Review article

Protective and positioning devices in maxillofacial prosthodontics and radiotherapy: Overview

W. El Hawari *, O. Bentahar

Department of Prosthodontics, Faculty of Dental Medicine, University MOHAMMED V, Rabat, Morocco

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ABSTRACT

Background: Radiation therapy (RT) is a common modality of treatment in patients with head and neck cancer, and can cause several oral complications. These mainly include radiomucitis, oral pain, hyposalivation, limitation of mouth opening, and osteoradionecrosis.

There are different intraoral devices aimed at reducing these complications. It can be used in association with the therapy of RT. They are used to protect healthy tissues surrounding the site to be irradiated, carry the radiation source, move away from certain anatomical structures, position certain devices, and to allow tissue remodeling.

The collaboration between the maxillofacial prosthodontist specialist and the radiotherapist is necessary for the design and realization of these devices which differ according to each clinical situation.

This work aims to review and illustrate the different radiation devices used in combination with head and neck radiotherapy and introduce a new device design to protect and remove non-radiation-targeted structures.

Conclusion: The use of maxillofacial devices as a protective and positioning stent during radiotherapy is beneficial and should be systematic if indicated in collaboration with the oncological team.

Background

Radiotherapy (RT) to treat head and neck cancers has long been a standard approach with the objectives of treating the pathology and preserving organ function [1].

External beam radiation therapy (EBRT) in head and neck cancers is indicated as a definitive treatment alone or in combination with chemotherapy, or as adjuvant therapy after tumor resection surgery [2].

Technological advances and alternative approaches have been directed to customize the radiation dose and target volume to maximize therapeutic efficacy while minimizing side effects [3]. However, it is still difficult to protect organs at risk, especially in locally advanced tumors. Brachytherapy may provide an excellent alternative for dose escalation therapy after external radiation [4].

The evolution of brachytherapy followed a sigmoid curve where it reached its peak between 1970 and 1990 [9]. It has got a specific indication and can be used alone (exclusive brachytherapy) or in combination with EBRT [5].

During radiotherapy, movement of intraoral structures remains a challenge requiring the use of oral positioning devices (OPRs) aimed at reducing movement and toxicities [6].

There are different intraoral devices aimed at reducing these complications. They are used in association with radiotherapy and may allow the protection of healthy tissues surrounding the concerned site. They can also be destined to carry the radiation source, move away from certain anatomical structures, position certain devices as well as remodel tissue [7].

This work aims to review and illustrate the different radiation devices used in combination with head and neck radiotherapy and introduce a new device design to protect and remove non-radiation-targeted structures. It is a synthesis that gives the radiotherapist an idea of the types of radiation devices that have already been made, bearing in mind that in addition to standard devices, a device can be manufactured individually for the patient.

Main text

Materials used for making the protection and positioning devices

The elementary material of the intraoral stents should not irritate the

* Corresponding author at: Department of Prosthodontics, Faculty of Dental Medicine, University MOHAMMED V, Avenue Allal Al Fassi, Rue Mohammed Jazouli, Madinat Al Irfane, BP: 6212, Rabat, Morocco.

E-mail address: wijdane.elhawari@um5.ac.ma (W. El Hawari).
oral mucosa. It should be non-toxic, inert, thermo-mechanically resistant, and easy to handle [30]. The materials used for making protective and positioning devices are mainly thermopolymerizable polymethyl methacrylate resin, lead blocks, and Wood’s metal (Cerrobend alloy) [10].

The Cerrobend is widely used for the realization of the blocks of radio-protection [11]; it is commonly used to protect tissues not involved in the irradiation field [12]; It is a fusible eutectic alloy of 50 % bismuth, 26.7 % lead, 13.3 % tin and 10 % cadmium, and represents a low melting point of 70 °C [10, 13], compared with other alloys designed for the same purpose [11].

Another material used for radiation protection is polyvinyl siloxane. Recently a polyvinyl siloxane composite radiation protection system was developed. The two-component base and catalyst material provide a shielding effect similar to that of conventional shielding alloys. The disadvantage of this system is that it produces considerable back-scattered radiation when used alone [14].

