer remains a major global health challenge, and radiotherapy plays a central role in the treatment of many malignant tumors affecting this anatomical region. Although radiotherapy contributes substantially to tumor control and patient survival, ionizing radiation may also produce persistent changes

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in oral and maxillofacial tissues. These effects include salivary gland dysfunction, mucosal alterations, vascular damage, fibrosis, and changes in bone remodeling, which may compromise oral rehabilitation and long-term quality of life (PETERSON et al., 2024; CHAMBRONE et al., 2013).

Among the late complications associated with irradiation of the jaws, osteoradionecrosis represents one of the most clinically significant concerns. Radiation-induced vascular and cellular alterations may impair tissue repair and reduce the capacity of irradiated bone to respond to trauma or infection. Consequently, invasive dental procedures performed in irradiated bone require careful risk assessment, particularly when surgical trauma involves the mandible or other areas exposed to substantial radiation doses (PETERSON et al., 2024; GORJIZAD et al., 2025).

Dental implants may offer important functional and psychosocial benefits to patients who have undergone treatment for head and neck cancer. Implant-supported rehabilitation can improve prosthesis retention and stability, contributing to oral function and quality of life. However, implant placement in irradiated jaws remains a complex clinical decision because osseointegration depends on biological processes that may be altered by radiation-induced changes in bone vascularity, cellular activity, and remodeling capacity (CHAMBRONE et al., 2013; CHRCANOVIC; ALBREKTSSON; WENNERBERG, 2016).

The available evidence suggests that implant rehabilitation may be feasible in selected irradiated patients; however, clinical outcomes remain heterogeneous and appear to be influenced by radiation exposure, anatomical location, timing of implant placement, bone quality, reconstructive procedures, and patient-related variables (ZARZAR et al., 2024; KENDE; RANGANATH; LANDGE, 2022; PACHECO et al., 2025).

The relationship between radiation dose and implant outcomes is particularly relevant. The biological effects of radiotherapy are not uniformly distributed throughout the maxillofacial region, and the dose effectively delivered to the future implant site may be more clinically relevant than the total prescribed dose for the primary tumor. In addition, the mandible and maxilla may present different patterns of radiation exposure, vascularity, and susceptibility to complications. Therefore, the simple classification of a patient as having a history of radiotherapy may be insufficient for estimating the risk associated with implant surgery (CHAMBRONE et al., 2013; TONEATTI et al., 2021).

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Timing also represents a major challenge. Implant placement may be considered before radiotherapy, after completion of oncological treatment, or, in some circumstances, in patients with previously osseointegrated implants who subsequently require irradiation. Each clinical scenario presents distinct biological and oncological considerations. Although implant placement before radiotherapy may allow osseointegration under non-irradiated conditions, it may not always be feasible and should never interfere with timely cancer treatment. Conversely, implant placement after radiotherapy raises concerns regarding impaired healing and the potential development of osteoradionecrosis, while the management of pre-existing implants in patients scheduled for radiotherapy remains an area of growing clinical interest (CLAUDY et al., 2015; PRADO-PEÑA et al., 2024).

The prevention of osteoradionecrosis is therefore an essential component of implant-related decision-making in irradiated patients. Contemporary recommendations emphasize individualized risk assessment and careful consideration of radiation exposure, surgical trauma, oral infection, and patient-specific factors. Adjunctive approaches, including hyperbaric oxygen therapy, have also been proposed; however, their routine use for implant placement remains controversial because the available evidence has not consistently demonstrated a clear clinical benefit (PETERSON et al., 2024; BENITES CONDEZO et al., 2021).

Despite the growing body of literature, important uncertainties remain regarding the optimal selection of patients, the safest timing for implant placement, the influence of radiation dose at the implant site, and the strategies that may reduce the risk of implant failure and osteoradionecrosis. Furthermore, the available evidence includes heterogeneous populations, radiation protocols, anatomical sites, and rehabilitation approaches, limiting the establishment of universal recommendations (GORJIZAD et al., 2025; ZARZAR et al., 2024; PACHECO et al., 2025).

Therefore, this narrative review aims to examine the current evidence regarding dental implants in irradiated jaws, with particular emphasis on radiation-induced biological changes, osseointegration, implant survival, osteoradionecrosis, timing of implant placement, and clinical decision-making.

