Evaluation of success of dental implants in immediate vs delayed loading, post radiation in head and neck cancer patients: a systematic review and meta analysis

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Abstract

Background
Dental implantology has transformed oral rehabilitation over the past forty years by providing an essential treatment to restore both oral function and aesthetics. The notion of osseointegration has surfaced as a crucial element that substantially contributes to the revolutionary effects of dental implant treatments.

Aim
The difficulties with oral rehabilitation following ablative surgery for head and neck cancer are examined in this study. To improve treatment outcomes for this patient population, it compares immediate and delayed loading approaches when evaluating the efficacy of dental implants and their survival rates.

Methodology
27 pertinent articles that satisfied the inclusion criteria were found after a thorough search of several databases, including PubMed, MEDLINE, Embase, Google Scholar, and the Cochrane Library. Data extraction and a thorough quality assessment of the chosen studies were carried out by 4 independent reviewers. To combine the data and extract significant findings, statistical analysis including meta-analysis was applied.

Results
The meta-analysis of present study demonstrates a considerable improvement in treatment outcomes when implants are loaded immediately as opposed to delayed. Even then, it is important to recognize that different research designs and participant profiles have different effects on survival of implants. All things considered, the data strongly point to the conclusion that immediate loading produces better outcomes, which may make it the intervention of choice for the outcomes under analysis.

Conclusion
This analysis emphasizes that HNC patients require customized care, with early loading being preferred for higher success rates and faster recovery. Improved results with immediate loading and individualized overdenture programs have been stated by patients. Further studies that prioritize long-term follow-up and protocols are essential to improving oral rehabilitation for HNC patients.

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Keywords

Dental implants, Head and Neck Cancer, Osseointegration, Radiotherapy

INTRODUCTION

Dental implants has a significant role in restoring oral function and aesthetics in edentulous or partially dentate patients over the past 40 years. These advancements are built on the pioneer work of Branemark et al. (1977) and many others who established the theoretical framework for osseointegration, a crucial component of dental implantology (1).

Patients who had undergone ablative procedures in the head and neck due to malignant oral pathology constitute a special category of patients who face challenges in the larger context of oral rehabilitation. Despite being crucial for tumour treatment, these procedures can have serious post-surgical side effects. Australian population of survivors has seen a significant rise in 5-year survival rates, which has now reached 83.3% (2). The long-term effects of such treatments, including significant facial deformities, functional restrictions, are being experienced by the long-term survivors which has a significant impact on their overall quality of life (3).

The obstacles faced by these post-ablative patients requires special attention which is different than any standard dental prostheses. Oral rehabilitation in such cases becomes a challenge due to changes to the local anatomy, including changes to the bone and soft tissues, mucous membranes, and saliva, especially in irradiated patients. Loss of keratinized mucosa, presence of oronasal or oroantral fistulae, restricted access to oral cavity due to conditions like microstomia and scar bands, and decreased mouth opening are the associated consequences (4). Conventional dental prosthesis frequently fails to address these complex issues, which is reflected in poorer patient success rates (4). Chewing, swallowing, and speech can directly affect quality of life of the patients who have undergone ablative procedures, especially those affected with head and neck cancer (3).

In terms of improved quality of life and patient satisfaction, Implant-supported prostheses have emerged as a promising remedy to these complex problems (5). The quality of life for both irradiated and non-irradiated patients with implant-supported prostheses have statistically improved in comparison to cases rehabilitated with non-implant-supported prosthesis (5,6,7).

Even though dental implants have the potential to revolutionize post-ablative oral rehabilitation, the technique for implant insertion is still being researched. In the past, implant placement in patients who had undergone ablative surgery was done in a delayed timeline. This not only enables early disease recurrence monitoring but also aids in understanding how the local anatomy changes over time as a result of resections and flap reconstructions (3). Amongst the alternative techniques that have developed, most notable is the primary placement of implants during ablative surgery. Potential of this strategy is its capacity to lower the overall number of procedures necessary and the danger of osteoradionecrosis in areas where radiotherapy is intended. Additionally the time period of the defect to be restored with final prosthesis is also reduced (5).

There is a dearth of comprehensive literature examining dental implant results in patients with head and neck cancer (HNC) after radiation therapy, with a particular emphasis on contrasting immediate versus delayed loading techniques. There are still significant gaps in the knowledge having the need of treatment decisions with impact of patient-specific variables on these outcomes. There is a growing demand of post-ablative oral rehabilitation strategies due to the increasing number of HNC survivors. With strategies of standard prostheses fabrication frequently failing often, a greater comprehension of efficacy of implant techniques is required. This study aims at improving patient outcomes, contentment, and quality of life in this special demographic.

This study is unique as it compares immediate and delayed loading of dental implants in post-radiation HNC patients in a methodical manner while taking patient-specific characteristics into account. The goal of the evidence synthesis is to offer fresh perspectives on how to best tailor oral rehabilitation techniques to the unique needs of this patient population. By shedding light on the impact of implant loading procedures in this patient group, this systematic review aims to enhance the quality of life and overall well-being of patients with head and neck cancer (HNC) as they navigate the difficulties of post-ablative oral rehabilitation. This publication aims to address the challenges experienced by patients with head and neck cancer pursuing post-ablative oral rehabilitation and to provide evidence-based recommendations to clinicians and researchers in their pursuit of improved clinical outcomes.

