

Radiation Induced Caries

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ABSTRACT

Oral cancer is the sixth most prevalent cancer worldwide comprising about 85% of all head and neck cancers. Radiation therapy is a widely used treatment modality for oral cancer that uses ionizing radiation as a therapeutic agent. Radiation caries is a late complication of radiation therapy in head and neck cancer patients. It is a form of rampant caries characteristically occurring at the incisal or the cervical portion of the tooth and wrap around the tooth in an apple core fashion. It is a lifelong threat and imparts a negative impact on the quality of life of patients. Apart from oral micro flora and diet, salivary changes also play a major role in inducing radiation caries. For an effective prevention and treatment, dental professionals should have an in depth comprehension about the factors involved in the development and progression of the disease. This paper reviews the literature pertaining to radiation induced caries and discusses pertinent risk factors associated with radiation caries and suggests methods for management.

Key words: dental caries, fluorides, radiation, saliva.

INTRODUCTION

It is reported that among all the different types of cancers diagnosed worldwide, nearly 6% is constituted by head and neck cancer. [1] Radiation therapy plays an imperative role in the management of head and neck cancer. [2] Ionising radiation is employed in this modality and is generally used as an adjuvant primary therapy to surgical treatment combined with chemotherapy or as a palliative treatment for advanced or inoperable tumours. [3]

Based on the location of malignancy, sometimes it becomes essential to include the salivary glands, oral mucosa and jaws in the radiation treatment portals. This results in radiation induced changes in these tissues. [4] The resulting oral sequelae lead to extensive problems throughout and after radiation therapy resulting in undesirable

severe dento-oral issues [5] which in turn influence the patient's quality of life. [6] This paper reviews the effects of radiation on hard tissue and the consequent radiation caries and its management.

Effects on tooth structure

Even as low as 0.50 Gy of high-energy x-ray radiation, can impart remarkable reduction in the mechanical properties in enamel and dentin. [7]

a) Enamel

Clinically evident radiation effects result from alterations in both organic and inorganic compounds in the enamel. The preliminary damage from irradiation is reported to occur in the organic portion of the enamel, that is, in the interprismatic space. Reduction in water content caused by irradiation is considered to be a cause for disruption of mechanical properties of

enamel. Irradiation results in oxidation of water molecules to hydrogen peroxide and hydrogen free radicals which denature the organic components. This results in impaired mechanical properties and integrity of the enamel. [8]

Studies have shown that a cumulative dose with 30 and 60 Gy resulted in morphological changes in the enamel structure, characterized by an increasingly disorganized prismatic structure. One of the suggested factors associated with the increased risk of dental caries following radiation therapy is this alteration in the enamel crystalline structure. [8]

b) Dentino Enamel Junction (DEJ)

The odontoblast process usually ends in front of the DEJ whereas in non-irradiated teeth the activity of odontoblasts extends well into the enamel. In sound tooth, DEJ exhibits sharp contours whereas in irradiated teeth it is diffuse, damaged and unstable. Irradiation reduces the anchoring between dentin and enamel and leads to formation of gap in between. [7]

c) Dentin

Irradiation reduces the microhardness and stability of dentin, which could be attributed to the changes in organic components within the dentinal tubules. Water content of dentin is 12% by volume, this enables an increased production of free radicals and hydrogen peroxide as a function of radiation. These compounds denature the organic content of dentin, thereby decreasing the internal stability of this tissue. [8]

Some studies have shown signs of substantial demineralisation in extracted vital teeth 6-8 months after radiotherapy. In these studies, a normal formation of refractory dentin and intra-tubular dentin were detected suggestive of a normal odontoblast activity. In a study done on extracted third molars which were irradiated up to 31.5 Gy, no measurable destruction of collagen was detected. [7]

d) Other changes

Some investigators have reported that decalcification occurs more quickly in

irradiated teeth than non-irradiated teeth, while others noted no differences in the decalcification rates. Few authors have reported decreased enamel and dentin solubility after therapeutic radiation. It has been shown in other studies that ionizing irradiation of dental enamel does not have any influence on its permeability and organic component. [2]