METHODS

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This study was conducted as a narrative review of the literature to provide a clinically oriented overview of dental implant therapy in patients with irradiated jaws. The review focused on the relationship between head and neck radiotherapy and implant osseointegration, implant survival, osteoradionecrosis, radiation dose, anatomical site, timing of implant placement, and clinical decision-making.

A non-systematic search of the literature was conducted in PubMed/MEDLINE, Scopus, and Web of Science, with the final search/update considered through March 2026. The search combined terms related to dental implants and radiotherapy, including dental implants, osseointegration, radiotherapy, head and neck cancer, irradiated jaws, osteoradionecrosis, implant survival, radiation dose, and timing after radiotherapy. Reference lists of relevant reviews and clinical guidelines were also examined for additional clinically relevant publications. No language restriction was applied when an English-language record or adequate bibliographic information was available for interpretation.

Priority was given to clinical guidelines, systematic reviews, meta-analyses, umbrella reviews, prospective and retrospective clinical studies, and recent publications addressing implant outcomes in irradiated patients. Seminal studies were retained when relevant to the biological effects of radiation or the historical development of implant rehabilitation. Publications were selected when they addressed implant survival or failure, osseointegration, osteoradionecrosis, radiation dose, anatomical site, timing of implant placement, pre-existing implants exposed to radiotherapy, or adjunctive strategies. Because this was a narrative review, selection was based on clinical relevance and conceptual contribution rather than a prespecified systematic-review eligibility algorithm.

The literature was analyzed according to the following clinical domains: radiation-induced changes in bone and oral tissues; osseointegration and implant survival; osteoradionecrosis and implant-related risk; radiation dose and anatomical considerations; timing of implant placement; management of pre-existing implants; and adjunctive or preventive strategies.

Given the heterogeneity of the available evidence regarding patient populations, radiation protocols, anatomical sites, implant characteristics, and clinical outcomes, no formal meta-analysis was performed. The findings were therefore narratively synthesized to support clinically relevant and individualized decision-making.

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RADIOTHERAPY-INDUCED CHANGES IN BONE AND ORAL TISSUES

Radiotherapy produces biological effects that extend beyond tumor control and may persist long after the completion of oncological treatment. When the maxilla or mandible is included within the radiation field, ionizing radiation can induce progressive alterations in vascularity, cellular activity, and tissue remodeling. These changes are particularly relevant to dental implant therapy because successful osseointegration depends on an adequate biological response involving bone formation, vascular support, and continuous remodeling (CHAMBRONE et al., 2013; PETERSON et al., 2024).

Historically, irradiated bone has been described as hypovascular, hypocellular, and hypoxic. Although contemporary understanding of radiation-induced tissue injury has evolved beyond this classical model, vascular damage and progressive fibrosis remain central components of late radiation injury. Endothelial dysfunction, reduced microvascular density, fibrosis, and alterations in osteogenic cell activity may collectively compromise the capacity of irradiated tissues to respond to surgical trauma and infection (PETERSON et al., 2024).

The biological consequences of radiation may also affect bone remodeling and repair. Osteoblast activity and bone turnover may be altered, while progressive fibrosis can reduce tissue elasticity and vascular adaptability. Consequently, the biological environment surrounding an implant may differ substantially from that of non-irradiated bone, particularly in regions exposed to higher radiation doses (CHAMBRONE et al., 2013; TONEATTI et al., 2021).

Radiation-related injury is not uniformly distributed throughout the oral and maxillofacial region. The extent of tissue damage depends on several factors, including total radiation dose, fractionation, radiation technique, anatomical location, and the volume of bone exposed. Therefore, knowledge of the patient's history of radiotherapy alone may be insufficient for estimating surgical risk. Whenever possible, the radiation dose effectively delivered to the proposed implant site should be considered during treatment planning (GORJIZAD et al., 2025; ZARZAR et al., 2024).

In addition to bone alterations, radiotherapy may produce clinically significant changes in the oral environment. Xerostomia, reduced salivary flow, mucosal injury, fibrosis, and increased susceptibility to dental disease may indirectly influence implant rehabilitation. Reduced saliva may contribute to biofilm accumulation and increase the risk of dental caries and periodontal disease, while fibrosis and tissue

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changes may complicate oral hygiene, prosthetic rehabilitation, and surgical access (PETERSON et al., 2024).