OBJECTIVES OF THE STUDY

- To contrast the rates of implant survival for direct and delayed loading approaches.
- To evaluate speaking, swallowing, and chewing outcomes for both implant loading groups.
- To assess the effectiveness of overdentures in HNC patients that are supported by dental implants.
- Investigate patient-reported outcomes regarding implant loading techniques, such as satisfaction and quality of life.
- To look at how certain patient-specific factors, such as age, comorbidities, and radiation exposure, affect the outcomes of dental implant surgeries in HNC patients.

METHODOLOGY

- Timeline of the study:- The current study included published article from 2000 to 2023.
- Primary research question:

The following PICO issues will be addressed by this systematic review:

- Population (P):- Studies describing patients with head and neck cancer who have lost all their teeth or are on the verge to losing all teeth before or during radiation treatment.
- Intervention (I):- Following cancer therapy, immediate and delayed placement of dental implants during ablative or pan-endoscopic surgery.
- Comparison (C) of immediate vs delayed loading of dental implants after cancer treatment.
- Outcomes (O):-
- Primary outcome
- Implant survival rate:- the proportion of dental implants that properly fuse with the surrounding bone and continue to function for the duration of the predetermined follow-up time.
- Secondary outcome
- Functional results:- an assessment of capacity of dental implants to facilitate oral functions, including speech, swallowing, and chewing.
- Overdenture functionality:- evaluation of the overdentures backed by dental implants in terms of functionality.
- Patient-reported outcomes:- this covers metrics like quality of life, patient satisfaction, and other subjective evaluations provided by the patients.
- Secondary research question:
- Are there differences between immediate and delayed loading in terms of implant success rates, problems, or clinical outcomes in patients with head and neck cancer following radiation therapy?
- In this population, how do patient-specific variables such the quantity of radiation therapy, patient age, and comorbidities affect the results of dental implant procedures?

Search strategy and databases

The systematic review and meta analysis process has been registered under registration number CRD42024511753 at the National Institute of Health and Care Research, International Prospective Register of Systematic Reviews Database.

A comprehensive search strategy was employed, utilizing key Medical Subject Headings (MeSH) terms such as "Dental Implants," "Head and Neck Neoplasms," "Radiation Injuries," "Immediate-Loading Dental Implants," "Delayed-Loading Dental Implants," "Osseointegration," "Oral Rehabilitation," "Jaw Reconstruction," "Ablative Surgery," "Oral Cancer," and "Radiotherapy. These terms were combined using Boolean operators to create search strings for databases including PubMed, MEDLINE, Embase, Google Scholar and the Cochrane Library (Table 1). The search encompassed related synonyms and variations, aiming to identify a comprehensive range of relevant studies. Additionally, a manual search of grey literature and reference lists of pertinent articles was conducted to ensure the comprehensive identification of studies relevant to the success of dental implants in immediate versus delayed loading in post-radiation head and neck cancer patients for inclusion in the systematic review.

The search method concentrates on studies that directly compare “dental implant loading immediate versus delayed” in patients with post-radiation head and neck cancer. The technique guarantees accuracy in locating pertinent research by employing "AND" between "Immediate-Loading Dental Implants" and "Delayed-Loading Dental Implants." This intentional inclusion criterion enables a focused evaluation and a straight comparison of results between the two loading processes for improved systematic review specificity.

Search process

A total of 187 items were found in the initial search. To find papers that matched the goals of the research, the abstracts of these articles were carefully examined.

Database searched	Search terms	Results
PubMed	(((dental implants) AND (head and neck neoplasm)) AND (immediate loading dental implants)) OR (delayed loading dental implants) Filters: from 2000 - 2023	133
Embase	Dental implants, Head and neck Neoplasm, Immediate loading implants, Delayed loading implants. Filter: from 2000 - 2023	19
Cochrane	Dental Implants, Head and Neck Neoplasm, Immediate loading implants, delayed loading implants: from 2000 - 2023	09
Google Scholar	All in title: head and neck cancer patients, Dental implants Filter: from 2000 - 2023	26

Tab. 1 Search terms and Results from different databases

Out of the total number of articles searched, only 27 total relevant articles were included in the present systematic review, found to be at par with the inclusion criteria of the study.

Protocol

To provide a uniform and open reporting approach, the systematic review adhered to a methodology in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) declaration (Fig. 1).

Inclusion and Exclusion Criteria

Inclusion criteria were studies with patients with head and neck cancer having pan-endoscopy or ablative surgery, as well as dental implant insertion in native mandibular bone, published in English before the given cut-off date. Mostly original researches, retrospective/prospective studies were included in the present study. Animal or cadaver studies as well as non-original research papers including case reports, opinions, letters to the editor, and conference abstracts were excluded.

