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Radiation Prostheses: An Overview

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Abstract

Radiotherapy is used as an adjuvant form in treating head and neck tumors along with surgery and chemotherapy. Despite having latest technology, radiotherapy has many post-operative complications. This is because of radiation beyond the tolerance level of healthy tissues around the affected areas. Radiotherapy of head and neck malignancies result in tissue reactions that causes pain, discomfort, deterioration in the quality of life and affect mental well being of the person. Therefore, it is necessary to minimize these complications before it occurs. A Prosthodontist can work with the Radiotherapist in a team, to fabricate specific devices which confine radiation to affected tissues. These devices are positioning stents, shielding devices and radiation source carriers. Radiation stents are artificially fabricated intraoral prostheses that position/shield the tissues to deliver radiation to the desired area during radiotherapy of the head and neck regions. Various types of radiations stents can be given to oral cancer patients to provide better treatment and minimize post-radiation complications. This article is an attempt to present an overview the various devices that can be provided during radiotherapy in the head and neck region.

Keywords: Head and Neck malignancies, Radiotherapy complications, Radiation carriers, Positioning stents, Protection stents.

Introduction

Oral cancer is one of the three most common types of cancers in India posing a significant health problem among general population.[1] The term oral cancer constitutes cancers of the mucosal surfaces of the tongue, lips, floor of the mouth, buccal mucosa, hard palate, and retromolar trigone [2]. Various treatment modalities for head and neck cancers include conventional management with surgery, radiotherapy [external beam radiotherapy (EBRT) and brachytherapy], and chemotherapy [3]. Radiation therapy has been widely used over the past few decades in managing head and neck tumors. Most of the patients with these tumors undergo radiotherapy as a part of their treatment. In some tumors it is the preferred treatment, whereas, in others, it is employed in combination with surgery or sometimes with chemotherapy. An essential concept in head and neck cancer is organ preservation. Instead of depending on major surgery, organ preservation approach first uses chemotherapy and radiation in order to shrink or reduce the tumor size. This refers to lessen the extensive surgery and may even allow some patients not to undergo surgery. According to Radiation Therapy Oncology Group (RTOG) the maximum dose that can be given for head and neck cancers are 66 to 70 Gy extended over 7 weeks. This maximum dose is divided into 33 to 35 fractions and each fraction dose is 2 Gy, 5 fractions are given in a week [3]. Minimum of 6 hour interval is recommended between sequential exposure to facilitate the repair of irradiated healthy tissues from potential lethal damage. Radiotherapy of head and neck lesions are indicated in carcinoma of squamous cell type involving soft palate, lips, tongue, buccal mucosa, primary lymphomas of nasopharyngeal area, adenocarcinomas of salivary glands, carcinomas of upper and lower jaw, carcinomas of piriform sinus, subglottic area etc [4]. Patients undergoing radiation therapy need customized treatment plans. Several factors influence treatment planning, such as the type, size, and anatomical location of the tumor and the potential for the tumor to metastasize [5]. The major disadvantage of radiotherapy is the post-operative complications. To overcome these complications, specific devices are needed to limit radiation to a particular location. A team of specialists work out a treatment plan. Radiation therapist is a certified technician who can help set up patients daily for accurate delivery of radiation prescribed by the radiation oncologist whereas the Radiation oncologist specializes in treating cancer patients using radiation. A Prosthodontist is commonly consulted when custom prosthetic devices are needed to ease the delivery of radiation. These Prosthetic devices are frequently called as stents, splints, shields, positioners or carriers can be used to optimize the delivery of radiation while reducing the associated morbidity.

The effects of radiation therapy can be acute and chronic effects. Acute effects include, mucositis, salivary gland dysfunction leading to increased thirst, dry mouth/xerostomia, burning sensation, difficulties in oral functioning and wearing dentures, altered taste sensation, disturbances in oral microflora leading to bacterial infections, oral discomfort at night. Chronic effects of radiation therapy include, radiation-induced caries, hypersensitivity, pulpal pain, periodontal problems, osteoradionecrosis, dysgeusia, trismus, soft tissue necrosis and fibrosis [6].

