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Research Paper

Radioactivity of Dental Materials

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ABSTRACT
Head and neck cancer comprises a heterogeneous group of tumors arising from the upper aerodigestive tract, para-nasal sinus, salivary and thyroid gland. The optimal management of head and neck cancer requires a multidisciplinary approach in which surgery and radiotherapy are the major treatment modalities. One of the important issues in radiotherapy of head and neck cancer is the presence of dental implants and restorations. Majority of the patients with tumor in the head and neck region consists of non-removable dental restorations. These high-density materials cause alteration in photon dose distribution during radiotherapy and it may expose oral cavity and salivary glands to unwanted radiation.The purpose of this review is to understand about the selection of proper restorative material with minimum density and also about the use of dental guard or a stent in unavoidable situations while doing radiotherapy to minimize its effect.
A PubMed/MEDLINE search was conducted to gather available reports. A total of 25 articles were included which described about the use of different dental restorative materials and also ways to minimize the effect of radiotherapy to adjacent tissues.

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I. INTRODUCTION

Oral cancer is an important health issue in India as it is one of the most common types of cancer affecting a large population. Globally oral cancer ranks sixth among all types of cancer. In addition to this, there are patients with cancer of the nose, nasopharynx, paranasal sinuses and the oropharynx, where treatment involves the oral cavity as well as the head and neck area.

Radiation therapy

Radiation therapy is a type of cancer treatment that uses intense energy beams to kill cancer cells. Radiation therapy most often uses X-rays, but protons or other types of energy also can be used.

The term "radiation therapy" most often refers to external beam of radiation where, the high-energy beams come from a device outside the patient's body that aims the beams at a precise point on the body.

Radiation therapy damages cells by destroying the genetic material that controls how cells grow and divide. While both healthy and cancerous cells are damaged by radiation therapy, its goal is to destroy as few normal, healthy cells as possible. Normal cells can often repair much of the damage caused by irradiation.

II. METHODOLOGY

A PubMed/MEDLINE search was conducted using the terms,"dentalmaterials"and "radioactivity". 358 Articles dated between 1947-2022 were found in the search, out of which 333 articles were excluded because they didn't match with the review criteria. 25 articles were found relevant for the study which included various dental materials, there radioactivity, complications associated and also about the protective stents.

Among cancer patients with tumor in head and neck region, most of them have non-removable dental restorations. These high density materials cause perturbation in photon dose distribution in heterogeneous media when photon beam passes through these structures.[1] During the radiotherapy, oral cavity and salivary glands are exposed to extra doses of this unwanted radiation. Electron and non-particulate backscatter can occur when materials with high atomic number are exposed to high voltage xray beams.

High-energy electron or photon beams are often used in the treatment of head and neck cancer. These treatments are often delivered to a volume of tissue that contains heterogeneous media such as soft tissues, bone, teeth, or metal crowns.[2] The presence of a metal in the radiation field results in a dosage enhancement at the tissue-metal interface.[3] This enhancement is caused by the interaction of ionizing radiation with the atoms of the metal, liberating and setting into motion electrons from within the metal. When high-energy radiation (photons) interact with electron-dense materials, secondary electrons are produced from radiation interaction with these materials such as metals.[4] This is termed "Radiation backscatter" (fig 1) and this results in adjacent tissues receiving an additional, unintended dose.

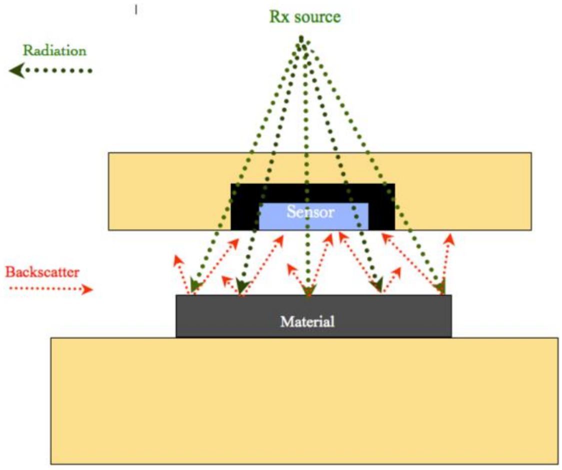

Figure 1 : Digramatic representation of radiation backscatter

The electrons set into motion in a direction that is the same or similar to that of the primary radiation beam are referred to as forwardscatter. Forwardscatter represents an increased dose to areas that lie on the exit site of the primary beam from the metal.[4]