Importantly, radiation-induced alterations do not necessarily preclude successful implant osseointegration. Rather, they may reduce tissue resilience and healing capacity. The clinical consequences of these alterations vary considerably between patients and depend on the interaction between radiation exposure, anatomical site, surgical trauma, systemic health, and local oral conditions (CHRCANOVIC; ALBREKTSSON; WENNERBERG, 2016; PACHECO et al., 2025).

Thus, the presence of irradiated bone should not be interpreted as a homogeneous clinical condition. Instead, implant-related risk should be understood as a spectrum influenced by the characteristics of radiation exposure and the biological condition of the specific site selected for rehabilitation.

OSSEOINTEGRATION AND IMPLANT SURVIVAL IN IRRADIATED JAWS

Successful dental implant therapy depends on the establishment and long-term maintenance of osseointegration, a biological process influenced by bone quality, vascular supply, cellular activity, mechanical stability, and local healing conditions. Because radiotherapy may alter several of these factors, implant rehabilitation in irradiated jaws has historically been considered less predictable than treatment performed in non-irradiated bone (CHAMBRONE et al., 2013; CHRCANOVIC; ALBREKTSSON; WENNERBERG, 2016).

Nevertheless, the available evidence demonstrates that successful osseointegration remains achievable in irradiated patients. Systematic reviews and meta-analyses have reported generally favorable implant survival rates, although outcomes tend to be less favorable than those observed in non-irradiated populations. Importantly, the reported survival rates vary substantially among studies, reflecting differences in radiation exposure, anatomical site, timing of implant placement, follow-up duration, and patient characteristics (KENDE; RANGANATH; LANDGE, 2022; SHOKOUHI; CERAJEWSKA, 2022; ZARZAR et al., 2024; PACHECO et al., 2025).

Toneatti et al. (2021) reported implant survival of 91.9% after radiotherapy compared with 97% in non-irradiated patients, with mean follow-up of approximately 40 months, and an osteoradionecrosis incidence of about 3% among irradiated patients. Schiegnitz et al. (2022) reported an overall implant survival of 87.8% across the included studies and found a significantly higher risk of implant failure in irradiated bone than in non-irradiated bone (OR 1.97, 95% CI 1.63–2.37). These estimates should be interpreted as population-level

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summaries rather than as individual eligibility thresholds. (TONEATTI et al., 2021; SCHIEGNITZ et al., 2022)

This heterogeneity is particularly important when interpreting the relationship between radiotherapy and implant failure. The presence of previous irradiation alone does not appear to determine the outcome of every implant. Instead, implant survival is likely influenced by the interaction between radiation-related tissue injury and additional clinical factors, including the dose delivered to the implant site, bone volume and quality, surgical trauma, oral hygiene, smoking, systemic conditions, and the need for reconstructive procedures (CHAMBRONE et al., 2013; TONEATTI et al., 2021).

The anatomical site also appears to play a relevant role. The mandible and maxilla differ substantially in bone density, vascularization, and patterns of radiation exposure. Although some studies have suggested differences in implant survival between these regions, the interpretation of anatomical risk is complicated by the fact that mandibular bone may receive higher radiation doses in certain head and neck cancer treatments. Therefore, the apparent effect of anatomical location cannot always be separated from the effect of radiation exposure itself (CHRCANOVIC; ALBREKTSSON; WENNERBERG, 2016; CHAMBRONE et al., 2013).

A further challenge is that implant survival does not fully capture the safety of rehabilitation in irradiated bone. An implant may remain clinically stable while the surrounding tissues remain biologically vulnerable to trauma, infection, or progressive radiation-related injury. Conversely, implant failure does not necessarily imply the development of osteoradionecrosis. These outcomes should therefore be considered separately when evaluating the risks associated with implant therapy in irradiated patients (GORJIZAD et al., 2025; TONEATTI et al., 2021).