Radiation Prosthesis is any prosthesis that helps to administer radiation to the diseased tissues efficiently, and thus limiting the post treatment morbidity [7] . Various materials are used in the fabrication of radiation prosthesis. The most commonly used material for the fabrication of radiation prostheses are Heat cure acrylic resins or self-curing resins. Silicone and Modeling plastic materials are used in emergency cases where there is no time to construct a stent, these materials may be used directly in the oral cavity [8]. Rigid polyester film of thickness of 2 mm softened by using a vacuum lamination machine can also be used to fabricate prosthesis [9].

Shielding alloys are used to protect the normal/unaffected tissue structures from unwanted radiation. Failure to shield the normal structures causes adverse tissue reactions. Tin foil, Lead, Aluminium, Pb-bi-sn (Lead, Bismuth, Tin) alloys, and Wood's metal or Lipowitz's alloy are used as shielding alloys [10]. Lead is a bluish gray metal with melting point 327.4°C , density 11.34 g/cm^3 and molecular weight 207.2 [11] Although lead has been used for shielding, it is no longer used in the prosthesis because of its high melting point. Aluminium is a silvery white ductile metal with atomic number 13, Young's modulus 70 GPa, density 2.70g/cm^3. As a matter of fact when the atomic number decreases the shielding efficiency also decreases, hence it is a weak shielder compared to lead [12]. Wood's metal commonly known as Lipowitz's alloy which are commercially available as Cerrobend (Cerrosafe, Cerrolow, Cerrotru), Bendalloy, Pewtalloy is a eutectic alloy of 50% bismuth, 26.7% lead, 13.3% tin, and 10% cadmium by weight [13]. It is used as high temperature coupling fluid in heat baths , a low-melting solder, and as low-temperature casting metal.

It has a modulus of elasticity 12.7 GPa, and 26.2 MPa of yield strength. Due to its melting point of 140F it can be liquefied and transferred into the prepared cavity. This alloy is effective in shielding the electron beam. The thickness of the Cerrobend alloy should be a minimum of 1

cm so that it can reduce 18MeV electron beam effectively by almost 95%.

Bolus materials are also used when tissues that are to be irradiated are irregularly contoured. Bolus is a material which share same properties as that of tissues when irradiated. It is used at the target site to control the amount of radiation exposure. Several types of bolus materials used clinically are acrylic resin, saline, human collagen, HLA (Glycosaminoglycans polymer), polyethylene glycol, hydrogel acellular human debris, tissue conditioners, waxes and water [14]. Superflab (synthetic oil gel with 1.05 specific gravity, it is based on vinyl plastic containing di-isodecyl phthalate.)[15] also used as bolus material. Most recently used bolus material is a Bolx (BOLX®, Klarity, USA) [16]is a flexible tissue equivalent material. It consists of polyurethane material that encases cured transparent gel. Its degree of radiation absorption is similar to that of body soft tissues to compensate for irregularities of the surface.

Types of Radiation Prostheses

Various radiation prostheses are used by the radiotherapist for treating oral and perioral tissue cancers. They are broadly classified as radiation carriers, positioning stents, protecting stents and others [3,17] (Fig 1).

