Vol. 138 No. 5 November 2024

# Osseointegrated dental implants that will undergo radiotherapy. Does risk of osteoradionecrosis exist? A scoping review

Irene Beatriz Prado-Pena, MSc,[a] Jose Manuel Somoza-Martin, PhD,[a,b] Tamara García-Carnicero, MSc,[a] Alejandro I. Lorenzo-Pouso, PhD, DDS,[a] Mario Pérez-Sayáns, PhD, PhD, DDS,[a,b,c] Valeria Sanmartín-Barragáns, MSc,[a] Andrés Blanco-Carrión, PhD,[a,b] Abel García-García, PhD,[a,b] and Pilar Gándara-Vila, PhD[a,b]

**Objective.** Given the absence of a standardized action protocol for treating patients with dental implants (DIs) who are subjected to radiotherapy (RT), we have conducted an extensive review and analysis of published literature on this subject. Our objective is to gain a comprehensive understanding of the impact of RT on the bone surrounding osseointegrated implants during and after treatment.

**Study Design.** We conducted a literature review using PubMed (MEDLINE) to identify studies describing the effects of RT on pre-existing osseointegrated and/or loaded DIs. Articles published between January 1963 and December 2023 were considered for inclusion.

**Results.** A total of 1,126 articles were retrieved, 64 full articles were reviewed, and only 13 articles were included in this review upon meeting the criteria. A total of 667 patients and 2,409 implants were included. Osteoradionecrosis (ORN) was observed in approximately 19 implants following antineoplastic treatment.

**Conclusions.** The interaction between DIs and RT is a complex and multifaceted issue that requires further research and clinical guidance. Although certain studies indicate a possible connection between DIs, radiation, and ORN risk, the precise relationship remains unclear. Factors such as radiation dosage, implant characteristics, material, and timing of placement significantly influence this association. (Oral Surg Oral Med Oral Pathol Oral Radiol 2024;138:594−601)

Head and neck cancer (HNC) is considered any malignant tumor that predominantly affects the upper aerodigestive tract, and it is subdivided according to the compromised anatomical region, thereby being classified as cancer of the oral cavity, pharynx, larynx, salivary glands, nasal cavity, and paranasal sinuses.

HNCs are most commonly diagnosed in the sixth decade of life, and the incidence in men is 3 times higher.[1,2] Oral cancer is among the 10 most frequent cancers worldwide. Malignant tumors of the oral cavity account for 4% of all malignant tumors, with 90% of said tumors corresponding to oral squamous cell carcinoma (OSCC), the most common of all HNCs.[3] The latest projections from the American Cancer Society reveal that approximately 58,450 individuals will be diagnosed with HNC, and about 12,230 people will succumb to these cancer types in the United States in 2024.[4] The primary treatment approach is tumor surgical resection (TSR), which may be administered independently or in combination with radiotherapy (RT) and/or chemotherapy (CHT).[5-8] Cancer treatment often results in a reduced quality of life, as it can lead to tooth loss or extensive bone resections, which in turn hinder patients from performing their regular chewing functions.[7,8]

Indeed, it has been demonstrated that the restoration of mandibular continuity significantly enhances facial aesthetics and overall postoncological surgical outcomes. Dental implants (DIs) play a pivotal role in this reconstructive process, as they provide the essential support required for dental prostheses, thereby contributing to the comprehensive rehabilitation for these patients.[6,9]

The vascularisation and regenerative capacity of irradiated tissues may decrease after RT, which can affect the subsequent osteointegration of the DIs.[9-14] Osteoradionecrosis (ORN) represents a significant and

## Statement of Clinical Relevance

The review underscores the need for standardized action protocols for patients with dental implants undergoing radiotherapy. Optimizing these protocols is crucial for enhancing clinical outcomes and patient quality of life.

[a]Oral Medicine, Oral Surgery, and Implantology Unit (MedOralRes), Faculty of Medicine and Dentistry, Universidade de Santiago de Compostela (USC), Santiago de Compostela, Spain.
[b]Instituto de Investigación Sanitaria de Santiago (IDIS), ORALRES Group Santiago de Compostela, Santiago de Compostela, Spain.
[c]Materials Institute of Santiago de Compostela (iMATUS), Santiago de Compostela, Spain.
Corresponding author: Jose Manuel Somoza-Martin, PhD, Entrerríos s/n, Santiago de Compostela C.P. 15782, Spain. E-mail address: jmanuel.somoza@usc.es
Received for publication Feb 28, 2024; returned for revision May 27, 2024; accepted for publication Jun 1, 2024.