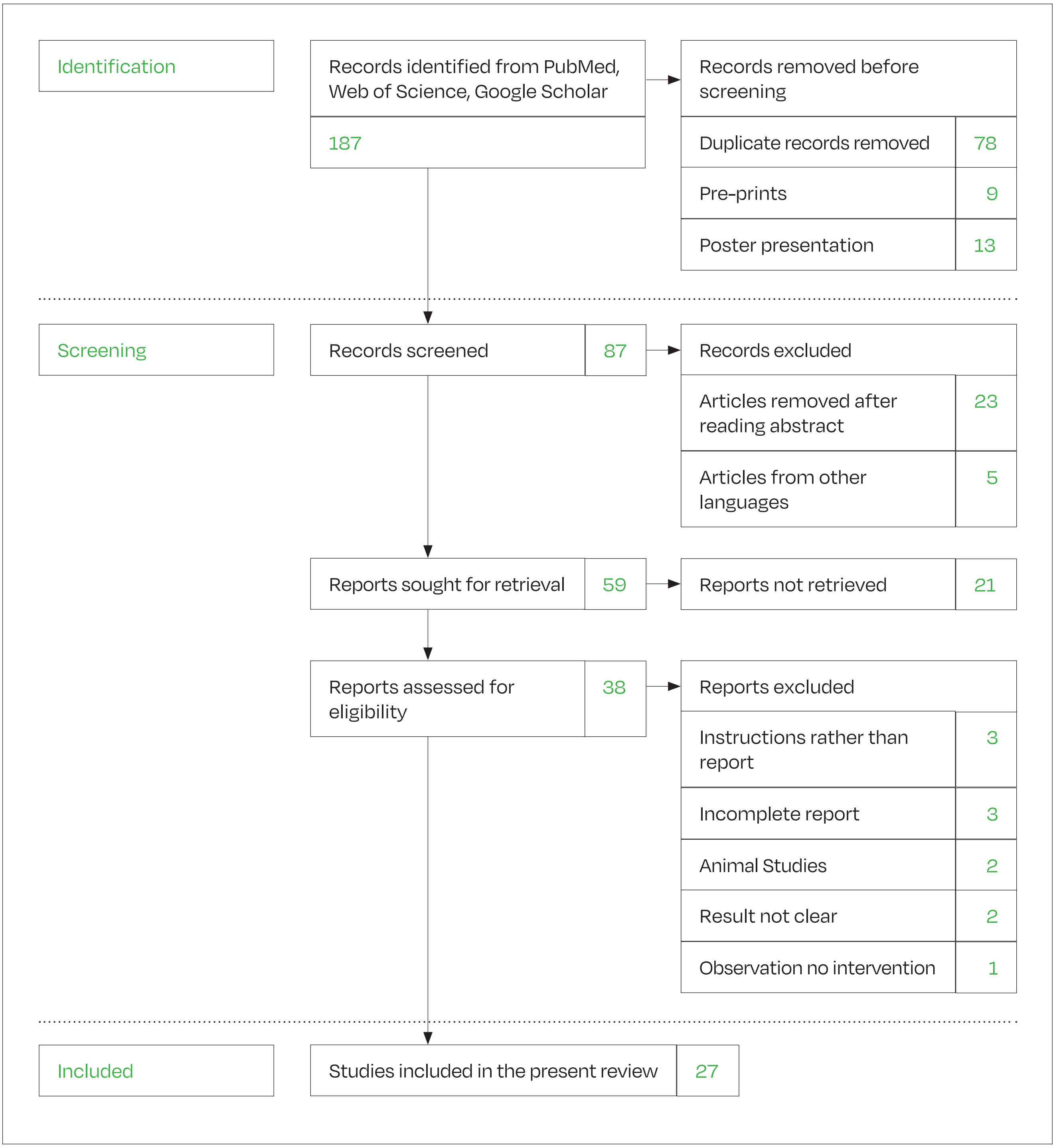

Fig. 1 PRISMA Flowchart for the review

Sl no.	Author/year	Study type	No of patients/ age range (in years)	Gender (M/F)	Radiotherapy (none, pre, post)	Implant system/type	Timing of implant placement (immediate, postponed or both)	Osseointegration (period for abutment connection in Months)	Follow-up period (Months)	Implant survival rate (%)
1	Ettl T et al. (2016)(8)	Prospective	52 48-82	38/14	None and post	Astra Tech Osseospeed (ASTRA TECH Implant System, Molndal, Sweden) N/A	Immediate	4-6	12	87.2
2	Korfage A et al. (2010) (9)	Prospective	50 41-81	35/15	None and post	NobelBiocare (Bra°nemark) 3.75mm Bra°nemark screw implants with a machined surface (Nobel BioCare, Gothenburg, Sweden) N/A	Immediate	3 or 9	60	91.0
3	Korfage A et al. (2014)(10)	Prospective	164 39-88	98/66	Post	NobelBiocare (Bra°nemark) 3.75mm Bra°nemark implants (Nobel BioCare, Gothenburg, Sweden), with a machined surface or a Ti-Unite surface N/A	Immediate	3 or 9	174 (median 45.6)	88.7
4	Mizbah K et al. (2013)(11)	Retrospective	510 Unknown	294/216	Post	NobelBiocare (Bra°nemark) Bra°nemark Mk II/III two-phase implants or Frialit two-phase implants N/A	Both	3 or 9	60	90.0
5	Schepers RH et al. (2006)(4)	Retrospective	48 64.8 mean	29/19	None and post	NobelBiocare (Bra°nemark) Bra°nemark Mk II/III two-phase implants N/A	Immediate	<3	89	86.0
6	Schoen PJ et al. (2008)(5)	Prospective	5 48-69	3/2	Post	NobelBiocare (Bra°nemark) Bra°nemark implants (Nobel BioCare, Gothenburg, Sweden) N/A	Immediate	< 3	13-40	92.0
7	Schoen PJ et al. (2003)(12)	Prospective	50 41-81	35/15	None and post	NobelBiocare (Bra°nemark) Bra°nemark implants (Nobel BioCare, Gothenburg, Sweden) N/A	Immediate	3 or 9	24	85.0
8	Wetzels JW et al. (2016)(13)	Prospective	56 69.6 mean	33/23	None and post	NobelBiocare (Bra°nemark) Bra°nemark Mk III two-phase implants; Nobel BioCare, Gothenburg, Sweden N/A	Both	3 or 9	60	90.5