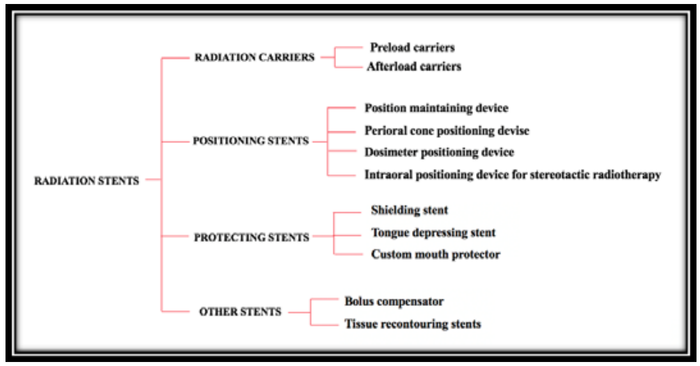

Fig 1: Types of Radiotherapy Stents

Radiation Carriers: are devices that helps to deliver radiation to confined areas. They use beads, needles or capsules in which radiation materials are inserted. Radioisotopes commonly used are of ***Cesium 137* (*Cs*^{137}*),** ***Cobalt 60*** **(Co^{60}), Iodine 135(I^{135}), Iridium 192 (Ir^{192}) Mercury *197* (Hg^{197})[17].** Radiotherapist marks the precise location and the desired number of sources needed on the dental model. The use of radiation carriers has enhanced radiotherapy for squamous cell cancer, adenocarcinomas of salivary glands, carcinomas of cheeks, lower lips, tongue, buccal mucosa and carcinoma of maxilla and mandible.

Radiation carriers are also called as, intracavity applicator, radium carrier, radiation applicator, intracavity carrier, radiotherapy device, carrier prosthesis. They retain the position of radiation source properly in same location till the end of radiotherapy. There are two types of radiation carriers namely, preloaded carriers and after loaded carriers.

In Preloaded carriers, radioactive sources like iridium seeds are sealed within the polyethylene tube and then incorporated into the prosthesis/carrier before it is inserted in the patient [18]. So, this becomes mandatory for the radiotherapist and prosthodontist to deliver the prosthesis immediately, or else the patient and doctor are exposed to unnecessary radiation during plot use the after-load carrier.

After loaded carriers: The carrier is placed in a predetermined position, and then radioactive isotopes are incorporated in the carrier, which allows for quick radiation and reduces the radiation exposure to the handling personnel.

Radiation carriers can be classified as **intracavitary and interstitial devices.** Intracavitary devices are used to carry the radiation sources incorporated in tubes, needles or seeds containing radioactive elements such as cobalt, cesium, iridium close to the site of treatment. Intracavitary devices provide doses of 6500-7500 rads over a period of 6-7 weeks for lesions situated around 6 cms from surface of skin. The interstitial devices provide high dose (20000rads) of radiation for a shorter duration of time for 10-15 hr. Interstitial devices place the iridium seeds within the tumor.[19]

Positioning Stents

These stents allow the radiation oncologist to place the radiation beam correctly whenever multiple treatment sessions are required.

a) **Position Maintaining Stent:** This is used to accurately hold the tissues in position which undergo radiation multiple times. These stents prevent the damage of tissues by displacing them away from radiation. It is used to maintain the position of movable structures like soft palate, tongue, cheeks, lips etc. and prevent unnecessary radiation. The disadvantage of this position maintaining stents is its difficulty in placing, if the patient develops trismus and radiation mucositis.

b) **Peri-oral cone positioning stent**

These stents maintain the intraoral cone in the correct position and directs radiation beam only to the desired area. These cones measures from 3-4 cm. Whenever treating oral lesions, it is necessary that the cone must be placed in continuous contact with mucosa of mouth within total perimeter of ionizing field. Any space between the mucosa and radiation cone can lead to the following two things: First, unaffected tissue around the radiation field gets exposed to radiation. Second, the required amount of radiation to the affected area is decreased by an amount proportional to the square of the distance between tissue and end of metal extension. It is advised to use Cerrobend (a bismuth-tin- lead alloy) around the radiation cone to prevent irradiation of surrounding normal tissues [20,21]. It is used in treating superficial lesions of soft and hard palate, anterior floor of the mouth like carcinoma of piriform sinus squamous cell carcinoma, subglottic area, squamous cell cancer, nasopharynx, lymphoma of tonsils.