2212-4403/$-see front matter
https://doi.org/10.1016/j.oooo.2024.06.003

debilitating late-stage complication associated with RT in patients with HNC. It is defined as the condition where irradiated bone remains exposed and fails to heal over a period of 3 months, without any evidence of a persistent or recurring tumor.[11,12] This condition can be triggered by surgical interventions like tooth extraction or DI placement, or it may manifest spontaneously. The exact underlying pathogenic mechanisms continue to be a subject of investigation. Nevertheless, the most prevalent cause is radiation arteritis, which gives rise to the formation of a pathological state characterized by a hypocellular, hypovascular, and hypoxic environment.[6,10,13] Radiation-induced damage is widely recognized as the primary factor responsible for diminished matrix formation and impaired bone mineralization. Radiation damage is considered to be the most important factor that leads to decreased matrix formation and bone mineralization, which has a negative effect on vascularisation and, therefore, on bone sclerosis.[1] The prevalence of ORN exhibits significant variation in the available literature, with reported figures spanning a broad range from 0.4% to 56%. Nevertheless, the most commonly cited prevalence rate falls within the range of 5%-15%, and a higher incidence is observed among patients aged 55 years and older.[14]

According to existing literature, DIs can be inserted either prior to RT and/or during TSR in a procedure referred to as primary DIs placement (C1), or they can be placed postsurgery in a procedure known as secondary DIs placement (C2).[10] While concrete scientific evidence pinpointing the optimal timing for DIs placement remains elusive, it has been suggested that the C1 approach offers the advantage of achieving osseointegration before the onset of adverse effects induced by RTP, such as ORN. This, in turn, mitigates the necessity for additional surgical interventions and facilitates early DI rehabilitation.[11]

As a consequence, the population of oncology patients with DIs undergoing treatments like RTP is poised to rise significantly. Considering the absence of a standardized action plan for managing these patients, we have undertaken the task of reviewing and analyzing the available literature on this subject. Our aim is to gain a comprehensive understanding of the effects of radiation on bone structures that house already osseointegrated and/or loaded dental implants.

## MATERIAL AND METHOD

### Methods

The PRISMA extension for scoping review (PRISMA-ScR) was followed during duration of this study.[15] A literature review was conducted to address the following research question: What is the appropriate protocol for patients with osseointegrated DIs who are scheduled to undergo RT, and what is the incidence of ORN following RTP? The PICO methodology was employed to frame the clinical question, where P represents patients with implants, I represents patients receiving RT, C represents the development of ORN, and O pertains to factors influencing ORN.

The search terms included: "*dental implants*," "*radiotherapy*," "*effect of radiotherapy*," "*pre-radiotherapy*," "*postoperative radiotherapy*," "*irradiated patients*" *and* "*osteoradionecrosis*," with Boolean operators "AND" and "OR" used to combine terms. To enhance search sensitivity, we also examined the reference lists of the included studies.

### Data collection

Data were collected on various variables, including type of study (S), number of patients (NP), gender (G), mean age (A), location of the OSCC, location of the DIs placement, type of bone where the DI was placed (B), radiation dose in Grays (Gy), number of patients who did not receive RT (PC0), number of patients who received RT following DI placement (PC1), number of patients who received RT prior to DI placement (PC2), number of patients who received RT prior to and following DI placement (PC1+2), type of DIs placed (TDI), surgical phases, months of follow-up failure/number of total implants (F/DI), failure/implants that did not receive RTP (F/C0), failure/implants that received postoperative RT (F/C1), failure/implants placed following tumor resection and RT (F/C2), survival rate in nonradiated (SRC0), survival rate in C1 (SRC1), survival rate in C2 (SRC2), ORN. These variables are summarized in Table I.

### Inclusion and exclusion criteria

Inclusion criteria were: (1) Articles published in English, French, and Spanish which included patients with DIs that were placed prior to receiving RT, (2) patients whose DIs were placed on the day of the TSR and before receiving RT were included in the review. (3) All types of papers (clinical trials, case-control, case series, cohorts . . . retrospective or prospective).

Exclusion criteria were: (1) Articles on extraoral/facial Dis, (2) articles addressing DIs placed on already radiated bone, (3) articles for which the abstracts were unavailable, (4) Articles with duplicate databases, (5) articles addressing experimental studies in animals, (6) systematic reviews, (7) meta-analysis.

## RESULTS

We conducted the search using the following combinations of terms: "Dental implants" AND "Radiotherapy," "Effect of radiotherapy" AND "Dental implants," "Pre-radiotherapy" AND "Dental implants," "Postoperative radiotherapy" AND "Dental implants" "Irradiated patients" AND "Dental