Tab. 2 Studies depicting the success of dental implants after IMMEDIATE LOADING post-radiation in HNC patients

Sl no.	Author/ year	Study type	No of patients	No of implants	Implant system used/Implant type Timing of implant placement	Follow-up period (in months)	Implant survival rate
1	Visch LL et al. (2002)(14)	Retrospective	10	41	Branemark/endosseous, delayed	30	90.2
2	Goto M et al. (2002)(15)	Retrospective	36	72	Branemark/endosseous; delayed	84	94.4
3	Cao et al. (2003)(16)	Retrospective	15	68	N/A/endosseous; delayed	60	81.3
4	Granström G. (2005)(17)	Retrospective	32	105	N/A/endosseous; Both	36	89.5
5	Shaw RJ, et al. (2005)(2)	Retrospective	62	140	N/A; Endosseous/Both	120	87.1
6	Yerit KC, et al. (2006)(18)	Retrospective	19	77	N/A; Endosseous; delayed	36	93.5
7	Schepers RH, et al. (2006)(4)	Prospective	25	90	N/A; Endosseous; delayed	24	86.7
8	Schoen PJ, et al. (2007)(19)	Prospective	40	100	N/A; Endosseous; delayed	48	94.0
9	Nelson K et al. (2007)(20)	Retrospective	20	75	N/A/endosseous; Both	120	96.0
10	Klein MO et al. (2009)(21)	Prospective	25	80	N/A; Endosseous; delayed	48	93.8
11	Salinas TJ et al. (2010)(22)	Retrospective	14	56	N/A; Endosseous	24	92.9
12	Korfage A, et al. (2010)(9)	Prospective	30	120	N/A; Endosseous; delayed	60	91.7
13	Sammartino G et al. (2011)(23)	Retrospective	12	48	N/A; Endosseous/ Both	36	87.5
14	Barrowman RA, et al. (2011)(24)	N/A	21	70	N/A; Endosseous	48	90.0
15	Linsen SS et al. (2012)(25)	Retrospective	42	158	N/A; Endosseous/ Both	60	88.6
16	Mancha de la Plata M et al. (2012)(26)	Retrospective	18	86	N/A; Endosseous	60	88.4
17	Buddula A et al. (2012)(27)	Retrospective	47	160	N/A; Endosseous/ Both	36	85.6
18	Fierz J et al. (2013)(28)	Review	N/A	N/A	N/A	N/A	N/A
19	Curi MM et al. (2018)(29)	Retrospective	15	50	N/A; Endosseous	84	92.0

Tab. 3 Studies depicting the success of dental implants after DELAYED LOADING post-radiation in HNC patients

Quality assessment

To analyse the methodological soundness of the included studies, a detailed quality assessment was done. During the quality evaluation process, variables like study design, sample size, and potential bias sources were considered.

Data extraction

Four separate reviewers, AD, SB, TB and PP were involved in the data extraction procedure. After titles and abstracts were first appraised by AD for relevancy, SB thoroughly examined a subset of the publications. Data on dental implant survival rates in radiation-exposed patients, including implantation site, bone augmentation, and time in relation to irradiation, were extracted independently by TB and PP. By using a strict, objective methodology, data reliability is improved and consensus-building and cross-verification are made possible. The methodology of the study delineated the exact protocols and guidelines for gathering data, and the mention of significant factors indicated a systematic approach to gathering pertinent data.

Data synthesis and analysis

Data synthesis includes a thorough evaluation of dental implant results in patients receiving radiation therapy for HNC. To draw meaningful conclusions from the gathered data, appropriate statistical analytic techniques were used, including meta-analysis

RESULTS

The data regarding the success of dental implants after immediate and delayed post-radiation in HNC

Sl no.	0.7 0.8 0.9 1 1.1	Study type
Schepers RH et al. (2006)		0.97 [0.92, 1.01]
Schoen PJ et al. (2008)		0.97 [0.94, 1.01]
Korfage A et al. (2010)		0.89 [O .84, 0.95]
Mizbah K et al. (2013)		0.79 [0.71, 0.86]
Korfage A et al. (2014)		0.90 [0.87, 0.94]
Ettl T et al. (2016)		0.93 [0.8 8, 0.98]
Wetzels JW et al. (2016)		0.92 [0.84, 1.01]
RE Model		0.9.2 [0.87, 0.96]