Perioral cone positioning stent consists of three parts:

1. The cylindrical cone is made of acrylic resin and is 5-6cm long in which the radiation cone will fit.

2. occlusal indices for dentulous patient and maxillary record base for edentulous patient

3.A small ring made of Cerrobend alloy, which joints the acrylic cone to the denture base [22].

c) Dosimeter positioning stents /Radiation measuring stent:

A device that calculates the amount of dose needed for a lesion is known as dosimeter. These stents are used for measuring the dose that is supplied to affected area and amount of radiation that is needed.

The absorbed dose is calculated by [23],

D= AEave*1.6E-13J/MeV*1E3g/kg

D= Absorbed dose

A=Radioactivity

Eave= Average energy

J= Joule,

MeV= Million electron Volts

E= HxW1

H= Equivalent dose

W1=Weighing factor

Radiation measuring stent holds the dosimeter close to the treatment site thus calculating the radiation exposure. Commonly used dosimeters are lithium fluoride capsules as they are more accurate and efficient. It consists of cured acrylic resin wrapping a 0.1 inch tinfoil inside which lithium fluoride capsule is present. The capsule is pushed out of acrylic resin casing by stainless steel wire through a hole at one end of the stent. The radiotherapist advices the attachment of resin case to the stent [24].

d) Intraoral positioning appliance for stereotactic radiation therapy: Stereotactic radiation therapy is an alternative to traditional radiation and surgery. This is used in delivering fractionated amounts of radiation to the tumor site from various positions. It is used in treating intracranial tumors like acoustic neuromas, meningiomas, craniopharyngiomas and pituitary adenomas. These appliances help the radiotherapist to increase the required dose while decreasing the dose to healthy tissues inorder to combine the dosimetric advantages of stereotactic precision with the biologic benefits of dose fractionation. It is necessary to position the head within the stereotactic space to maintain the accuracy of the treatment [25].

- For verifying the repositioning accuracy, two techniques are available
- 1. Invasive technique
- 2. Non-invasive technique

Invasive techniques: It consists of stereotactic head ring that maintains the head in a required position with the help of screws fixed to the cortical bone of the skull, locking it to the treatment unit.

Noninvasive technique

The intraoral positioning appliance is a noninvasive technique.

It has tungsten spheres of 3mm diameter inserted in the upper occlusal splint. For patients with completely edentulism, the positioner is made over upper denture and indexed to lower denture teeth. In patients without dentures, to attain centric occlusal position the occlusal rims are made on acrylic resin denture bases at correct vertical dimension of occlusion. In palatal area of the upper denture base tungsten spheres are fixed. To verify correct head position orthogonal pairs of radiographs are taken in every treatment session. To confirm the orientation and location of head in stereotactic space, these metal spheres in the palatal area are used as reference points [26].

Protecting Stents

a) Shielding stent

These stents shield the vital structures from radiation exposure which are present near the affected tissue. Failure to shield the normal structures causes adverse tissue reactions. Shielding stents are mainly indicated when a patient is under radiation unilaterally near skin, mucosa of cheeks, alveolar ridge.

It consists of a radio-opaque material that shields the vital structure from exposure to radiation. Lipowitz, Pb-Bi-Sn, are used for shielding as they have low melting points. Lipowitz alloy is preferred due to its effectiveness in preventing the transmission of the electron beam. In this stent fabrication, reservoir /a hollow cavity is filled with Cerrobend alloy, and an auto polymerizing resin is added to seal the alloy in place. The thickness of the Cerrobend alloy should be a minimum of 1 cm so that it can reduce 18MeV electron beam effectively by almost 95% [27].