**Table I.** Articles review

| *Study* | *S* | *NP* | *G* | *A* | *loc OSCC* | *loc DI* | *B* | *Gy* | *PC0* | *PC1* | *PC2* | *PC1+2* | *TDI* | *SP* | *MF* | *F/DI* | *F/C0* | *F/C1* | *F/C2* | *SRC0* | *SRC1* | *SRC2* | *ORN* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ben Slama et al.**[11] | ***CC*** | 1 | W | 75 | Cheek | 4mand 1max | NB | 45-65 | 0 | 1 | 0 | 0 | 4 cylindrical implants 1 implant blade | - | - | 5/5 | - | - | - | - | - | - | 5 |
| **Teramoto et al.**[12] | ***CC*** | 1 | M | 66 | Oropharynx | 4 mand | NB | 70 | 0 | 1 | 0 | 0 | - | - | - | - | - | - | - | - | - | - | 2 |
| **Li et al.**[24] | RS | 58 | 38M<br>20W | 59 | Nasopharynx sinus:7<br>Oral cavity:38<br>Oropharynx:4<br>Hypopharynx/larynx:3<br>Multilevel:6 | 7 max<br>79 mand | NB | 62.4 tumor site<br>40.3 implant site | 0 | 58 | 0 | 0 | - | - | - | 4/151 | - | 0/151 | - | - | 99, 94 (1 year)<br>97.4 (after 3 years) | | 0 |
| **Sandoval et al.**[16] | RS | 10 | - | 70 | Mand:3<br>Bucal mucosa:3<br>- | - | AG | 60 | 0 | 10 | 0 | 0 | - | - | | -/29 | 0 | 29 | 0 | - | 93% | | 0 |
| **Woods et al.**[19] | ***RS*** | 20 | 13M<br>7W | 56 | - | Max<br>Mand | AG | - | 10 | 10 | 0 | - | NEOSS ProActive (82)<br>Biomet 3i NanoTite[8]<br>ITI/Straumann SLA[2]<br>ITI/Straumann SLActive [12] | 1 (30DIs)<br>2 (72DIs) | 2-140 | 7/102 | 2/51 | 5/51 | 0/0 | 96.8% | 90.2% | - | - |
| **Korfage et al.**[18] | ***RS*** | 164 | 98M<br>66W | 64.8 | - | Sy | NB | - | 64 | 100 | 0 | 0 | Nobel Biocare-Branemark 3.75 mm, treated surface/TiUnite | 2 | 45.6 | 28/524 | 1/206 | 27/318 | 0/0 | 97.1% | 82% | - | 10 |
| **Mizbah et al.**[20] | ***RS*** | 128* | - | - | - | Sy | NB | 60-68 | 64 | 47 | 17 | 0 | Branemark MK II/III<br>Frialit | 2 | 60 | 30/314 | 0/163 | 24/113 | 6/38 | 100% | 78.7% | 84.21% | 0 |
| **Shoen et al.** [9] | ***PS*** | 50 | 35M<br>15W | 61.5 | Floor of mouth13<br>Tongue18<br>Buccal mucosa12<br>Tonsil:3<br>Oropharynx:4 | Sy | NB | 60-64 | 19 | 31 | 0 | 0 | Nobel Biocare—Branemark 3.75 mm, treated surface | 2 | 18-24 | 4/195 | 2/71 | 2/124 | 0/0 | 97% | 98.3% | - | 0 |
| **Schepers et al.**[10] | ***RS*** | 48 | 29M<br>19W | 64.8 H<br>68.1 M | *Floor of mouth:22*<br>*Tongue:14*<br>*Buccal mucosa:2*<br>*Trigone:9*<br>*Alveolar ridge:1* | Sy | NB | 60 | 27 | 21 | 0 | 0 | Branemark MK II/III | 2 | 29.6 | 2/139 | 0/78 | 2/61 | 0/0 | 100% | 97% | - | 0 |
| **Cuesta-Gil et al.**[17] | ***DS*** | 111 | 80M<br>31W | 52 | *Maxilla:12*<br>*Gums, jaw, tongue, floor of mouth, jugal mucosa, and lower lip:98* | Max<br>Mand | AG<br>NB | 50-60 | 32 | 45 | 34 | 0 | Biomedical Lifecore threaded Hydroxyapatite Coated Titanium Implants | 2 | 6-108 | 29/706 | 2/266 | 21/205 | 6/190 | 99.2 | 92, 9% | 96.8% | - |
| **Iizuka et al.**[23] | PS | 28 | 19M<br>9W | 58.2 | - | Mand | AG | 65 | 9 | 7 | 9 | 3 | ITI-Straumann | | >24 | 0/37 | 0/- | 0/13 | 0/- | 100% | 100% | 100% | - |
| **Keller et al.**[21] | ***RS*** | 31 | 16M<br>15W | 50.5 | - | Mand | AG | 50-80 | 22 | 1 | 8 | 0 | Nobel Biocare, titanio, 3.75, 4 or 5 mm<br>cylindrical implant, threaded without coating | | 6-168 | 7/154 | 6/52 | 0/4 | 1/98 | 96.7% | 100% | 98.9% | - |
| **Mericske-Stern et al.**[22] | RS | 17 | 13M<br>4W | - | - | Max<br>Mand | - | 50-74 | 6 | 7 | 4 | 0 | ITI-Straumann | | <84 ms | 4/53 | 0/20 | 2/17 | 2/16 | 100% | 93%<br>1 year<br>90% (after 3 years) | 87.5% | 2* |
| **Total** | 13 | 667 | 342M<br>186W | 62.7 | - | - | - | | 253 | 339 | 72 | 3 | | | | 120/<br>2,409 | 13/907 | 83/1,086 | 15/342 | - | - | - | 19 |

*S*, type of study; *RS*, retrospectice study; *PS*, prospective study; *DS*, descriptive study; *CC*, report of a case; *NP*, number of patients; *G*, gender; *M*, man; *W*, women; *A*, mean age; *loc OSCC*, location of the OSCC; *loc DI*, location of the DI placement; *B*, type of bone where the DI was placed; *NB*, native bone; *AG*, autologous graft; *Sy*, mandibular symphysis; *max*, maxilar superior; *mand*, mandible; *Gy*, radiation dose in Grays; *PC0*, number of patients who did not receive RTP; *PC1*, number of patients who received RTP following DI placement; *PC2*, number of patients who received RTP prior to DI placement; *PC1+2*, number of patients who received RTP prior to and following DI placement; *TDI*, type of DI placed; *SP*, surgical phases; *MF*, months of follow-up; *F/DI*, failure/number of total implants; *F/C0*, failure/implants that did not receive RTP; *F/C1*, failure/implants that received postoperative RTP; *F/C2*, failure/implants placed following tumour resection and RTP; *SRC0*, survival rate in nonradiated; *SRC1*, survival rate in C1; *SRC2*, survival rate in C2; *ORN*, osteoradionecrosis.