The most recent evidence reinforces this nuanced interpretation. Although irradiation is associated with an increased risk of implant failure at the population level, successful rehabilitation is frequently achievable in appropriately selected patients. Thus, previous irradiation should be regarded as an important risk modifier requiring individualized assessment rather than as an isolated determinant of treatment outcome (GORJIZAD et al., 2025; ZARZAR et al., 2024; PACHECO et al., 2025).

Consequently, the central clinical question is not simply whether an implant can osseointegrate in irradiated bone, but under which biological and clinical

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conditions implant rehabilitation can be performed with an acceptable balance between functional benefit and treatment-related risk.

RADIATION DOSE AND ANATOMICAL CONSIDERATIONS

Radiation dose is one of the most relevant variables in the assessment of implant therapy in irradiated patients. However, the total prescribed dose for the primary tumor does not necessarily correspond to the dose received by the specific bone region selected for implant placement. Modern radiotherapy techniques can produce substantial dose variation within the maxillofacial complex. Therefore, whenever feasible, treatment planning should consider the actual radiation dose delivered to the proposed implant site, ideally through review of the radiotherapy treatment plan in collaboration with the oncology and radiation oncology teams (PETERSON et al., 2024; GORJIZAD et al., 2025).

Higher radiation exposure remains clinically relevant, particularly when substantial doses are delivered to the bone intended for implant placement, even though no single cutoff can independently determine eligibility. The risk of implant failure and the risk of osteoradionecrosis should not be assumed to follow identical anatomical patterns: the mandible has greater historical relevance for osteoradionecrosis, whereas some implant-survival syntheses have reported less favorable outcomes in the maxilla. These findings reinforce the need to interpret anatomy together with site-specific dosimetry rather than as isolated predictors.

Higher radiation exposure is generally associated with greater biological impairment, including vascular injury, fibrosis, and reduced bone remodeling capacity. Nevertheless, the literature does not support a universally applicable radiation-dose threshold above which implant placement should automatically be considered contraindicated. Differences in study design, radiation protocols, anatomical sites, and outcome definitions make it difficult to establish a single cutoff value for clinical decision-making (ZARZAR et al., 2024; TONEATTI et al., 2021).

For this reason, dose should be interpreted as part of a broader risk assessment rather than as an isolated determinant. The distribution of radiation within the jaws, the volume of irradiated bone, the proximity of the implant site to the tumor bed, and the presence of other local tissue changes may be as important as the nominal radiation dose. This approach is particularly relevant in contemporary oncology, in which highly conformal radiation techniques may spare portions of the maxillofacial skeleton while exposing others to substantial doses (PETERSON et al., 2024).

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The mandible has traditionally received particular attention because osteoradionecrosis occurs more frequently in this bone. Its relatively dense cortical structure and vascular characteristics may contribute to greater vulnerability when compared with the maxilla. In addition, depending on tumor location, mandibular regions may receive substantial radiation exposure. However, the distinction between mandibular and maxillary risk should not be interpreted as purely anatomical, since differences in radiation dose distribution may strongly influence the observed outcomes (CHAMBRONE et al., 2013; TONEATTI et al., 2021).

Anatomical considerations also extend beyond the distinction between the mandible and maxilla. Posterior and anterior regions may receive different radiation doses, and reconstructed areas may present biological characteristics distinct from those of native bone. Consequently, implant planning should ideally incorporate detailed imaging, assessment of bone quality and volume, and review of the radiation field whenever this information is available (GORJIZAD et al., 2025; ZARZAR et al., 2024).

Therefore, the clinically relevant question is not simply how much radiation the patient received, but how much radiation was delivered to the specific bone intended for implant placement and what biological consequences are present at that site.

TIMING OF IMPLANT PLACEMENT: BEFORE OR AFTER RADIOTHERAPY?

The timing of implant placement represents one of the most challenging aspects of oral rehabilitation in patients treated with head and neck radiotherapy. Implant therapy may be considered before oncological treatment, after completion of radiotherapy, or in patients with previously placed implants who subsequently undergo irradiation. Each scenario involves distinct advantages, limitations, and potential risks.

Implant placement before radiotherapy theoretically allows surgical healing and initial osseointegration to occur in non-irradiated bone. This approach may therefore reduce some of the biological concerns associated with implant surgery performed after radiation exposure. However, pre-radiotherapy implant placement is not feasible in all patients and should never delay the initiation of definitive cancer treatment. The urgency of oncological therapy, tumor characteristics, the expected radiation field, and the patient's overall condition must remain the primary

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determinants of treatment sequencing (CLAUDY et al., 2015; CHAMBRONE et al., 2013).