b) Tongue depressing stent

This stent is to depress the tongue, position the mandible and protect the salivary glands during radiotherapy of head and neck tumors. It has an interocclusal stent on both the ridges with a flat acrylic plate that has a lingual extension depressing the tongue. To establish a reproducible position a hole is created in the anterior region at which tip of the tongue rests. These stents prevent lesions due to tongue and cheek biting in these regions. These stents are used in patients with carcinoma of tongue.[28]

c) Custom mouth protectors

Mucositis is not so uncommon. It appears 2-3 weeks after the initiation of treatment and gets maximum at the end of therapy. Maximum severity is seen at affected site and is so painful leading to weight loss due to dysphagia. This complication is very difficult to treat. In severe cases custom mouth protectors are used. These are flexible smooth devices used to protect the inflamed mucosal tissues from irritating foods and sharp tooth surfaces. They help in maintaining proper weight and nutrition while undergoing radiation treatment. Patients often complaints of hypersensitivity of teeth during treatment because of temperature changes. Topical fluoride gel for 10 to 15 minutes thrice daily can be used in custom mouth protectors to treat hypersensitivity for 4 to 6 weeks. However, these custom mouth protectors are widely used in sports activities to avoid injuries [29].

Bolus compensators

Tissue Bolus Compensators/ Balloon Bolus Supporting Stents are used when tissues that are irradiated are irregularly contoured. Few regions in the field might be left unexposed because of these irregularly contoured tissues, while other areas may develop hotspots (when active sources are placed too closely). Tissue equivalent material called as bolus is placed on irregularities directly helping in conversion of irregular tissue surfaces to flat contours. The central axis of the ionizing radiation is perpendicular to these surfaces thereby resulting in uniform distribution of the radiation [30,31]. The materials such as acrylic resin, water, waxes, tissue conditioners, saline are commonly used. They are mainly helpful in the treating irregular contours and surfaces of superficial lesions.

Tissue Recontouring Stent

This type of stent is successful when treating skin lesions associated with the upper and lower lips. When the radio oncologist adjusts the beam for the midline because of the convex curvature of the lips and face in this region, the dosage delivered will be less at the corners of the mouth. Entire lip is brought in to the same plane by flattening the lip and corner of mouth by using this stent. Such stents often are combined with a shield. They are easily fabricated by forming dental modeling plastic to the desired dimensions. This pattern is invested and processed in acrylic resin [32].

Discussion

Radiotherapy is described as "the therapeutic use of ionizing radiation in the management of neoplasms of the body without surgery, or as an adjunctive palliative treatment after surgery, either in combination with or without chemotherapy" [3]. The types of radiations used in radiotherapy are: 1.electromagnetic radiation (x-rays, photons, gamma rays) which have no charge and mass, 2.particulate radiations (protons, neutrons, electrons). The two modes of radiation therapy are external and interstitial. The External radiation/teletherapy provide doses of 6500-7500 rads over a period of 6-7 weeks for lesions situated around 6 cms from surface of skin. The interstitial /brachytherapy provide high dose (20000rads) radiation for a shorter duration of time for 10-15 hr. Interstitial devices place the iridium seeds within the tumor. It uses radioisotopes (Co60, Cs137, Ir 197) that are positioned in or close to the tumor site [17,18,19]. Some of the oldest literature regarding radiation stents dates back to 1978, obtained from the unpublished works of Schare L in M.D Anderson Hospital, Texas. According to his research, backscatter produced directly adjacent to a metal stent is approximately 74% for Co 60 , 73% for 8 MV x - rays and 35% for 18 MV electrons. He suggests that the effect can actually be reduced by increasing the distance from the alloy. A 6mm thickness of polymethyl methacrylate essentially reduces the backscatter radiation by 10% in 18 MV electrons and 18 MV X-rays whereas by 1% in Cobalt 60.5 [33]. Radiotherapy causes adverse tissue reactions to adjacent structures. These include mucositis, erythema, fungal infections, ulcers, xerostomia, radiation induced caries, which occurs from the decreased salivary flow and pH changes, and also osteoradionecrosis from trauma or infection of bone exposed to radiation, teeth hypersensitivity, dysgeusia, altered oral microflora, and periodontal breakdown [6,34]. Various radiation prostheses are available which reduce or eliminate many oral complications associated with radiotherapy. These include carrier prostheses, shielding stents, recontouring stents, and positioning stents. These devices displace, position, or shield the tissues from the radiation, limiting post therapy morbidity. Auto polymerizing resin is often used in fabricating radiation stents. Silicone is the other material of choice. Shielding metal/alloy may or may not be present in a prosthesis, which depends on following factors such as state of the diseased hard and soft tissues, type of the radiation given, mouth opening ability, and based on requirements of radiotherapist. Radiation stents generally uses a bolus material along with shielding. cerrobend / Lipowitz metal (eutectic alloy consists of 50% Bi, 26.7% Pb, 13.3% Sn, and 10% Cd) is commonly used to shield healthy tissues from radiation exposure.[10,11,35]