*Not mention whether radiotherapy was administered.

implants," "Osteoradionecrosis" AND "Dental implants."

A total of 5.098 articles were obtained.

A total of 1,126 articles were obtained, of which 327 were duplicates. The title of 799 was read and finally, the abstracts of 260 articles were read; 196 were discarded because they were unrelated to the topic in question. Sixty-four full articles were read, and 51 articles were excluded because they did not meet the inclusion criteria for data collection (Figure 1).

Two published clinical cases showed ORN developed around DIs placed years before initiating RT[11,12] and, likewise, we also found 14 human studies, published between 1963 and 2023, in which patients with HNC underwent DI placement on the day of tumor resection and before RT[9,10,16-24] One of the articles was discarded because it did not discuss intraoral DIs,[25] and 2 other articles were discarded in order to prevent the existence of bias in the data collection process, given that these addressed the same database as one of the selected articles.[26,27]

Regarding clinical cases, Ben Slama et al.[11] in 2014 made a significant contribution to the field by reporting the first documented case of ORN associated with five DIs that had been inserted a decade prior to RT. The authors suggested that besides RTP, potential contributing factors included occlusal trauma and peri-implantitis.[11] Notably, ORN became evident 3 months after the initiation of RT in the mandibular DIs and surfaced 40 months later in the maxillary DIs, as summarized in Table I. Subsequently, in 2016, Teramoto et al.[12] presented a case where ORN manifested solely on the side subjected to radiation treatment. The DIs had been placed 2 years prior to the initiation of antineoplastic therapy, and ORN became apparent 48 months following RT,[12] as detailed in Table I. These instances shed light on the complex interplay of various factors in the development of ORN.

The analysis of the literature included a total of 12 studies, of which eight were retrospective, two were descriptive, and two were prospective. (Table I). This comprehensive review encompasses data collected from 667 patients and 2,409 DIs. Tumor location was documented in only five of the studies,[9,10,16-18,24] with the most frequently location identified as the floor of the mouth, as presented in Table I.

With respect to the timing of DI placement, five studies reported that all patients received their implants

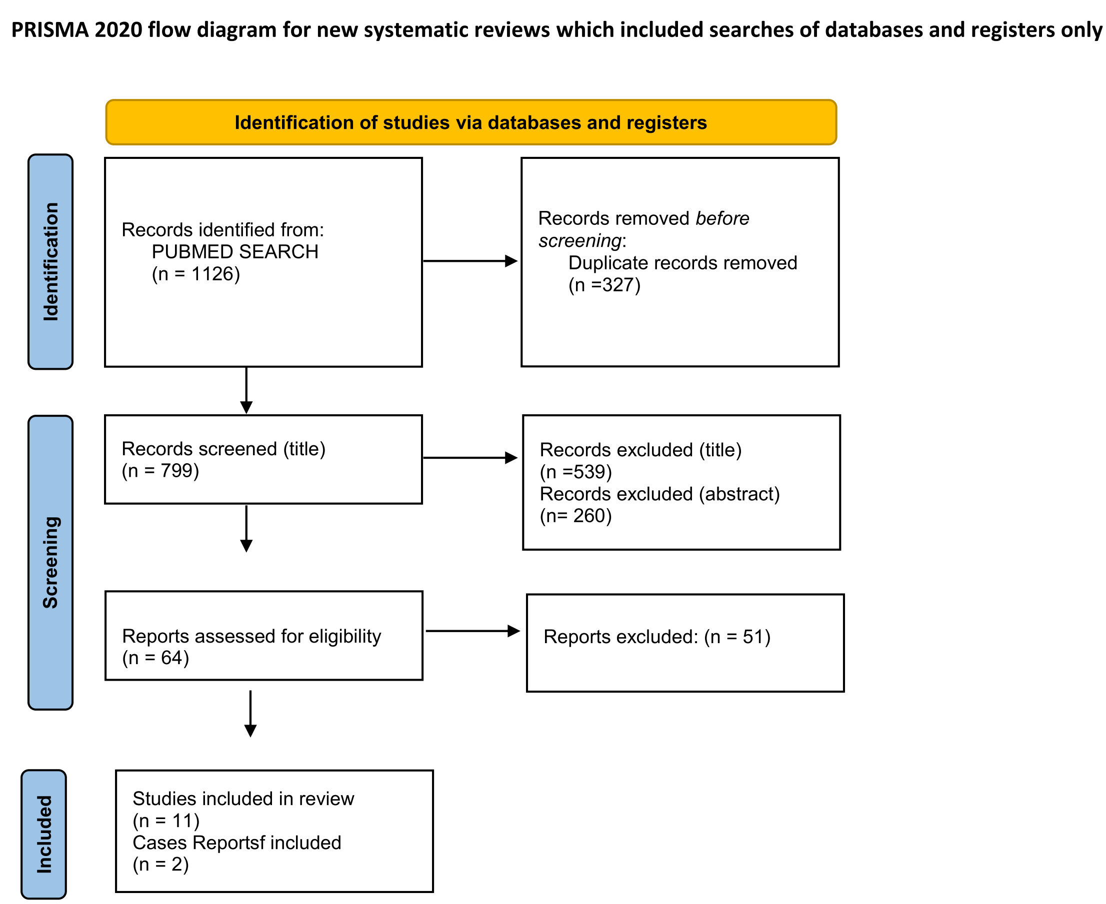


Fig. 1. Prisma flow diagram.

in phase C1. In the remaining articles, DIs were placed in both phases, encompassing C1 and C2. Among the 667 patients, 339 had their implants inserted during the surgical procedure and subsequently received RTP, as outlined in Table I. Out of the 2,409 implants analyzed, 1,086 underwent RT in C1, with radiation doses ranging from 40 to 70 Gy. Unfortunately, the radiation dosage was not documented in two of the studies[18,19] Various DI systems were employed, and in most studies, these systems were inserted in two phases, as summarized in Table I.