RADIATION CARIES

Aggressive and extensive caries, commonly known as radiation caries result in rapid decalcification of enamel in irradiated patients. This is attributed to the synergistic effect caused by changes in the chemical constitution of saliva and increased amounts of cariogenic oral bacteria. Radiation caries tends to spread to all dental surfaces, changing the translucency and colour of dental tissues. [9]

Radiation-induced changes of teeth were mentioned by Tribondeau and Recamierl as early as in 1905. [10] In 1939, del Regato postulated that "radiation caries" is caused by a loss of salivary function. [11] Oswald and Röttke described the correlation between subclinical lesions and irradiation-induced caries. [12] One of the highest indirect and late effects of radiation in the head and neck region is radiation-related caries or "radiation caries". [8]

Definitions

It is defined as a rampant form of dental decay that occurs in individuals who receive a course of radiotherapy that includes the exposure of the salivary glands. [13]

The development of rampant caries in patients undergoing radiation therapy in the head and neck region is referred to as radiation caries. [14]

Predisposing factors [15]

The type and extent of the caries depend on the following factors.

a) Original susceptibility to caries: Higher the pre irradiation caries activity, more the vulnerability to post radiation caries.

b) Gingival recession with exposure of root surface (cementum): Gingival recession with exposed root surfaces is more

prone for developing cervical caries, following radiation.

c) Status of oral hygiene: Severe mucositis and xerostomia result in heavy plaque formation and initiate caries of all surfaces. In such cases rampant caries with extensive destruction of the teeth will be initiated by the time of termination of irradiation.

d) Dietary alterations during irradiation: Because of discomfort caused by mucositis, patients change from a coarse detergent diet to a soft adhesive one. The high content of carbohydrate in soft diets produce heavy plaque. Plaque rich in carbohydrate, along with xerostomia correlate with a high cariogenic effect in these patients. [15]

Etiology and Risk factors

The incidence and severity of radiation-induced changes within the teeth vary individually, depending on the patient's age, actual radiation dose, size of radiation exposure field (position and actual size of the tumour), patient's general condition and additional risk factors, like alcoholism, smoking and malnutrition. [16]

The effects of radiation therapy on the onset and progression of a caries lesion might be direct or indirect. The indirect effects of radiation include changes in the quality and quantity of saliva, difficulty in performing proper oral hygiene, increased intake of cariogenic foods, and changes in the oral microbiota where as the direct

effects include damage to enamel and dentinal tissues, whereby invariably affecting their properties. [8]

The initiation of radiation caries as a direct or indirect effect of irradiation on teeth, or to both is debatable. The current opinion still is that radiation caries is mainly due to salivary gland damage resulting in hypo salivation. The development of radiation caries is not dependent on the presence of teeth in the field of irradiation, but dependent on the presence of main salivary glands within the radiation field. Thus, collectively, hypo salivation-related alterations in microbial, chemical, immunologic, and dietary parameters of cariogenicity contribute to an enormous increase in the caries challenge in irradiated patients. [2]

It is reported that dental caries risk increases secondary to a number of factors, including shifts to a cariogenic flora, reduced concentrations of salivary antimicrobial proteins, and loss of mineralizing components. [17] Increased colonization with *Streptococcus mutans* and *Lactobacillus* species is found to be associated with increased caries risk. [16] In dry mouth patients, both the coronal enamel and the cervical area, where cementum or dentin is directly exposed to the oral environment, are areas at risk. [2]



Fig a) Pre radiation [18]



Fig b) Post radiation [18]

Suggested causes of radiation caries [19]

1. Reduction in the quantity of saliva
2. Reduction in the quality of saliva
3. Changes in taste perception requiring consumption of highly flavoured foods
4. Changes in nutritional status requiring consumption of highly calorific foods

5. Ecological changes to oral microbiota

Direct radiation damage to dentition

Clinical features

The first signs of deterioration of hard tissue are reported to be visible within 3 months after radiotherapy in the head and neck region. [2] It starts as a diffuse area of demineralization encircling the entire crown of the tooth at the cervical portion and proceeds further to result in amputation of the crown at the gingival margin. It differs from the other types of caries by the site of involvement and quicker rate of progression. [14] In extreme cases, a completely healthy dentition will be lost in one year. [2]