With the progress in technology, brachytherapy carriers are fabricated using CT scan. **Van Derhei et al** used CT to fabricate and design customised radiation carrier for a case with nasopharyngeal rhabdomyosarcoma [36]. With the CT scan, the number of patient visits minimized only for thin cut scan with no fitting appointments or anesthesia. In contrast to this conventional methods would require more appointments and is invasive and expensive. Of late rapid prototyping and CADCAM technology are widely utilized. [37]. **Wilke CT et al (2017**) fabricated a tongue-depressing stent by using stereolithography printer [38]. This gives us the advantage of minimizing the patient appointments and avoiding the delay in treatment as it does not require physical presence of the patient. They had chosen a patient with pre-existing diagnostic CT scan with slice thickness of 1 mm through upper and lower dentition [39]. The resultant data is a DICOM data that is converted to an STL file format. The stent is designed using Autodesk Meshmixer (software which is freely available for powerful 3D sculpting and modeling) . The final stent is printed using Form2 desktop stereolithography printer-approved for dental applications having dimensional accuracy of 50–100 μm [40]. **Hong et al (2019)** fabricated a semi-customized tongue displacement device (SCTDD) that is unique for each person which was made by a 3D printer (3DP). They compared and evaluated the dosimetric characteristics of standard mouthpiece (SMP) and SCTDD [41]. The device (SCTDD) has three parts: a tongue displacer, which displaces tongue opposite to the side of the radiation and a mouthpiece, connector with an immobilization mask. By changing the length and thickness of SCTDD Semi-customization was done. The SCTDD designed was printed with 3DP material (Kitchen & Deco, Rokit, Korea) by using a FDM (fused deposition modeling) 3DP (3DISON Multi, Rokit, Korea) printer. Total of two sets of CT scans were obtained one set from patients using SCTDD and other from SMP, Results showed that in SCTDD, when compared to the SMP there is no significant change in tongue volume instead the tongue was displaced from planning target volume. They concluded that SCTDD significantly minimized the radiation dose required in radiotherapy thus decresing the radiation toxicity to the tongue when compared to SMP.A systematic review was conducted by **Asfia et al(2020)** across thirty-eight databases regarding 3D printed immobilisation devices that are patient specific in radiotherapy [42]. Results confined to publications between January 2000 and January 2019. Advantages of these immobilisers include, enhanced patient experience, comfort over conventional methods, and highly accurate. The Disadvantages included are slow process of 3D printing, inaccurate digitization of patient geometry. They concluded that due to insufficient technical knowledge, and uncomparable studies among small samples, further research is needed for supporting the advantages of 3D printing in improving the comfort of patient and also for accurate treatment.

Conclusion

Patients undergoing surgical resection for head and neck tumors affect the quality of life. Radiotherapy plays a vital role in the treatment modalities of oral cancer. A Prosthodontist can provide various intraoral prostheses that reduce or eliminate many oral complications associated with radiotherapy. A team approach by the Radiotherapist in seeking advice from a Prosthodontist for deciding the type of radiation stent needed and its fabrication would benefit the oncological patients. These measures make better treatment and increase prognosis.

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