Importantly, timing evidence should be interpreted as an association rather than a universal rule. Claudy et al. reported a pooled relative risk of 1.34 (95% CI 1.01–1.79) for implant failure when implants were placed between 6 and 12 months after radiotherapy compared with placement after 12 months. This finding does not establish 12 months as a universally safe interval and may be influenced by the observational nature and heterogeneity of the underlying studies.

When implants are considered after radiotherapy, the clinician faces a biologically altered environment in which healing capacity and bone remodeling may be compromised. Nevertheless, delayed implant placement can be successful in carefully selected patients. The available evidence does not support a universally applicable waiting period that guarantees predictable osseointegration in every irradiated patient. Instead, the interval between radiotherapy and implant placement should be interpreted together with the radiation dose at the proposed site, the extent of local tissue injury, oncological status, and the anticipated benefits of rehabilitation (CLAUDY et al., 2015; GORJIZAD et al., 2025).

A longer interval after radiotherapy may allow recovery from acute treatment-related toxicity and facilitate a more comprehensive assessment of oncological control and oral rehabilitation needs. However, delayed treatment does not necessarily eliminate radiation-induced biological changes, which may persist for years. Therefore, the assumption that implant placement becomes completely safe after a fixed period should be avoided (TONEATTI et al., 2021; ZARZAR et al., 2024).

Timing decisions should also account for the patient's expected prognosis and functional needs. In some individuals, extensive delays may prolong functional impairment and compromise quality of life, whereas in others, a more conservative approach may be justified because of substantial local risk or uncertainty regarding disease control. Implant timing should therefore be individualized rather than based exclusively on arbitrary chronological thresholds.

Overall, the optimal timing of implant placement should be determined through a balance between oncological priorities, local tissue conditions, radiation exposure, and the expected functional benefit of rehabilitation.

PRE-EXISTING DENTAL IMPLANTS AND SUBSEQUENT RADIOTHERAPY

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An increasingly relevant clinical scenario involves patients who already have osseointegrated dental implants and subsequently require radiotherapy for head and neck cancer. This situation differs substantially from the placement of a new implant in previously irradiated bone because surgical trauma associated with implant insertion is absent. Nevertheless, the presence of implants within the radiation field raises concerns regarding changes in peri-implant tissues and the potential development of osteoradionecrosis.

Current evidence remains limited, and the available literature consists predominantly of observational studies and case-based reports. The recent scoping review by Prado-Peña et al. (2024) highlighted the scarcity of robust evidence regarding the management and prognosis of previously osseointegrated implants exposed to subsequent radiotherapy.

The presence of a stable implant before radiotherapy should not automatically lead to its removal. Unnecessary surgical manipulation may itself represent an additional source of trauma to tissues that will subsequently be exposed to radiation. Instead, treatment planning should consider implant stability, the presence of peri-implant inflammation or infection, the radiation dose expected at the implant site, and the overall oral condition of the patient (PRADO-PEÑA et al., 2024).

Close oral monitoring before, during, and after radiotherapy is particularly important. Peri-implant inflammation and local infection should be controlled whenever possible, and patients should receive individualized guidance regarding oral hygiene and maintenance. Communication between the dental and radiation oncology teams may also help clarify whether the implant lies within a high-dose region and whether specific precautions are warranted.

Thus, pre-existing implants should be regarded as an individual clinical condition requiring monitoring and risk assessment rather than as an automatic indication for removal or a definitive contraindication to radiotherapy.

CLINICAL DECISION-MAKING AND ADJUNCTIVE STRATEGIES

Clinical decision-making regarding implant therapy in irradiated jaws should integrate oncological, anatomical, biological, and patient-related factors to determine the appropriateness of rehabilitation in each individual case. The available evidence supports a more individualized approach in which the potential benefits of

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rehabilitation are weighed against the biological and surgical risks associated with the specific clinical situation (PETERSON et al., 2024; GORJIZAD et al., 2025).