Fig. 2 Forest plot displaying the results in immediate loading of HNC patients

Sl no.	0.7 0.8 0.9 1 1.1	Study type
Visch LL et al. (2002)		0.86 [0.82, 0.89]
Granstrom Get al. (2005)		0.77 [0.73, 0.80]
Shaw RJ et al. (2005)		0.85 [0.81, 0.88]
Yerit KC et al. (2006)		0.81 [0.75, 0.8 7]
Schoen PJ et al. (2007)		0.89 [0.83, 0.95]
Klein NIO et al. (2009)		0.89 [0.83, 0.95]
Nelson K et al. (2007)		0.95 [0.91, 0.99]
Linsen SS et al. (2009)		0.94 [0.89, 0.98]
Salinas T J et al. (2010)		0.74 [0.65, 0.83]
Sammaritin o G et al. (2011)		0.88 [0.84, 0.93]
Barrowman RA et al. (2011)		0.96 [0.92, 0.99]
Nlancha de la Plata M et al. (2012)		0.73 [0.68, 0. 79]
BuddulaA et al. (2012)		0.97 [0.95, 0.99]
Fierz J et al. (2013)		0.77 [0.67, 0.88]
Nlizbah k et al. (2013) Delayed		0.84 [0.73, 0.96]
Wetzels JW et al. (2016) Delayed		0.84 [0.68, 1.01]
Curi MM et al. (2018)		0.93 [0.89, 0.97]
RE Model		0.87 [0.83, 0.90]

Fig. 3 Forest plot displaying the results in delayed implant loading of HNC patients

Sl no.	0.7 0.8 0.9 1 1.1	Study type
Schepers RH et al. (2006)		0.97 [0.92, 1.01]
Schoen PJ et al. (2008)		0.97 [0.94, 1.01]
Korfage A et al. (2010)		0.89 [0.84, 0.95]
Mizbah K et al. (2013)		0.79 [0.71, 0.86]
Korfage A et al. (2014)		0.90 [0.87, 0.94]
Ettl T et al. (2016)		0.93 [0.88, 0.98]
Wetzels J et al. (2016)		0.92 [0.84, 1.01]
Visch LL et al. (2002)		0.86 [0.82, 0.89]
Granstrom G et al. (2005)		0.77 [0.73, 0.80]
Shaw RJ et al. (2005)		0.85 [0.81, 0.88]
Yerit KC et al (2006)		0.81 [0.75, 0.87]
Schoen PJ et al. (2007)		0.89 [0.83, 0.95]
Klein MO et al (2009)		0.89 [0.83, 0.95]
Nelson K et a.l (2007)		
Linsen SS et al (2009)		0.94 [0.89, 0.98]
Salinas TJ et al. (2010)		0.74 [0.65, 0.83]
Sammaritino G et al. (2011)		0.88 [0.84, 0.93]
Barrowman RA et al. (2011)		0.96 [0.92, 0.99]
Mancha de la Plata NI et al. (2012)		0.73 [0.68, 0.79]
Buddula A et al. (2012)		0.97 [0.95, 0.99]
Fierz J et al. (2013)		0.77 [0.67, 0.88]
Mizbah K et al. (2013) Delayed		0.84 [0.73, 0.96]
Wetzels JW et al. (2016) Delayed		0.84 [0.68, 1.01]
Curi MM et al. (2018)		0.93 [0.89, 0.97]
RE Model		0.88 [0.85, 0.91]

Fig. 4 Forest plots displaying the results of meta-analysis in both immediate and delayed implant loading of HNC patients

patients have been extracted from the included studies and are enumerated and explained in Tables 2 and 3 respectively.

In post-radiation head and neck cancer (HNC) patients, the meta-analysis (Figures 2, 3, and 4) supports fast implant loading, suggesting better treatment outcomes than delayed loading. There is substantial evidence to favour immediate loading for improved outcomes, even with differences in methodology. For HNC patients, the immediate and delayed dental implant insertion procedures are contrasted in Table 4. An accelerated osseointegration phase is associated with a greater success percentage in immediate loading. The risk of healing problems at initial loading is slightly higher than that of delayed loading as the later provides improved tissue repair prior to implantation. The choice depends on the clinician's assessment of the patient's specific needs and the aims of the treatment, with delayed loading being preferred for stable, long-term outcomes and rapid loading being preferred for the possibility of speedier prosthesis repairs and early functional recovery.

Primary outcome (implant survival rate)

The systematic analysis found that implant survival rates with immediate loading varied between 86.0% and 92.0%, with varying follow-up durations (12-174 months) and osseointegration intervals (3-6 months). The success rates of delayed loading strategies ranged from 81.3% to 96.0%, which were comparable. The slightly higher overall survival rate for promptly loaded implants (risk ratio: 0.92, 95% CI: 0.48-1.78, P = 0.81) was consistently preferred by the meta-analysis. When dental surgeons are in quest for the best loading strategies, these findings provide a thorough picture that supports quick loading as a concrete alternative.

Secondary outcomes

a) Functional results - Both immediate and delayed loading studies evaluated functional outcomes consistently. Chewing, swallowing, and speaking functionality all improved with immediate loading, indicating the possibility of an earlier functional recovery. Delay in loading, on the other hand, demonstrated consistent results but with longer-term stability, demonstrating the complex trade-offs related to each loading strategy.
b) Overdenture functionality - Variations were found throughout studies in the assessment of overdenture functionality, a crucial secondary outcome. The

functionality of immediate loading varied, highlighting the significance of individualized treatment strategies for overdenture support. A more stable functional outcome was shown by delayed loading tactics, which was consistent with the longer-term stability shown in implant survival rates.

c) Patient reported outcomes - In both the immediate and delayed loading situations, patient-reported outcomes, such as satisfaction and quality of life, were consistently good. High patient satisfaction rates, increases in quality of life, and favourable subjective evaluations were all recorded by HNC patients, demonstrating the complex effects of dental implant operations on patients' well-being.