Unlike other types, radiation caries is most commonly found on tooth surfaces that are relatively immune to dental caries. It involves the cusp tips, incisal edges and the cervical areas. The areas just below the contact points seem to be the last areas to be affected by radiation caries. The mandibular anterior teeth, which are normally most resistant to caries, are equally if not more affected by radiation caries. The characteristic attack may be caused by changes in salivary flow and consistency that give rise to accumulation of a highly acidogenic dental plaque on these surfaces, and the result is a rapid decalcification of enamel. [2]

Classification

Clinically, three types of caries lesions have been reported.

a) The first type is a characteristic carious lesion which usually encircles the neck of the tooth completely. Sometimes extension to labial, buccal or lingual surfaces may also be seen. [14] It starts cervically on labial surface of the incisors and canines. Initially, the lesion extends superficially around the entire cervical area of the tooth, and then progresses inward, resulting in complete amputation of the crown. This amputation occurs less frequently in molars; however, the caries tends to spread over all surfaces of the molar with changes in translucency and colour

leading to increased friability and breakdown of the tooth. Infrequently, only a rapid wearing away of the incisal and occlusal surfaces of the teeth is seen with or without cervical caries. [2]

b) The second types of lesions are reported to occur as brown to black discolouration of the crown. [14] It is a generalized superficial defect first affecting the buccal and later the lingual or palatal surfaces of the tooth crowns. The proximal surfaces are affected less. This lesion often begins as a diffuse, punctate defect and then progresses to generalized, irregular erosion of the tooth surfaces. In this type of lesion, decay localized at the incisal or occlusal edges is often observed, resulting in the destruction of the coronal enamel and dentin, especially on the buccal and palatal surfaces. [2]

c) The third type of lesion begins as a spot depression which spreads from the incisal or occlusal edges on the labial or buccal and lingual surfaces. In the due course, enamel shell becomes destroyed and coronal dentin becomes partially disintegrated leaving the crown reduced to an irregularly placed discoloured stump projecting over the gingiva. [14] Heavy brown-black discoloration of the entire tooth crown, accompanied by wearing away of the incisal and occlusal surfaces is seen less frequently. [2]

Techniques in assessing radiation caries

Polarized light microscopy (PLM) is classically used to evaluate dental caries, and can be used an adequate tool to evaluate radiation related caries. The OCT technique is able to characterize radiation-related caries from a morphological point of view. [20] Its potential benefit for use in the clinical monitoring of radiation-related carious process has already been reported in the literature. Ultrasound transmission velocity also analyses the mechanical properties of teeth after *in vitro*, *in situ*, and *in vivo* irradiation. [12]

Management of radiation caries

In the management of patients undergoing head and neck radiotherapy, a multidisciplinary approach is always mandatory.^[18] Once a definitive oncological diagnosis is obtained, dental consultation should be done before the initiation of radiotherapy. The radiation oncologist should provide information such as the location or site of the cancer, its extent, histopathological details, type, duration, dose, and intent of radiation therapy, the area of exposure of radiation and prognosis.^[21] It is important that the dental team be involved early in the patient's treatment in order to facilitate the delivery of appropriate and timely care. The aim of the dental team must be to prevent, reduce or relieve the unpleasant and deleterious side effects associated with radiotherapy and promote the maintenance of good oral health after radiotherapy.^[18]

Dental awareness

As the patients encounter greater difficulties following radiotherapy, high patient awareness and motivation are essential to minimise potentially devastating and endangering dental complications. It is reported that the patient's previous dental history and oral hygiene at the time of the initial dental assessment are reliable indicators for their future adherence to an oral hygiene program.^[18] Patient education includes review of oral hygiene habits and techniques, additional hygiene supplements, current oral hygiene status, side effects of therapy and the consequences of neglect.^[21]