Among the 2,409 DIs placed, 120 exhibited failure, representing 5.8% of the total. Notably, a lower failure rate was observed in DIs that did not undergo radiation.

A lower failure rate was recorded in DIC0 (SR greater than 96%). In only one of the collected articles, the SRC2 was higher than in SRC1; in the rest, the implant survival rates were higher when they were placed before receiving RT, in nonirradiated bone.

Among the 120 failed DIs, 19 were associated with the development of ORN in two of the studies. However, it is worth noting that one of these studies[22] did not specify whether ORN occurred in phase C1 or C2, as detailed in Table I.

Regarding the timing of prosthesis placement, patients receiving postoperative RTP typically commenced treatment 6 weeks after the surgical procedure. The placement of prostheses occurred within a range of 3-5 months for DIs not exposed to RTP, while the timing extended from 4.5 to 12 months for implants that received postoperative RT.[9,10]

## DISCUSSION

In the current literature, there has been a greater number of studies focused on DIs placed in irradiated bone[6,13,28-31] compared to research exploring the consequences of RT on previously placed implants.[5,32,33] Understanding how RT affects preexisting DIs is of paramount importance to improve patient care and provide clearer clinical guidelines in increasingly common clinical scenarios. Currently, no consensus or guideline has been found regarding how to manage DIs in the context of RT.

To date, only two clinical cases of ORN related to DIs after RT have been reported.[11,12] In one of the cases, ORN only occurred in the DIs included in the RT field, suggesting a possible causal relationship between the presence of DIs and the development of ORN.[12] Korfage et al.[18] found 10 cases of ORN in 5 patients after receiving RT and in the study published by Mericske-Stern et al.,[22] 2 patients developed ORN, although this article did not mention whether RT was administered.

ORN is a serious complication that occurs after RT. The radiation dose, tumor location, implant position, dental trauma, prior dental condition, and CHT are considered contributing factors to ORN. It has been suggested that a change in the radiation dose distribution around DIs could favor the development of ORN.[32-37] This dispersion in implant materials and electronic imbalance is believed to cause complications in both soft and hard tissues of the oral cavity[11,32]

Ozen et al.[32] reported a 21% increase in radiation dose in the mandibular bone around DIs in phantom jaws, an increase that became insignificant at 2 mm from the interface. Stoll et al.[35] found a 12.5% to 16% increase in dose at 0.45 mm from the metallic implant, although this did not affect the lifespan of the DIs.[38] It remains unclear whether a local overdose of around 15%-21% would significantly increase the incidence of ORN around DIs.[32] According to Korfage et al.[18] even when this risk increases, it will remain lower than in the case of DIs placed after RT.

Regarding bone-implant contact (BIC) and bone mineral density (BMD), more positive results were found in the literature for delayed implantation before RT. Brogniez et al.[38] pointed out that osseointegration of DIs is possible both before and after RT, but the BIC obtained in their experimental study in animal models was higher in C1. Stramandinoli-Zanicotti et al.[39] also observed a higher BIC when DIs were placed 15 days before RT. In the study carried out by Doh et al.[5], BMD was significantly lower in the immediate irradiation groups (RT administered 1 day after implantation) and similar in the delayed irradiation group (RT administered 4 weeks after implantation) and the control group (no RT). Several authors have suggested waiting at least 4 weeks after DIs placement before starting RT.[5,40] Most authors waited a period of 5-6 weeks between DIs placement and the start of RT.[9,10,18,19]

The presence of keratinized tissue (KT) around DIs may be important for peri-implant health, especially in patients undergoing RT. Keratinized tissue, also known as attached gingiva, acts as a protective barrier, providing stability, protection against trauma, and improved oral hygiene. Maintaining adequate KT can potentially prevent inflammation, reduce risks of issues, and enhance the response to radiation therapy. Radiation treatment can impact oral tissues, and the need for more scientific evidence and research in this area is crucial. The presence of peri-implantitis has also been described in the literature as a potential cause of ORN.[12] The negative effects that can occur as a result of radiation exceeding 50 Gy include capillary destruction, associated endarteritis, damage to osteoprogenitor cells, and reduced neovascularization.[38] These effects increase the risk of soft tissue dehiscence around DIs,[24] reducing the peri-implant tissue's resistance to oral bacteria and increasing the risk of peri-implantitis. Both Ben Slama et al.[11] and Teramoto et al.[12] associated the presence of peri-implantitis with the progression to ORN after RT, indicating that it could become a potential cause of ORN. Li et al.[24] confirm that RT negatively impacts peri-implant bone resorption, especially for a specific dose to the upper implant bed exceeding 40 Gy.