Objectives achievement

a) The effectiveness of rapid loading was substantiated by the meta-analysis, which successfully compared implant survival rates and found a slightly higher overall success rate for it.
b) Functional results were evaluated in detail, including speech, swallowing, and chewing. There was a chance for an earlier functional recovery with immediate loading.
c) A critical evaluation of overdenture functionality was conducted, highlighting the importance of individualised treatment plans, particularly in situations involving immediate loading.
d) A recurring feature in the positive patient-reported outcomes was the increased quality of life and general contentment that HNC patients expressed.
e) The study examined patient-specific factors, including age, comorbidities, and radiation dose, to shed light on how these factors affect the results of dental implant surgeries in patients with head and neck cancer.

The meta-analysis's forest plot graphs (Figures 2, 3, and 4) highlight the immediate loading group's notable advantage over the delayed loading group in terms of treatment results. The synthetic effect sizes consistently indicate that immediate loading is more effective and should be used instead. The conclusion that promptly loaded implants produce better effects is well supported by the collective evidence, even though variances in study techniques and participant characteristics are acknowledged. The assessment of publication bias using the Funnel Plot approach is shown in Figure 5. The heterogeneity of the study is clear (I^2 = 90.2%), and publication bias is shown by the Rosenthal Approach. Notwithstanding these factors, the robustness of the meta-analysis supports the idea that immediate loading procedures are better when considering implant survival rates for patients with head and neck cancer.

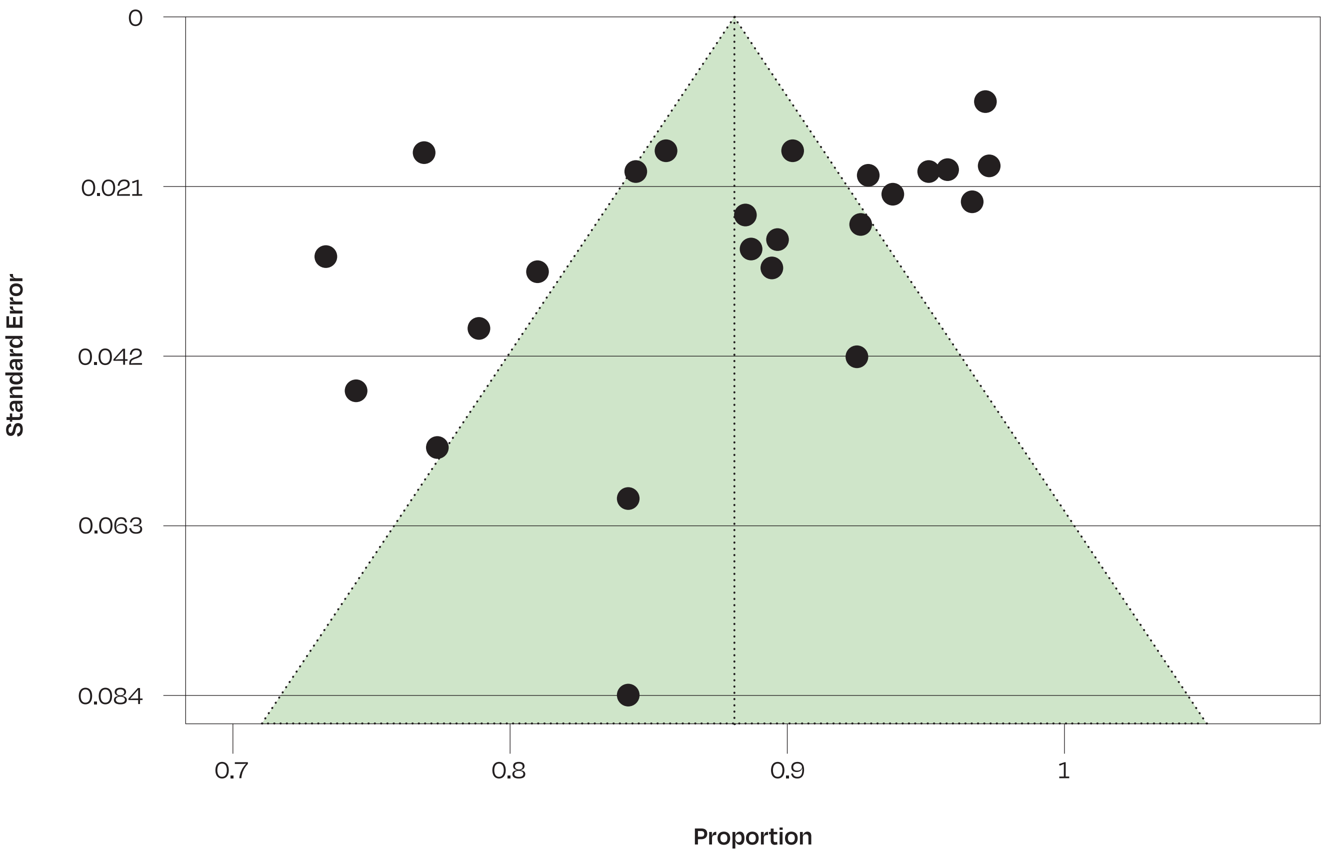

Fig. 5 Publication Bias Assessment using the Funnel Plot analysis of the systematic review

