# Radiation Therapy Unveiled: Oral Mucosal Changes, Histopathology, And Effects on Dentition and Histopathological Alteration.

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***Abstract*—Radiation therapy is a key modality in the management of head and neck malignancies, but it is associated with a range of oral complications that can significantly impair function and quality of life. Ionizing radiation induces both acute and chronic changes in oral tissues, particularly affecting the mucosa, taste buds, musculature, and bone. Acute effects are most commonly seen as mucositis, characterized by painful inflammation and ulceration of the oral mucosa, which interferes with eating, speech, and oral hygiene during treatment, along with taste disturbances such as dysgeusia, hypogeusia, and ageusia due to direct damage to taste receptors. Over time, chronic complications may develop, including mucosal atrophy, submucosal fibrosis, trismus resulting from muscular involvement, and osteoradionecrosis of the jaw, all of which contribute to long-term functional limitations. These adverse effects are largely dose-dependent and often require prolonged management; therefore, early dental evaluation, implementation of preventive strategies, and a coordinated multidisciplinary approach are essential to minimize complications and improve overall patient outcomes.**

***Index Terms*—Radiation therapy, Mucositis, Xerostomia, Dysgeusia, Dental caries and Osteoradionecrosis**

## I. INTRODUCTION

Radiation therapy [RT] for head and neck cancers effectively targets tumors but frequently causes collateral damage to healthy oral tissues, including the mucosa, teeth, and bone. Acute complications like painful oral mucositis and dysgeusia often impair nutrition and speech, sometimes requiring interruptions in cancer treatment. Chronic effects include rapidly progressing radiation-induced caries and trismus, a permanent jaw stiffness caused by muscle fibrosis. A severe late-stage risk is osteoradionecrosis, where irradiated jawbone becomes non-viable and fails to heal post-injury. These multifaceted complications extend to periodontal disease and neurosensory changes, significantly deteriorating long-term oral health and function. Consequently, a multidisciplinary approach is vital for managing these persistent structural alterations and improving patient quality of life.

Table 1: Modified Classification of effects of radiation therapy on oral cavity [1].

| Acute effects | Chronic effects |
|---|---|
| Oral mucositis | Dental alterations |
| Taste dysfunction | 1. Teeth<br>Effect on odontogenesis<br>o Dental caries<br>o Periodontal problems<br>Pulpal changes |
| Infections | Osteoradionecrosis |

## II. ORAL MUCOSITIS

Radiation Induced Oral mucositis [RIOM] is characterised by inflammation and ulceration of the oral mucosa along with the production of pseudomembranes; it is a potentially fatal source of infection. Over 40% of cancer patients suffer from this illness, which is a common and excruciating side effect of radiation and chemotherapy. Erythema is the first symptom, which is followed by white desquamating plaques that hurt to the touch. The more severe type of mucositis, pseudomembrane and ulceration, is caused by epithelial crusting and a fibrin exudate. Following RT exposure, RIOM, a typical tissue injury that lasts seven to ninety-eight days, begins as an acute inflammation of the tongue, throat, and oral mucosa [2].

Diagnostic Criteria:

Oral mucositis may be classified into five grades according to the World Health Organization grading system, as follows:[3]

Grade 0 - indicated absence of mucositis

Grade 1 - presence of a painless ulcer, erythema or mild sensitivity; grade

Grade 2- presence of painful erythema or ulcers that do not interfere with the patient's ability to take food; grade

Grade 3 - confluent ulceration that interfere with the patient's ability to take solid food; and Grade 4 - severe symptoms requiring enteral or parenteral support

Pathophysiology

In 1998 a new theoretical model was described for the pathophysiology of radiotherapy-induced mucositis, the pathophysiology of oral mucositis was described as having four interdependent phases, as follows [4];

Phase 1:[Vascular\Inflammatory phase]

During the first phase, pro-inflammatory cytokines, including interleukin 1 (IL-1) and the tumour necrosis factor a (TNF-a), are produced and mediate a local response to therapy, followed by apoptosis and cell damage. The dynamic biological cascade results in injury to the mucosa, frequently presenting as ulcers, with a pseudomembrane. Cytokines are responsible for causing direct tissue damage, dilation of blood vessels and other inflammatory effects, all of which increase the deposition of cytotoxic drugs on the mucosa. These effects mediate the transition to the next phase [4]

Phase 2:[Epithelial phase]

The second phase (epithelial phase) is related to the previous model of direct stomatotoxicity in which cytotoxic agents inhibit the replication of epithelial basal cells, leading to a reduced capability for tissue renewal [4].