A comprehensive assessment should begin with the patient's oncological history. Relevant information includes the primary tumor site, radiation technique, total prescribed dose, radiation field, date of treatment completion, and, whenever possible, the estimated dose delivered to the proposed implant site. Collaboration with radiation oncologists may be particularly valuable when detailed treatment planning information is available.

Local evaluation is equally important. Bone volume and quality, mucosal condition, salivary function, periodontal and peri-implant health, oral hygiene, and the presence of infection should be carefully assessed. Advanced imaging may assist in evaluating the anatomical characteristics of the proposed implant site, although imaging findings alone cannot fully determine the biological capacity for healing.

The indication for implant therapy should also be evaluated according to its expected functional benefit. Implant rehabilitation may substantially improve prosthesis retention, mastication, speech, and quality of life in selected patients. However, elective surgical intervention may offer limited benefit in situations involving poor oncological prognosis, uncontrolled local disease, severe tissue injury, or substantial risk of postoperative complications. In these circumstances, non-surgical or less invasive rehabilitation alternatives should also be considered.

The prevention of osteoradionecrosis requires particular attention to the control of oral infection and minimization of unnecessary surgical trauma. Contemporary clinical guidelines emphasize preventive dental care and individualized management rather than universal application of a single preventive protocol (PETERSON et al., 2024).

Hyperbaric oxygen therapy has historically been proposed as an adjunctive strategy for surgical procedures in irradiated jaws. For implant survival, systematic review and meta-analytic evidence has not demonstrated a consistent benefit of routine hyperbaric oxygen therapy. For osteoradionecrosis prevention or management, routine prophylactic use should likewise not be presented as a universal standard. Selected patients may nevertheless require individualized multidisciplinary assessment according to local tissue risk, radiation exposure, planned surgery, and the clinical context.

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The surgical approach should also aim to minimize trauma and achieve adequate primary stability without excessive manipulation of the surrounding bone. At the same time, clinicians should avoid interpreting technical success during surgery as a guarantee of long-term safety. Implant stability at placement does not eliminate the possibility of delayed complications associated with radiation-induced tissue vulnerability.

Long-term follow-up is therefore an essential component of treatment rather than merely a postoperative formality. Clinical surveillance should include assessment of implant stability, peri-implant tissue health, oral hygiene, prosthetic function, and signs of infection or tissue breakdown. Because radiation-related complications may occur long after completion of cancer treatment, patients should ideally remain under periodic dental follow-up.

Ultimately, implant therapy in irradiated jaws should be based on individualized clinical judgment, multidisciplinary communication, and careful consideration of whether the expected functional benefit justifies the biological and surgical risks in each patient.

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TABLE 1. Evidence-informed clinical considerations for dental implant therapy in irradiated jaws

Clinical domain	Key considerations	Clinical implications	Main references
Radiation exposure	Total prescribed dose does not necessarily represent the dose received at the implant site	Whenever possible, assess the radiation dose and field affecting the specific bone selected for implant placement	Peterson et al., 2024; Gorjizad et al., 2025
Bone biology	Radiation may cause vascular injury, fibrosis, and altered bone remodeling	Healing capacity may be reduced, requiring careful patient and site selection	Chambrone et al., 2013; Peterson et al., 2024
Osseointegration	Successful osseointegration remains possible in irradiated bone	Radiotherapy should not be considered an absolute contraindication to implant therapy	Zarzar et al., 2024; Pacheco et al., 2025
Implant survival	Survival rates may be lower than in non-irradiated populations, although outcomes are heterogeneous	Evaluate radiation exposure together with patient- and site-specific factors	Gorjizad et al., 2025; Toneatti et al., 2021
Osteoradionecrosis	ORN is less frequent than implant failure but represents a potentially severe complication	Minimize surgical trauma, control infection, and perform site-specific, individualized risk assessment	Peterson et al., 2024; Gorjizad et al., 2025
Anatomical site	Radiation distribution and bone characteristics vary; implant survival and ORN may show different anatomical patterns	Assess the specific jaw and implant site together with local radiation exposure	Chambrone et al., 2013; Toneatti et al., 2021