Additionally, it has been considered that the type of material could influence the radiation scatter. Friedrich et al.[37,41] observed that DIs containing gold had less scatter in the BIC area than pure titanium alloy DIs or Ti-6Al-4V DIs. Niroomand-Rad et al.[42] suggest that the choice between DIs with or without hydroxyapatite coating may not be a critical factor in reducing radiation scatter around implants, as this difference was considered minimal. Wang et al.[36] also observed better outcomes in hydroxyapatite-coated DIs than pure titanium DIs and titanium-aluminum-vanadium alloy DIs. On the other hand, neither Korfage et al.[18]nor Woods et al.[19] found significant differences when considering the type of DIs and the surface used.

The geometry of DIs, including the type of screw and the type of connection, can potentially affect the results of RT in patients with HNC. Cylindrical or conical screws, as well as the type of connection, can create metallic artifacts in imaging studies such as computed tomography and magnetic resonance imaging. These artifacts can hinder precise RT planning and administration, as they can obscure structures of interest. Radiation scattering around DIs can reduce the dose received by the tumor if it is located behind them. However, it can also reduce osseointegration and increase the risk of ORN development in the bone adjacent to the DIs, as described in the literature.[33] Wang et al.[36] found three cases of tumor recurrence in patients undergoing RT after the simultaneous placement of DIs in the same ablation surgical procedure. Changes in radiation dose scattering were cited as a possible explanation.

Talking about oncology patients' "survival" means the number of years without evidence of tumors. In implantology, "survival" means the number of years for which implants are functional. In the implantology literature relating to oral or head and neck oncology this might be confusing and is usually not clear or discussed.[20] In this study, implants were ranked by survival, and not by failure. DIs were only considered lost if osseointegration failed. The studies published thus far have agreed that the SR is higher in those patients who are not going to receive RT[7,13,29-31,43] and no statistically significant differences have been observed in terms of the DIs placed before or after radiation.[30] In the systematic review published by Nooh et al,.[6] 34 studies with C2 were analyzed, with an SR of 92.2% (320 DIs). Other studies, such as that of Korfage et al.[18], or that of Schepers et al.[10] published an SR of 89.4% and 97% for C1, respectively. In the systematic review by Colella et al.[44] no significant differences were found between the failure of the C1 and C2. However, in an experimental animal study, Stramandinoli-Zanicotti et al.[39] observed a greater failure in C2 compared to C1 or C0. (30%, 21.7%, and 4% respectively). In this study, a higher fibrointegration was also found in C2.

If DIs are placed on the same day as tumor site resection surgery, it is preferable for this procedure to be performed in two stages to prevent radiation exposure to titanium components.[10] This approach aligns with findings from an experimental study by Brogniez et al.,[38] which demonstrated superior outcomes with submerged DIs compared to nonsubmerged ones. In these patients, it is recommended to wait 6 weeks before starting RTP, 6 months between RTP and the second surgical procedure, and 2 more weeks before the beginning of the prosthodontic procedure.[9,10,17,18] According to some authors, when radiation is administered after the prosthesis placement, there is a greater risk of ORN and it is also advisable to remove metal structures and pillars[5,9,27,43] and/or to submerge again before RTP treatment.[40,45]

We have compiled a list of tips and recommendations based on the literature review.

- Concerning the status of preexisting implants, the condition of DIs prior to oral cancer treatment, including occlusal trauma and peri-implantitis, appears to influence the development of ORN in patients undergoing radiation therapy.
- In consideration of titanium accessories, IR is recommended to avoid connecting the abutment and instead remove metallic prosthetic structures before starting RT.
- For patients who receive DIs on the same day as TS, it is suggested to wait at least 6 weeks before initiating RT.
- It is recommended to wait at least 6 months after completing RT before considering a second implant surgery.
- To ensure proper healing, it is advisable to wait at least 2 weeks between abutment connection or the second surgery and the initiation of the prosthesis for patients who have undergone RT.

## CONCLUSION

In conclusion, the interaction between DIs and RT is a complex and multifaceted issue that requires further research and clinical guidance. While some studies suggest a potential risk of ORN associated with DIs and radiation, it is clear that the relationship is not fully understood, and factors such as radiation dose, implant type, material, and timing of implant placement play important roles. Close collaboration between dental and radiation oncology teams is crucial to make informed decisions regarding treatment protocols for patients with DIs undergoing RT. Therefore, it is recommended that these patients undergo periodic reviews during and after RT. The condition of DIs prior to antineoplastic treatment, the performance of nonsurgical treatment, and the removal of prosthetic metal structures should be assessed before commencing RTP until more data is available on the possible disadvantages of irradiation on titanium accessories.

## FUTURE CONSIDERATIONS

It is necessary to carry out prospective studies on patients with implants who will receive radiotherapy to clarify how radiation affects already integrated implants.

## DECLARATION OF INTERESTS

None.

## CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

**Irene Beatriz Prado-Pena:** Writing – original draft, Writing – review & editing, Investigation, Methodology. **Jose Manuel Somoza-Martin:** Methodology, Investigation, Data curation, Writing – review & editing. **Tamara García-Carnicero:** Visualization. **Alejandro I. Lorenzo-Pouso:** Formal analysis, Supervision. **Mario Pérez-Sayáns:** Supervision, Conceptualization, Methodology. **Valeria Sanmartín-Barragáns:** Investigation, Formal analysis. **Andrés Blanco-Carrión:** Formal analysis, Supervision, Conceptualization. **Abel García-García:** Validation, Supervision. **Pilar Gándara-Vila:** Investigation, Writing – review & editing, Conceptualization, Writing – original draft.