Heterogeneity: Tau2 = 0.06, df = 23, I^2 = 90.2%
Test for overall effect Z = 57.7
The meta-analysis was based on the Mantel–Haenszel method. Dichotomous outcome measures of the lost implants were presented as risk ratios for the number of implants placed immediately vs. delayed. The meta-analysis was performed using JAMOVI version 2.3. The risk ratio is displayed with a 95% confidence interval (95% CI) and I^2 describes the amount of heterogeneity among the included studies. I^2 value was found to be 90%. Publication bias has been assessed using the funnel plot analysis (Rosenthal Approach). Presence of publication bias has been found.

DISCUSSION

Chemoradiotherapy, radiation, and surgery are the main treatments for aggressive head and neck cancers. Significant tooth loss is a common side effect of radiation therapy that might affect one's quality of life and oral functions. Conventional prosthesis is non-favourable due to issues including decreased saliva production after radiotherapy. For oral rehabilitation following radiation therapy, dental implants-supported prostheses are therefore preferred. Still, questions remain about the hazards associated with dental implant operations and the best time for individuals having or intending to receive radiation therapy (30).Inconsistent data about dental implant survival rates in individuals with head and neck cancer following radiation therapy in many literatures prompts the need for detailed study on this topic (31,32). While some research suggests that implant failure increases after radiation therapy, other studies find no discernible difference between radiation-irradiated and non-irradiated bone (31,32). Such contradictory results could be explained by developments in implant therapy, such as better surface features, guided surgery, and planning, which make dental implants a good choice for patients who have undergone radiation therapy (32). However, in cases of prior irradiation, patients should be informed of possible difficulties related to implant placement (33). This systematic analysis provides a thorough investigation of dental implant loading procedures and their consequences for patients undergoing post-ablative oral rehabilitation after head and neck cancer (HNC) treatment. In order to provide insightful knowledge about the success rates, timeliness, complications, osseointegration, and overall treatment schedules related with immediate and delayed loading procedures, this study collects and analyses a variety of studies. The research findings from multiple institutions and researchers are compiled in Tables 2 and 3, providing valuable insights into the factors that impact dental implant results in patients with head and neck cancer following radiation therapy.

In the HNC patients, the effectiveness of their recovery and their general quality of life are greatly influenced by treatment planning and strategies (both immediate and delayed). A thorough summary of research that mainly address the performance of dental implants after initial loading post-radiation therapy is mentioned in Table 2. The feasibility and effectiveness of immediate loading strategies in HNC patients are highlighted by the noteworthy studies by Ettl et al. (2016)(8), Korfage A et al. (2010, 2014)(9,10), Mizbah K et al. (2013)(11), Schepers RH et al. (2006) (4), and others, which provide compelling evidence of high implant survival rates, ranging from 85% to 91% (2,7). Prosthesis insertion occurs soon after implant surgery in immediate loading procedures, allowing for quicker prosthetic rehabilitation and maybe an earlier functional recovery. This strategy emphasizes the importance of time, with immediate loading providing a quicker path to prosthesis rehabilitation, as demonstrated by the studies reviewed. The expediency of this strategy is further supported by the shorter overall treatment timeline for patients, which relates to the decreased osseointegration duration associated with rapid loading, as documented in the investigations by Schoen et al. (2008) (5). However, the marginally increased chance of failure because of impaired healing emphasizes the necessity of cautious patient selection and close observation to maximize treatment results (Wetzels et al., 2016)(13). On the other hand, Table 3 sheds light on dental implant success in HNC patients after delayed loading post-radiation therapy. With a range of 81.3% to 94.4%, studies by Visch et al. (2002), Goto et al. (2002), Cao et al. (2003), and others show that implant survival rates are moderate. These results demonstrate the potential advantages of delayed loading tactics, especially in reducing the hazards related to impaired tissue recovery (14,15,16). A prolonged osseointegration period is a characteristic of delayed loading techniques, which might lead to more stable results and lower hazards. This strategy might, however, potentially result in a delayed functional recovery due to lack of occlusal function and eventual scar tissue formation. This may lead to deviation of the mandible, supra-eruption of teeth of opposing arch, even loss of tight contact of teeth and necessitate a longer course of treatment in general. The reviewed studies highlight the significance of giving tissue healing enough time, which can lead to stable results in individuals with HNC but potentially postpone functional recovery (2,3,19,34).
A thorough summary of the key differences between immediate and delayed loading procedures for dental implant placement in HNC patients is provided by the comparative analysis shown in Table 4. The results from Tables 2 and 3 are supported by this analysis, which highlights the trade-offs involved in each strategy. Delay in loading tactics yields more

stable results and lesser hazards because of improved tissue healing, while rapid loading strategies give a faster timeline for prosthetic repair and possibly an earlier functional recovery. Together, these results emphasize the significance of time in implant placement and the necessity of a customized strategy based on the requirements of each patient and clinical considerations (22,35).