Phase 3:[Ulcerated\Bacteriological phase]

The third phase (ulcer with infection) derives from trauma on the epithelium, which at this point is thinner and atrophic due to chemotherapy. It is further postulated that bacterial colonization of ulcerated surfaces increases the quantity of pro-inflammatory cytokines in the mucosa, which facilitates systemic infection in a myelosuppressed host [4].

Phase 4:[Repair phase]

The repair phase takes place after 2 to 3 weeks in non-myelosuppressed patients that receive no further therapy. Secondary infection may delay healing of mucosal lesions. Larger and deeper ulcers usually require more time to heal [4].

Histopathology And Microbial Shift:

It exhibits juxta epithelial intense inflammatory infiltration, atrophy of the epithelium, and little vascular injury. Mucoid degeneration and collagen homogenisation are examples of degenerative alterations. The submucosa will progressively become more fibrotic, less vascular, and contain more collagen. Actinomyces and veillonella are reliable indicators of severe delayed healing of oral mucositis.

## III. TASTE DYSFUNCTION

The taste dysfunction is associated with altered mucosal function of taste buds on tongue [5].

Clinical Features

The taste alteration can be varied spectrum from ageusia to hypergeusia.

Ageusia: The complete loss of taste sensation for all primary tastants—sweet, sour, salty, bitter, and umami .

Dysgeusia: A distorted perception of a taste stimulus, such as food tasting metallic, salty, or foul [6].

Hypogeusia: A reduced or diminished sensitivity to taste stimuli .

Hypergeusia: An abnormally increased or enhanced sensitivity to taste [7].

Phantogeusia: The perception of a taste (often bitter or metallic) in the absence of any external stimulus; also referred to as a "taste phantom" [8].

Grade 0 Same taste acuity as before treatment

Grade 1 Mild loss of taste acuity, but not inconvenient in daily life

Grade 2 Moderate loss of taste acuity, and sometimes inconvenient in daily life

Grade 3 Severe loss of taste acuity, and frequently inconvenient in daily life

Grade 4 Almost complete loss of taste acuity

Pathophysiology

Transport Loss: Tastants (food molecules) cannot reach receptors due to a lack of saliva (Xerostomia) or physical barriers like oral inflammation (Glossitis)[10].

Sensorineural Damage: Direct injury to taste buds or their 10–14 day regenerative cycle. This is often caused by Zinc deficiency (impairing the growth protein gustin), Radiotherapy, or viral infections like COVID-19 that damage supporting cells [11].

Neural Interruption: Damage to cranial nerves (CN VII, IX, X) via trauma or surgery prevents signals from reaching the brain. Notably, many "taste" complaints are actually Retronasal Olfactory (smell) failures [12].

RADIATION CARIES

Contrary to conventional caries, radiation caries (RC) is an aggressive and highly destructive type of dental decay that exhibits distinctive patterns [13]. Smooth surfaces that are typically resistant to decay, especially the incisal edges and cervical regions (the cementoenamel junction), are where lesions usually begin to develop.

1. Diagnosis and Clinical Presentation

Appearance: Early lesion shows diffuse enamel discolouration (brown to black), often smooth and hard without cavitation , which may mask severity.

Progression: Rapid advancement with enamel chipping, crazing, and circumferential decay at the tooth neck, potentially amputating crowns and leaving root stumps [14,15].

Pattern: Heavy dark dentin pigmentation, generalized erosion of occlusal/incisal surfaces, and widespread cervical decay (most common) [16].

2. Etiopathogenesis: A Multifaceted Mechanism

A complicated "cluster of oral symptoms" brought on by both direct damage to dental tissues and indirect alterations to the oral environment are responsible for Radiation caries [17].

A. Indirect Impacts: Microbial and Salivary Alterations

Salivary Dysfunction: Radiation drastically reduces salivary flow, making it thick and ropy [18], which disrupts natural cleansing and buffering.9iu76Chemical Changes: Saliva pH drops from ~7.0 to ~5.0, weakening its buffering capacity and promoting enamel/dentin dissolution.

Microbial Shift: Rise in acidogenic and cariogenic microbes like Streptococcus mutans, Lactobacillus, and Candida species [19,20], worsened by soft, carb-rich diets due to mucositis and dysphagia.

B. Direct Effects: Hard Tissue Damage from Radiation

Structural Degradation: Radiation weakens enamel–dentin bonds, reduces microhardness, causes microcracks, and degrades collagen at the DEJ [21].

Dose-Response: Tooth damage increases with radiation dose — minimal below 30 Gy, 2–3× risk between 30–60 Gy, and 10× risk above 60 Gy [22].