## REFERENCES


1. Jou A, Hess J. Epidemiology and molecular biology of head and neck cancer. *Oncol Res Treat*. 2017;40:328-332.
2. Kim L, King T, Agulnik M. Head and neck cancer: changing epidemiology and public health implications. *Oncology (Williston Park, N Y)*. 2010;24:915-919. 924.
3. Ferlay J, Colombet M, Soerjomataram I, et al. Cancer incidence and mortality patterns in Europe: estimates for 40 countries and 25 major cancers in 2018. *Eur J Cancer*. 2018;11:356-387.
4. American Cancer Society. *Cancer Facts & Figures 2024*. Atlanta: American Cancer Society; 2024. Available from:. https://www.cancer.org/research/cancer-facts-statistics/all-cancer-facts-figures/2024-cancer-facts-figures.html.
5. Doh R, Kim S, Keum KC, et al. Postoperative irradiation after implant placement: a pilot study for prosthetic reconstruction. *J Adv Prosthodont*. 2016;8:363-371.
6. Nooh N. Dental implant survival in irradiated oral cancer patients: a systematic review of the literature. *Int J Oral Maxillofac Implants*. 2013;28:1233-1242.
7. Barbier L, Pottel L, De Ceulaer J, et al. Evaluation of quality of life after mandibular reconstruction using a novel fixed implant-supported dental prosthesis concept: a pilot study. *Int J Prosthodont*. 2019;32:162-173.
8. Parahoo RS, Semple CJ, Killough S, McCaughan E. The experience among patients with multiple dental loss as a consequence of treatment for head and neck cancer: a qualitative study. *J Dent*. 2019;82:30-37.
9. Schoen PJ, Raghoebar GM, Bouma J, et al. Prosthodontic rehabilitation of oral function in head-neck cancer patients with dental implants placed simultaneously during ablative tumour surgery: an assessment of treatment outcomes and quality of life. *Int J Oral Maxillofac Surg*. 2008;37:8-16.
10. Schepers RH, Slagter AP, Kaanders JHAM, van den Hoogen FJA, MaW M. Effect of postoperative radiotherapy on the functional result of implants placed during ablative surgery for oral cancer. *Int J Oral Maxillofac Surg*. 2006;35:803-808.
11. Ben Slama L, Hasni W, De Labrouhe C, Bado F, Bertrand J. [Osteoradionecrosis and dental implants]. *Rev Stomatol Chir Maxillofac*. 2008;109:387-392.
12. Teramoto Y, Kurita H, Kamata T, et al. A case of peri-implantitis and osteoradionecrosis arising around dental implants placed before radiation therapy. *Int J Implant Dent*. 2016;2:11.
13. Pompa G, Saccucci M, Di Carlo G, et al. Survival of dental implants in patients with oral cancer treated by surgery and radiotherapy: a retrospective study. *BMC Oral Health*. 2015;15:5.
14. Chronopoulos A, Zarra T, Ehrenfeld M, Otto S. Osteoradionecrosis of the jaws: definition, epidemiology, staging and clinical and radiological findings. A concise review. *Int Dent J*. 2018;68:22-30.
15. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med*. 2018;169:467-473.
16. Sandoval ML, Rosen EB, Robert AJ, Nelson JA, Matros E, Gelblum DY. Immediate dental implants in fibula free flaps to reconstruct the mandible: a pilot study of the short-term effects on radiotherapy for patients with head and neck cancer. *Clin Implant Dent Relat Res*. 2020;22:91-95.
17. Cuesta-Gil M, Ochandiano Caicoya S, Riba-García F, Duarte Ruiz B, Navarro Cuéllar C, Navarro Vila C. Oral rehabilitation with osseointegrated implants in oncologic patients. *J Oral Maxillofac Surg*. 2009;67:2485-2496.
18. Korfage A, Raghoebar GM, Slater JJRH, et al. Overdentures on primary mandibular implants in patients with oral cancer: a follow-up study over 14 years. *Br J Oral Maxillofac Surg*. 2014;52:798-805.
19. Woods B, Schenberg M, Chandu A. A comparison of immediate and delayed dental implant placement in head and neck surgery patients. *J Oral Maxillofac Surg*. 2019;77:1156-1164.
20. Mizbah K, Dings JP, Kaanders JHAM, et al. Interforaminal implant placement in oral cancer patients: during ablative surgery or delayed? A 5-year retrospective study. *Int J Oral Maxillofac Surg*. 2013;42:651-655.
21. Keller EE. Placement of dental implants in the irradiated mandible: a protocol without adjunctive hyperbaric oxygen. *J Oral Maxillofac Surg*. 1997;55:972-980.
22. Mericske-Stern R, Perren R, Raveh J. Life table analysis and clinical evaluation of oral implants supporting prostheses after resection of malignant tumors. *Int J Oral Maxillofac Implants*. 1999;14:673-680.
23. Iizuka T, Häfliger J, Seto I, Rahal A, Mericske-Stern R, Smolka K. Oral rehabilitation after mandibular reconstruction using an osteocutaneous fibula free flap with endosseous implants. *Clin Oral Implants Res*. 2004;16:69-79.
24. Li J, Feng K, Ye L, Liu Y, Sun Y, Wu Y. Influence of radiotherapy on dental implants placed in individuals before diagnosed