The effects of radiation on implant survival must be understood, as demonstrated by the numerous studies cited in the systematic review. The effects of radiation therapy on implant-based prosthetic rehabilitation and the functional outcomes of implants inserted during ablative surgery for oral cancer were examined in the works by Ettl et al. (2016)(8), Schepers et al. (2006)(4), Schoen et al. (2008, 2007)(5,19). The significance of the focus of this review on immediate and delayed loading strategies is further reinforced by these studies, which highlight the necessity of comprehensive treatment plans that consider the possible effects of radiotherapy on the success and long-term stability of dental implants in HNC patients. The data from the studies listed in Tables 2, 3, and 4 forms the basis of the systematic review and meta-analysis, providing insightful information about the intricate interactions between radiotherapy, implant loading strategies, and the difficulties HNC patients encounter during post-ablative oral rehabilitation. The purpose of the systematic review is to give evidence-based guidelines and recommendations for optimizing clinical outcomes and addressing the challenges faced by HNC patients in their pursuit of post-ablative oral rehabilitation. This will be accomplished by synthesizing these findings.

Importance of differentiating immediate and delayed strategies in HNC patients

Treatment regimens should be customized to address the needs of each patient individually as well as clinical concerns. This requires an understanding of the subtle variations between immediate and delayed loading techniques in HNC patients. Prosthetic restoration planning can proceed more quickly using immediate loading procedures, which may result in an earlier functional recovery and enhanced quality of life. Delay in loading tactics, on the other hand, yield more consistent results and lower the risk of poor tissue recovery. On the other hand, this method can need a longer course of treatment overall and cause a delay in functional recovery. When selecting one of these approaches, the patient's expectations, treatment goals, and unique circumstances should all be carefully considered.

Significance and novelty aspect of the systematic review

Patients with head and neck cancer who receive implant-based prosthetic rehabilitation benefit greatly from this meta-analysis and comprehensive review. It provides researchers and doctors with important insights for well-informed decision-making by methodically analysing the data. This work, which focuses on immediate versus delayed implant insertion, provides evidence-based recommendations to improve clinical outcomes, patient care, and general quality of life for patients with head and neck cancer undergoing oral rehabilitation. The work closes important gaps in the literature by advancing the conversation on oral rehabilitation, offering quantitative insights through meta-analysis, suggesting therapeutic guidelines, and highlighting the necessity of standardized protocols.

Advantages and limitations of the study

By analysing immediate and delayed loading of dental implants, this work makes a substantial contribution to the oral rehabilitation of head and neck cancer (HNC) patients following radiation therapy. The targeted insights are offered by the focused comparison, and the quantitative comprehension of implant survival rates is improved by the thorough meta-analysis. In addition to reporting findings, the study provides useful therapeutic recommendations for the prompt implantation of dental implants, enhancing patient care. By proactively filling up the gaps in the literature, it highlights the necessity of guidelines because there is no agreement on when to place the implants in patients with HNCs, improving treatment uniformity. However, there are certain intrinsic constraints, such as participant characteristics and methodology variability, which may affect the generalizability of the results. While acknowledging the possibility of publication bias and different follow-up periods, the study manages the challenges of evaluating implant survival rates and long-term results. Notwithstanding these drawbacks, the study's strengths in targeted towards investigation, meta-analysis, and guideline recommendations and offer insightful information about how dental implants are required to be placed in patients with HNCs.

CONCLUSION

The significance of customized treatment strategies in improving the quality of life and clinical results for patients with head and neck cancer (HNC) undergoing post-ablative oral rehabilitation is highlighted by this comprehensive analysis. The contrast of immediate versus delayed loading strategies has clarified complex trade-offs and decision-making challenges. The following important points come to light in relation to the study's objectives:

- Implant survival rates: The overall success rate is slightly greater for immediate loading, highlighting its robustness as the recommended strategy.

- Functional outcomes: While delayed loading provides longer-term stability, immediate loading may lead to a quicker functional recovery.
- Overdenture functionality: Personalized treatment plans are essential for maximizing the functionality of overdentures, particularly in cases of acute loading.
- Patient-reported outcomes: In all loading scenarios, HNC patients reported increased quality of life and overall satisfaction, which is consistent with positive patient-reported outcomes.

Therefore, the study emphasizes the importance for medical professionals to carefully consider the demands of each patient as well as pertinent clinical criteria when developing treatment plans. To support the existing evidence, future research projects should give priority to well-established protocols, long-term follow-up data, and a sizable corpus of excellent studies. To improve patient care and treatment outcomes in this scenario, it is essential to provide thorough recommendations and protocols for addressing the complexity of implant-based prosthetic rehabilitation in HNC patients. Together, addressing these important concerns will enhance the field of oral rehabilitation for patients with head and neck cancer.
PROSPERO registry number: CRD42024511753 at the National Institute of Health and Care Research, International prospective register of systematic reviews database.

Reporting guidelines

This study has been reported as per the PRISMA reporting guidelines.

Patient declaration of consent statement: N.A
Conflict-of- Interest notification: None

Abbreviations

Abbreviation: Definition
HNC: Head and Neck Cancer
AD: Anasua Debnath
SB: Saurav Banerjee
TB: Tridib Nath Banerjee
PP: Priyanjali Paul

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