Complications

Electron beam therapy of the head and neck region is well known to fraught with complications, frequently observed in areas which are adjacent to the metallic dental restoration.[5] The therapy beam scatters electrons from the high-Z metals used in the dental alloys, resulting in a local dose enhancement, which leads to excess dose in the surrounding tissues, thus causing mucositis.[6] Other complications include radiation caries and osteoradionecrosis that can be complicated by a severe and intractable osteomyelitis. The latent radiation damage to nonmalignant tissues can range in severity from slight post treatment discomfort to life-threatening necrosis. Manifestations of oral complications from head and neck radiotherapy include xerostomia, loss of taste, changes in oral microflora and salivary chemistry, glossitis, radiation caries, salivary dysfunction, dysphagia, muscle fibrosis, and necrosis. Osteoradionecrosis is correlated to high radiation doses and is a more severe complication, which is difficult to treat for head and neck radiotherapy patients.[4]

Different restorative materials used in dentistry including Zirconia & other types of ceramics, Titanium and its alloys(for dental implants), Gold Alloys, Amalgam, Ni – Cr Alloy, Au- Ag- Pd Alloy, Peek, Glass fiber reinforced composite, Bioactive Glass etc. affect dose distribution in head and neck radiation therapy. The presence of these restorative materials with higher density in the radiation field results in a dosage enhancement.

According to Hatim A Leghuel, backscattered dose enhancement was found to be 60% for amalgam, 30% for zirconia, 20% for Titanium and 10% for Lithium Disilicate.[7] A dose increase by 15% was measured for titanium in the study by Mian et al and an increase by 10% was obtained through extrapolation of the results by Scrimger.[8] Overdoses in the range of 30-70% are suspected when soft tissue in contact with Cu surfaces are irradiated with ^{60}Co photon radiation by Rosengren et al.[3]

Wang et al , in his study, described that in the cpTi implant material, the average backscattered dose enhancement ranged from 14% to 16% for 6 MV x-ray and 13% to 14% for 10 MV x-ray with no bone substitute inserted between the implant sample and the ionization chamber. At a distance of 1 mm from the implant/bone interface, 3% to 4% relative dose enhancement from backscattering was measured for both energies, and 0% to 2% dose enhancement was indicated when measurements were conducted for cpTi material at locations greater than 1 mm away from the implant/bone interface. The backscattered radiation decreased as the distance from the implant bone interface for cpTi increased. For the Ti-6Al-4V implant material, the highest amount of average backscattered radiation for zero bone substitute thickness was 14% for 6 MV x-ray and 12% for 10 MV x-ray. Dose enhancement of 1% from backscattering was recorded with 1 mm thick bone substitute, With bone substitute disks thicker than 1 mm between the ionization chamber and Ti-6Al-4V material, there was no dose enhancement from backscattering for both x-rays.[4]

For single beam irradiation, Farahani et al reported that the dose enhancements on the backscatter side adjacent to the various dental materials were 70% for gold, 60% for Ag-Hg amalgam, and 40% for Ni-Cr.[9]Spirydovich et al also reported an approximately 50% scatter dose increase at the incident surface from dental amalgam (mass density: 8.76 g cm-3) and high-gold alloy (mass density: 11.7 g cm-3).[10] In a recent study, Shimamoto et al. reported increases in the scatter dose from silver-palladium-gold alloy (50% Ag, 20% Pd, 14.4% Cu, 12% Au, 3.6% Ir + Zn + In), Ag alloy (72% Ag, 13% Zn, 9% Sn, 6% In), cobalt-chromium alloy (52% Co, 25% Cr, 14% W, 8% Ga, 1% Al), and nickel-chromium alloy (78.8% Ni, 19.5% Cr, 1.1% Si, 0.4% Fe, 0.2% Al) of 16.6%, 15.8%, 8.5%, and 7.3%, respectively, at the incident surface of the materials. The scattering of doses by pure metals is strongly affected by the atomic number. In the case of dental alloys, the scattered doses are affected by the effective atomic number.[11]

Also, dental zirconia has concentrations of natural radionuclides of the uranium, radium, and thorium series. These radionuclides are impurities present in the zirconia powder, and their presence implies a potential risk to human tissues from radiation exposure.[12]

Since it's not feasible to remove dental implants or any other dental restorations from oral cavity while doing radiation therapy in the head and neck region, its recommended to use protective devices/stents as a preventive measure. These devices are used to displace the position or to shield tissues or to assist in the efficient administration of radiotherapy to the affected areas, thus limiting the post therapy morbidity. The actual success of any treatment is being free of post-operative complications and the post-operative complications hamper the prognosis of the treatment. Therefore it is inevitable to protect the surrounding tissues from radiation exposure.[13]

The need for a radiation stent is determined by the treating radiotherapist. The Prosthodontist can actively help in the rehabilitation of cancer patients by fabricating a whole array of possible prostheses that can be constructed to meet specific patient needs[13]

Radiation stents

Heat cure acrylic resin is commonly used for the fabrication of stents.The alloys used for shielding are Cerroband (50% bismuth, 26.7% lead, 13.3% tin and 10% cadmium).[13] Radiation stents can be classified into various types depending upon its functioning and positioning(fig.2). In this, protecting stents are utilized to shield the vital structures which are abutting radiation treatment locations from overabundance dose of radiation.