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Clinical domain	Key considerations	Clinical implications	Main references
Timing	No universally safe waiting period after radiotherapy has been established	Timing should consider oncological priorities, local tissue conditions, and functional needs	Claudy et al., 2015; Zarzar et al., 2024
Pre-radiotherapy implants	Implants may achieve initial healing before radiation exposure, but placement must not delay cancer treatment	Oncological treatment remains the priority	Chambrone et al., 2013; Claudy et al., 2015
Pre-existing implants	Evidence regarding implants subsequently exposed to radiotherapy remains limited	Stable implants should not be removed automatically; monitoring and infection control are essential	Prado-Peña et al., 2024
Hyperbaric oxygen therapy	Evidence does not consistently demonstrate improved implant survival	Routine use cannot currently be recommended for all patients	Benites Condezo et al., 2021; Peterson et al., 2024
Long-term follow-up	Radiation-related complications may occur years after treatment	Continuous clinical surveillance is essential	Peterson et al., 2024; Gorjizad et al., 2025

DISCUSSION

Dental implant rehabilitation in patients with irradiated jaws remains one of the most complex areas of oral rehabilitation because the available evidence supports two apparently conflicting conclusions. On the one hand, successful osseointegration and long-term implant survival are clearly achievable in selected irradiated patients.

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On the other hand, previous radiotherapy is associated with a biologically compromised environment and a potentially increased risk of implant failure and osteoradionecrosis. Rather than representing a contradiction, these findings highlight the heterogeneity of irradiated patients and reinforce the limitations of treating radiotherapy history as a single, uniform risk factor (GORJIZAD et al., 2025; ZARZAR et al., 2024; PACHECO et al., 2025).

One of the main clinical implications of this evidence is that treatment decisions should not be based solely on a history of radiotherapy. Although implant rehabilitation may provide substantial functional benefits, favorable survival rates should not be interpreted as evidence of uniform safety. The risk of complications, including osteoradionecrosis, must be weighed against the expected benefit of rehabilitation in each individual patient (PETERSON et al., 2024; TONEATTI et al., 2021).

The interpretation of implant survival data also requires caution. Implant survival is an important outcome, but it does not fully represent treatment safety. A clinically stable implant does not necessarily indicate that the surrounding tissues have recovered their normal biological capacity, particularly when substantial radiation exposure has occurred. Similarly, implant failure and osteoradionecrosis represent distinct outcomes and should not be treated as interchangeable complications. Future studies should therefore evaluate implant survival together with peri-implant health, patient-reported outcomes, surgical complications, and the occurrence of radiation-related tissue injury (GORJIZAD et al., 2025; TONEATTI et al., 2021).

Radiation dose remains another area in which the literature has not yet produced universally applicable clinical thresholds. Although higher radiation exposure is generally associated with greater tissue injury, the use of a single total-dose cutoff may oversimplify a highly heterogeneous clinical situation. The dose delivered to the specific implant site may be more relevant than the total dose prescribed for the primary tumor. This perspective supports closer collaboration between dentists and radiation oncologists, particularly when radiotherapy planning data are available. Site-specific dosimetric information may allow clinicians to move from a generalized classification of the patient as “irradiated” toward a more individualized assessment of local surgical risk (PETERSON et al., 2024; ZARZAR et al., 2024).

Timing remains an unresolved clinical issue because chronological intervals alone do not adequately reflect biological recovery. Rather than applying a fixed

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waiting period, clinicians should integrate oncological status, site-specific radiation exposure, local tissue conditions, and functional needs when determining the most appropriate moment for rehabilitation (CLAUDY et al., 2015; GORJIZAD et al., 2025).

The possibility of implant placement before radiotherapy introduces an additional strategic consideration. From a biological perspective, allowing initial healing and osseointegration before radiation exposure may be advantageous. However, this potential benefit should never compete with the urgency of definitive cancer treatment. The oncological timeline must remain the primary determinant of treatment sequencing, and implant placement should only be considered when it can be integrated safely into the overall therapeutic plan. This principle is particularly important because unnecessary delays in cancer treatment may have consequences that far exceed the potential benefits of early oral rehabilitation (CHAMBRONE et al., 2013; CLAUDY et al., 2015).