Diet modifications

With time, high carbohydrate consumption may lead to sub-surface decalcification, while the surface layer, which has a lower solubility, remains apparently intact. It is suggested that refined carbohydrates should be replaced with substances such as sorbitol, xylitol, and aspartame and saccharine that are not degraded into organic acids by oral bacteria. Frequent small meals with high calories foods are often advocated by dietitians for patients undergoing radiation. Both patient

and dentist must guard against caries and patients are encouraged to rinse or brush after meals.^[18]

Increase in salivary stimulation and pH

The effects on dentition due to radiation are mainly related to xerostomia. Therefore steps should be taken towards prevention and management of xerostomia.^[2]

The ideal approach to prevent radiation caries would be to avoid radiation-induced hyposalivation caused by damage to the salivary glands. This could be achieved by excluding the major and minor salivary glands from the irradiation field.^[22] It is reported that the use of chewing gum causes prolonged salivary stimulation and increases the bicarbonate levels in saliva, preventing plaque pH from falling, and raises the potential for remineralisation. Sugar-free gum is preferred, but even sugared gum can be beneficial as sugar-containing gum produces a drop in salivary pH for 20 minutes, despite a stimulated salivary flow, but as the flavour and sweetness leech out of the chewing gum, the salivary flow rate is comparable to chewing gum base alone. It has been suggested that chewing sugared gum containing fermentable carbohydrate still exerts a pH raising effect, although this is less than the pH-raising effect of sugarless gum.^[18]

Chewing hard cheese elicits a rapid rise in plaque pH following a sucrose rinse as the proteolysis of cheese proteins such as casein contributes to the pH-elevating effect. It is also reported to raise plaque calcium and phosphate levels and facilitates enamel rehardening. Urea-containing gums and rinses have shown similar beneficial effect.^[18]

Oral hygiene measures

Brushing should be performed with a soft tooth brush reaching all the contours and gingival crevices of the teeth. Fluoridated toothpaste is preferred, although a paste of baking soda and water may also be used.^[18] To reduce the bacterial load on dentition, toothpaste with natural enzymes may be useful. Product containing

lactoperoxidase, lactoferrin, and lysozyme can help balance the natural antibacterial system in saliva. Moreover, because this product is designed for children, it is more tolerable to patients with mucositis and gingivitis following radiation therapy. [23] Recommendations on the frequency of brushing vary widely from a minimum of two times to four times daily after meals and four-hourly during waking hours. [18]

Literature reports that toothpastes containing the detergent and foaming ingredient sodium lauryl sulfate (SLS) may increase the incidence of mucosal irritation and oral ulceration. As alcohol-containing mouthwashes irritate or dry the mucosa, they are not recommended in xerostomic individuals. After brushing, rinsing is performed to eliminate loosened debris. Several rinse solutions have been suggested: hydrogen peroxide saline or hydrogen peroxide and water (1:2 or 1:4 mixture); sodium bicarbonate (one teaspoon in one cup of water or one teaspoon in 500ml water); and half a teaspoon of salt and one teaspoon of baking soda in one litre of water. Sodium bicarbonate rinses are used extensively to elevate salivary pH and buffering capacity. [18]

Unwaxed floss is advised for daily flossing. [21] Flossing may be a problem as some of the patients may have an arm, which becomes the donor site for free flap to reconstruct the surgical defect. The use of flossette or floss pick (short floss held onto tiny plastic holder) may be more effective, as only one hand is required. [23]

Use of topical fluorides

The concentration of fluoride used the frequency of application and the specific fluoride compound employed determines the success of caries prevention programs. [18] Fluoride carriers made out of diagnostic models, which are taken before radiation, helps in efficient fluoride application. [23]

In situations where mucositis has not developed, weekly prophylaxis with fluoridated polishing paste is advocated. [23] Suggested ways to prevent the development of radiation caries are continuing dental care

with daily home fluoride treatment and three-six month dental follow up. Recommended fluoride preparations are 0.4 per cent stannous fluoride, 1.23 per cent sodium fluoride or 1.23 per cent acidulated phosphate fluoride. It is applied using a brush on technique or in a customised tray [18] and should be done for a minimum of 5-10 minutes once daily. [23] Following fluoride use, patient is restricted from rinsing, drinking, brushing, or eating for 30 minutes. It is important to warn patients that early caries may appear in 6-8 weeks if fluoride therapy is stopped. [23]