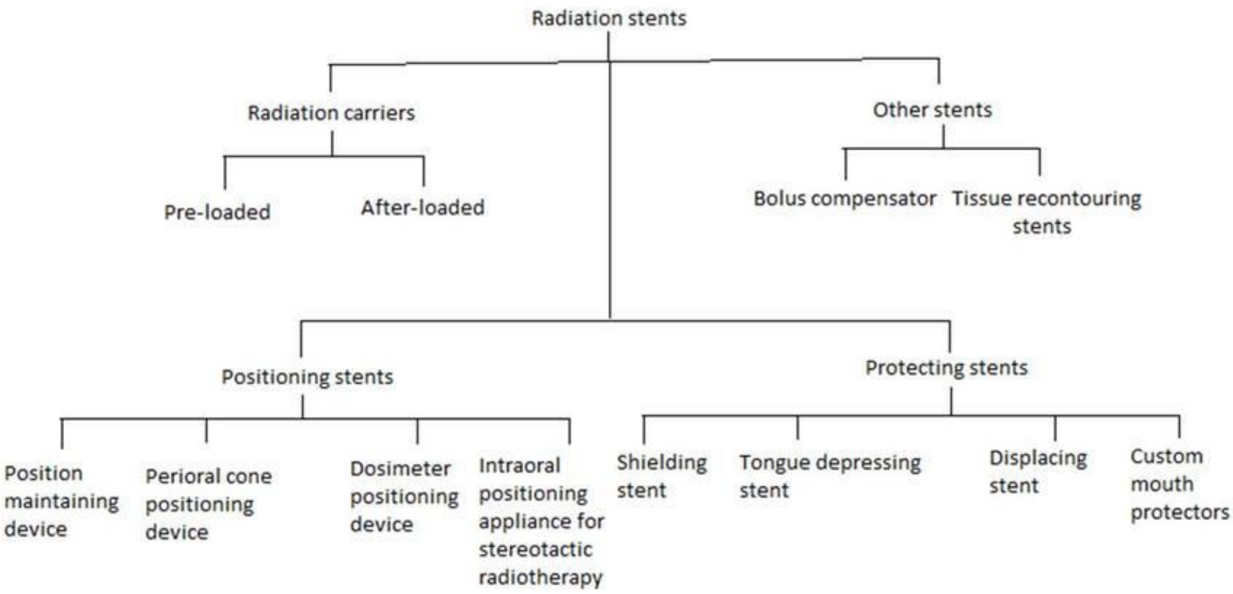

Figure 2 : types of radiation stents

Shielding stents

As the name suggests these stents are intended to shield the vital structures adjacent to the affected tissue from radiation exposure. Failing to protect the adjacent structures leads to their damage and painful complications. Many cases of radiotherapy to treat lesions of the buccal mucosa, skin, alveolar ridge, without any protective measure has led to mucositis and xerostomia. Effective shields can be fabricated to protect the tongue, salivary glands and the opposite side of the mandible. These stents consists of a radio-opaque material placed in such a way that it shields the vital structure from radiation exposure.[13]

Tongue depressing stent

The purpose of this stent is to depress the tongue and prevent it from unwanted radiation exposure. The device additionally positions the mandible and prevents the parotid gland from exposure during radiotherapy. It consists of an interocclusal stent which extends lingually from both the alveolar ridges, with a flat plate of acrylic resin which serves to depress the tongue. They are indicated in carcinoma of tongue, head and neck cancers. If the stents are not placed then it results in lesions of retromolar region, buccal mucosa and tongue predispose to cheek and tongue biting.[13]

Displacing stents

They are used to move or displace the vital structures from the radiation field. It is commonly used in the treatment of tumor involving the alveolus of the mandible, posterolateral borders of the tongue and the buccal mucosa. The stent is designed in such a way that it separates the maxilla from mandible, which prevents maxilla from unwanted radiation exposure.[13]

Custom mouth protectors

Custom mouth protectors find its application greatly in sports-related activities in order to prevent injuries.[13] However, the flexible smooth protectors protect painful edematous mucosal tissues from irritation by tooth surfaces and irritating foods. This protection aids the irradiated patient in maintaining weight and nutritional status during therapy.[14]

Other preventive measures include use of low density material for dental restorations, cotton roll soaked in water to shield mucosa and also placement of bone substitute around dental implants.[15]

III. CONCLUSION

Backscatter radiation is an important phenomenon that needs to be considered when dental restorations are in the beam path. Since dental material can amplify radiation to adjacent tissues, proper material selection with lower density has to be considered.

Prevention is better than cure. So it is always good to prevent the complications before it occurs. The complications will increase the patient’s pain and suffering. So it is better to use individualized intraoral stents which will give promising results in decreasing the adverse effects of radiation therapy. Hence, prior to every case of head and neck radiotherapy, the surgeon and the radiotherapist should consult a Maxillofacial Prosthodontist regarding the ideal selection and fabrication of radiation stent.

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