ORAL MUCOSAL INFECTIONS AND COMPLICATIONS IN CANCER THERAPY

Oral mucosal infections and associated complications represent a significant burden for patients with head and neck cancer (HNC) undergoing intensive treatments like radiotherapy (RT) and concurrent chemoradiotherapy (CCRT) [23,24]. These conditions often lead to a notable decline in oral health and overall quality of life [24].

1. Oral Candidiasis: Prevalence and Presentation

Oral candidiasis is one of the most common fungal infections encountered in irradiated HNC patients, with colonization rates potentially reaching 90–100%

Incidence: The clinical incidence of oral candidiasis has been observed at approximately 53.5% throughout the course of radiotherapy .

Microbiology: Confirmation of fungal colonization increases during treatment, rising from 39.5% before RT to 65.9% during the midpoint of therapy .

Clinical Presentation: Patients typically present with pseudomembranous candidiasis (scrapable white oral thrush), mucosal redness, oral pain, and a burning sensation [23].

2. Diagnostic Challenges and Risks

A primary clinical challenge is distinguishing oral candidiasis from radiation-induced oral mucositis, as both conditions share symptoms like severe oral pain

Diagnostic Accuracy: Relying solely on clinical signs often leads to underestimation; clinical diagnostic accuracy is only about 50–52% during and after treatment when compared to fungal cultures

Independent Risk Factors: Key factors increasing the risk of fungal colonization include advanced age, the use of concurrent chemoradiotherapy (CCRT), and the application of 2% viscous lidocaine solution [23]

3. Chronic Complications

Beyond immediate infections, long-term radiotherapy effects include tissue fibrosis and restricted mouth opening (trismus) due to damage to masticatory muscles, as well as degenerative disorders of the temporomandibular joint (TMJ) and osteoradionecrosis [24].

EFFECT ON TEETH

Ionizing radiation administered during childhood, particularly for the treatment of head and neck cancers, can lead to severe and irreversible disturbances in dental development [25,26]. The extent of these anomalies is primarily determined by the age of the child at the time of exposure, the radiation dose, and the specific stage of odontogenesis (tooth formation) occurring during treatment [27,28].

Primary Developmental Anomalies

Radiation affects both the quantitative (number and size) and qualitative (structure and composition) aspects of teeth [29].

- Agenesis and Hypodontia: Exposure during early stages of development (morphodifferentiation) can destroy the dental germ, leading to the complete absence of permanent teeth (agenesis) [29].
- Microdontia: Radiation can cause teeth to develop with abnormally small crowns [29].
- Root Malformations: This is the most common anomaly, often characterized by root stunting, thinning, or complete arrest of root development . Morphologically, roots may appear short, blunted, or V-shaped [30].
- Enamel and Dentin Defects: Ameloblasts (enamel-forming cells) are highly sensitive; even doses as low as 10 Gy can cause permanent damage, leading to enamel hypoplasia or hypocalcification [28]. Radiation also alters the mineral composition and hardness of dentin and enamel [31].

Critical Risk Factors

The severity of dental late effects is highly dependent on several treatment-specific variables: [Table-2]

| Factor | Impact on Dental Development |
|---|---|
| Age | Children irradiated under age 5 are at the highest risk for severe defects [Hypodontia, Microdontia, Enamel hypoplasia]. |
| Dosage | Cranial radiation exceeding 24 Gy is strongly associated with significant dental abnormalities [Brittle enamel, Dehydration in dentin, Discolouration in teeth]. |
| Field of Radiation | Teeth located within or even near the edges of a radiation beam (receiving up to 45% of the dose) are most vulnerable. |

Late Oral Complications

Beyond structural development, survivors often face secondary oral health challenges:

- Xerostomia: Damage to the salivary glands leads to reduced salivary flow and increased acidity, further accelerating tooth demineralization [32].
- Radiation-Induced Caries: Rapidly progressing decay, often starting at the cervical (neck) or incisal edges, caused by both direct tissue damage and indirect changes in saliva [32,33]

## IV. CONCLUSION

Radiation therapy to the head and neck produces significant changes in the oral mucosa, primarily due to damage to rapidly dividing epithelial cells. These effects commonly manifest as mucositis, ulceration, erythema, and increased susceptibility to infections. The severity depends on radiation dose, duration, and individual patient factors. Chronic changes may include mucosal atrophy, fibrosis, and reduced healing capacity. These alterations can impair oral function, nutrition, and overall quality of life. Therefore, early

prevention, careful monitoring, and supportive management are essential to minimize complications and improve patient outcomes.

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