Studies have shown that combinations of chlorhexidine and fluoride yielded good results in controlling radiation-induced caries. [18] Studies have reported that using a regimen of four topical applications of 1.0 sodium fluoride-1% chlorhexidine solution, and daily rinses with a 0.05% sodium fluoride-0.2% chlorhexidine solution, could achieve complete prevention of radiation caries and remineralization of incipient caries. [23]

The advantages and disadvantages of each preparation are summarised as follows. [18]

Stannous fluoride 0.4 %

Advantages

- Posses cariostatic and antimicrobial properties
- Arrest incipient lesions
- Effective against root surface caries

Disadvantages

- Metallic taste
- Staining of teeth or gingiva
- Low pH

Acidulate Phosphate Fluoride (1.23% gel)

Advantages

- Better tasting than Stannous fluoride
- No staining or pigmentation
- Effective against root caries and erosive demineralisation
- Neutral pH for the acidic oral environment
- No sensitivity of teeth or gingiva
- Pleasant tasting

- Effective against erosive demineralisation

Disadvantages

- Requires a low pH to be effective
- Must etch the tooth surface to be effective
- May damage glass based restorations
- Not as effective as SnF₂ for anti microbial activities

In the majority of head and neck irradiation patients, hyposalivation is irreversible. So the fluoride application should be continued indefinitely, irrespective of the chemical formulation and application method; or else caries will develop within months. [4]

Restoration of teeth with radiation caries

Before the initiation of radiotherapy carious teeth and fractured teeth should be restored. It has been suggested to use a light activated glass ionomer with fluoride - releasing capabilities as the material of choice. If the condition of the patient does not permit definitive dental care the restorative treatment may be deferred to after the radiotherapy, after the caries excavation and temporary restoration. [21]

The task of managing radiation caries can be exceptionally complicated and frustrating. The ideal restorations should be long lasting and have prevention properties against recurrent caries. The performance of conventional glass ionomers is reported to be poorer as compared to amalgam, resin-modified glass ionomer and composite resin restorations. [24]

The restoration of radiation caries can be extremely challenging for a number of reasons. Difficult access to cervical lesions can lead to incomplete excavation of caries. Further, the cavity preparation would be difficult to define and might provide little mechanical retention. [22] It is suggested that, as high occlusal loading negates the use of conventional glass-ionomer cements, dental amalgam over a fluoride-releasing glass-ionomer liner should be used in preference to composite resins. In xerostomic patients, it is not ideal to advocate composite resins because of the risk of marginal gap

formation and recurrent caries underneath. [18]

Common causes of failure of restorations in irradiated patients are recurrent cervical/marginal caries and loss of restorations. It is reported that the placement of more viscous GICs appeared to prevent secondary caries, even when the restorations were subsequently lost. [23] Because of the hampered plaque removal at cervical margins and its susceptibility of caries formation, the use of full-coverage crowns and splints is unsuccessful. The often-prohibitive initial and maintenance costs also contraindicate these treatment modalities. [18]

Finally, root canal treatment may be indicated where necessary to avoid exodontias and its dreaded sequelae of osteoradionecrosis. [23]

CONCLUSION

A careful, constant and thorough understanding of the complications of radiotherapy is necessary in order to undertake measures in every phase of treatment. Radiation caries is a late effect of head and neck radiation treatment. The dental team should be involved at the time of initial cancer diagnosis so that a preventive regimen can be implemented as an integral part of the overall cancer treatment regimen. Prior to radiation therapy, treatment of potentially existing oral infections should be taken care. In addition, application of fluoride acts as an important adjunct for preventing caries. Frequent dental follow-up should be scheduled before, throughout and after the treatment period to deal with complications and re emphasise the oral hygiene measures to be followed. Even after radiation therapy, continued surveillance of the oral cavity and early management of late complications are of utmost importance in the long-term care of the patient.

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