with head and neck cancer: focus on implant-bed-specific radiation dosage. *Clin Oral Invest*. 2022;26:5915-5922.
25. Abu-Serriah MM, McGowan DA, Moos KF, Bagg J. Extra-oral craniofacial endosseous implants and radiotherapy. *Int J Oral Maxillofac Surg*. 2003;32:585-592.
26. Korfage A, Schoen PJ, Raghoebar GM, Roodenburg JLN, Vissink A, Reintsema H. Benefits of dental implants installed during ablative tumour surgery in oral cancer patients: a prospective 5-year clinical trial. *Clin Oral Implants Res*. 2010;21:971-979.
27. Schoen PJ, Raghoebar GM, Bouma J, et al. Rehabilitation of oral function in head and neck cancer patients after radiotherapy with implant-retained dentures: effects of hyperbaric oxygen therapy. *Oral Oncol.* 2007;43:379-388.
28. Ihde S, Kopp S, Gundlach K, Konstantinović VS. Effects of radiation therapy on craniofacial and dental implants: a review of the literature. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009;107:56-65.
29. Chrcanovic BR, Albrektsson T, Wennerberg A. Dental implants in irradiated versus nonirradiated patients: a meta-analysis. *Head Neck*. 2016;38:448-481.
30. Shugaa-Addin B, Al-Shamiri H, Al-Maweri S, Tarakji B. The effect of radiotherapy on survival of dental implants in head and neck cancer patients. *J Clin Exp Dent*. 2016;8:194.
31. Zhang L, Ding Q, Liu C, Sun Y, Xie Q, Zhou Y. Survival, function, and complications of oral implants placed in bone flaps in jaw rehabilitation: a systematic review. *Int J Prosthodont*. 2016;29:115-125.
32. Ozen J, Dirican B, Oysul K, Beyzadeoglu M, Ucok O, Beydemir B. Dosimetric evaluation of the effect of dental implants in head and neck radiotherapy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2005;99:743-747.
33. Bazalova M, Beaulieu L, Palefsky S, Verhaegena F. Correction of CT artifacts and its influence on Monte Carlo dose calculations. *Med Phys*. 2007;34:2119-2132.
34. Beyzadeoglu M, Dirican B, Oysul K, Ozen J, Ucok O. Evaluation of scatter dose of dental titanium implants exposed to photon beams of different energies and irradiation angles in head and neck radiotherapy. *Dentomaxillofac Radiol*. 2006;35:14-17.
35. Stoll P, Wächter R, Hodapp N, Schilli W. Radiation and osteosynthesis. Dosimetry on an irradiation phantom. *J Craniomaxillofac Surg*. 1990;18:361-366.
36. Wang R, Pillai K, Jones PK. Dosimetric measurement of scattered radiation from dental implants in simulated head and neck radiotherapy. *Int J Oral Maxillofac Implants*. 1998;13:197-203.
37. Friedrich RE, Todorovic M, Todrovic M, Krüll A. Simulation of scattering effects of irradiation on surroundings using the example of titanium dental implants: a Monte Carlo approach. *Anticancer Res*. 2010;30:1727-1730.
38. Brogniez V, D'Hoore W, Grégoire V, Munting E, Reychler H. Implants placed in an irradiated dog mandible: a morphometric analysis. *Int J Oral Maxillofac Implants*. 2000;15:511-518.
39. Stramandinoli-Zanicotti RT, Sassi LM, Schussel JL, Torres MF, Matos Ferreira SA, Carvalho AL. Effect of radiotherapy on osseointegration of dental implants immediately placed in post-extraction sites of minipigs mandibles. *Implant Dent*. 2014;23: 560-564.
40. Nobrega AS, Santiago JF Jr, Almeida DAF, Santos DMD, Pellizzer EP, Goiato MC. Irradiated patients and survival rate of dental implants: a systematic review and meta-analysis. *J Prosthet Dent.* 2016;116:858-866. https://doi.org/10.1016/j.prosdent.2016.04.025.
41. Friedrich RE, Todorovic M, Heiland M, Scheuer HA, Krüll A. Scattering effects of irradiation on surroundings calculated for a small dental implant. *Anticancer Res*. 2012;32: 2043-2046.
42. Niroomand-Rad A, Razavi R, Thobejane S, Harter KW. Radiation dose perturbation at tissue-titanium dental interfaces in head and neck cancer patients. *Int J Radiat Oncol Biol Phys*. 1996;34:475-480.
43. Granström G, Tjellström A, Brånemark PI, Fornander J. Bone-anchored reconstruction of the irradiated head and neck cancer patient. *Otolaryngol Head Neck Surg*. 1993;108:334-343.
44. Colella G, Cannavale R, Pentenero M, Gandolfo S. Oral implants in radiated patients: a systematic review. *Int J Oral Maxillofac Implants*. 2007;22:616-622.
45. Schoen PJ, Reintsema H, Raghoebar GM, Vissink A, Roodenburg JLN. The use of implant retained mandibular prostheses in the oral rehabilitation of head and neck cancer patients. A review and rationale for treatment planning. *Oral Oncol*. 2004;40:862-871.