An emerging and clinically distinct issue concerns patients with pre-existing osseointegrated implants who subsequently undergo head and neck radiotherapy. In this scenario, the absence of new surgical trauma differentiates these patients from those receiving implants after radiation exposure. Current evidence remains limited, but available data do not support the routine removal of stable implants solely because radiotherapy is planned. Instead, careful control of peri-implant disease, maintenance of oral hygiene, and multidisciplinary assessment appear more rational than automatic surgical intervention, which could itself introduce unnecessary trauma (PRADO-PEÑA et al., 2024).

The role of adjunctive strategies also deserves a cautious interpretation. Hyperbaric oxygen therapy has historically been incorporated into the management of irradiated jaws based on its potential to improve tissue oxygenation and healing. However, contemporary evidence has not consistently demonstrated that its routine use improves implant survival. This does not necessarily mean that hyperbaric oxygen therapy has no role in selected situations, but it argues against its indiscriminate application as a universal prerequisite for implant surgery in irradiated patients (BENITES CONDEZO et al., 2021; PETERSON et al., 2024).

Perhaps the most consistent message emerging from the literature is the importance of individualized clinical decision-making. Factors such as tumor status, radiation field, dose at the implant site, anatomical location, bone condition, salivary function, oral hygiene, smoking, systemic health, and the expected functional benefit of rehabilitation should be considered together. No single variable appears sufficient to determine whether implant therapy is appropriate. This reinforces the need for

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multidisciplinary communication involving the dentist, prosthodontist or implant specialist, surgeon when necessary, and oncology and radiation oncology teams.

The expected benefit of rehabilitation should also occupy a central position in treatment planning. Implant therapy should not be pursued solely because osseointegration is technically possible. In some patients, implant-supported rehabilitation may substantially improve mastication, speech, prosthesis stability, and quality of life. In others, particularly those with limited prognosis, uncontrolled disease, severe local tissue damage, or a high surgical risk, non-surgical alternatives may provide a more appropriate balance between benefit and burden. Thus, the indication for implant therapy should be patient-centered rather than procedure-centered.

Several limitations should also be acknowledged. In addition to the heterogeneity of the available primary studies, this narrative review may be affected by selection bias because publication selection was based on clinical relevance rather than a systematic screening process. No formal risk-of-bias assessment was performed. The evidence base also contains overlapping umbrella reviews and systematic reviews, which may draw on some of the same primary studies. Furthermore, differences in patient populations, cancer diagnoses, radiation techniques and doses, anatomical sites, implant characteristics, surgical protocols, outcome definitions, and follow-up periods limit direct comparisons. Osteoradionecrosis remains an uncommon outcome in many cohorts, which also limits statistical precision.

Future research should prioritize prospective multicenter studies incorporating detailed dosimetric information for individual implant sites. Standardized reporting of radiation exposure, anatomical location, surgical protocols, implant outcomes, and osteoradionecrosis would substantially improve the comparability of future studies. Equally important, research should move beyond implant survival alone and incorporate functional outcomes, quality of life, peri-implant health, and patient-reported measures.

Overall, the available evidence supports a transition from a categorical to an individualized approach. Irradiated jaws should not automatically be considered unsuitable for implant rehabilitation; however, successful treatment depends on recognizing that radiation exposure creates a variable and site-specific biological risk. The most appropriate clinical strategy is therefore not to ask whether dental implants are universally safe after radiotherapy, but whether implant rehabilitation is justified, feasible, and acceptably safe for a particular patient and a particular anatomical site.

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CONCLUSION

Dental implant rehabilitation may be feasible in carefully selected patients with irradiated jaws, but previous radiotherapy remains an important modifier of implant survival and local tissue risk. Implant failure and osteoradionecrosis should be considered distinct outcomes, and neither the total prescribed radiation dose nor a fixed chronological interval can independently determine implant eligibility. Whenever possible, treatment planning should incorporate the radiation dose delivered to the specific implant site, local tissue conditions, anatomical location, oncological status, oral health, and the expected functional benefit of rehabilitation. Routine prophylactic hyperbaric oxygen cannot be recommended for all patients, and stable pre-existing implants should not be removed solely because radiotherapy is planned. Overall, implant therapy after head and neck radiotherapy should be approached as a site-specific and risk-modified treatment requiring individualized multidisciplinary decision-making and long-term surveillance.

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