Martins and al.’s study evaluated the density and molecular arrangement of different materials. Four materials were selected: Polymethyl (white and black), polymethylmethacrylate (PMMA) polyurethane, and polyvinyl chloride (PVC). The study concluded that PMMA showed the ideal density for making these protective stents [30].

Another material was evaluated in terms of ease of manufacture, cost, and radiopacity, it is an acetate resin (dental D). The material is more expensive and takes a long time to manufacture. It exhibits an interesting property and radiopacity since these devices are evaluated at the time of radiotherapy treatment [16].

**Different types of protection and positioning devices in maxillofacial prosthodontics**

Maxillofacial stents are devices constructed to cover tissue and/or teeth for their protection; carrying drugs and/or radium materials; controlling bleeding or guiding the insertion of dental implants [17].

We can classify them as follows: Radiation carriers, leaded protective devices, Tongue depressing devices, positioning devices, and tissue remodeling devices.

These devices are designed by a specialist in maxillofacial prosthodontics in collaboration with the radiotherapist/oncologist. Depending on the type of tumor and its location, the protocol, and the method of radiotherapy, the radiotherapist’s instructions are given to the prosthodontist for the conception of the appropriate device according to each clinical case.

These devices must be reproducible concerning the positioning of the tissues, they must allow easy insertion and removal, patient comfort tolerance, and stability in the treatment position. They must also be simple in design [18].

A summary table of these devices is presented allowing a simplified synthesis of the most used stents in combination with head and neck radiotherapy (Table 1).

**Radiation carriers**

Brachytherapy is indicated for carcinomas of the cheek, oral mucosa, lower lips, tongue and squamous cell carcinoma, adenocarcinomas of the salivary and mucous glands, and carcinomas of the maxilla and mandible.

Radiation carriers can be used when radiation should be administered to the target site, while minimizing the dose to healthy tissue surrounding. In addition, the device enables to maintain the radiation source in the same location during treatment [19].

Radiation carriers or surface applicators are devices used to place capsules or beads, containing radioactive elements such as iridium192 or caesium132, on the structure target volume to be treated. They may also contain tubes or needles that can serve as a brachytherapy source pathway.

There are two types of radiation carrier devices; pre-charged devices where the radioactive sources are placed and sealed in the carrier (polyethylene tube) [19];

Afterloading applicator is used as a guide; plastic probes are applied close to the tumour or are inserted interstitially into the tumour area. Then it is loaded with the radioactive elements [19].

This guide applicator is loaded, either manually (Manual Afterloading) or using machines (Automatic Afterloading). There are many different models from different manufacturers, based on the dose rate used: pulsed-dose rate or high-dose rate [32]. The manual loading allows use only a low dose rate.

The automatic Afterloading has advantages in terms of radiation protection for patient, radiation oncologist and prosthodontist.

The radiation oncologist determines the appropriate procedure and planning [20], and then proceed with the simulation with a fictitious

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**Table 1** Summary of intraoral radiation stents.

| Type of devices | Type of use | Materials | Advantages | Disadvantages |
|-----------------|-------------|-----------|------------|--------------|
| Radiation carriers | Intraducal or interstitial brachytherapy for bucals macosa, tonsillar pillars, pharynx, maxillary sinus and alveolus | Polymethylmethacrylate resin | Bringing the sources close to the treatment site or directly into the tumor | Radiation exposure for pre-charged carriers |
| Leaded protective devices | Brachytherapy or external beam therapy for skin and oral lesions | Lead or Cerrobend | Protection of healthy tissue | Weight of the stents: source of discomfort of patient |
| Tongue depressing devices | Brachytherapy or external beam therapy for lesions of tongue and floor of mouth | Polymethylmethacrylate resin | -Limitation of mobilization tongue during radiation<br>-Prevention of exposure of the parotid glands to radiation<br>-Reduction of unnecessary doses to adjacent healthy structures<br>-Reduction of the dose of radiation to the tongue, the grade of radiomucositis and the use of opioids | Large size of the device: source of discomfort of patient |
| Positioning devices | Brachytherapy or external beam therapy for lesions of the floor of mouth, mandible, palate, tongue, or oral mucosa | Polymethylmethacrylate resin | -Reduction of the dose of radiation to the tongue<br>-Immobilization of the perioral cone during radiation<br>-Verification of the accuracy of cranial positioning in the stereotactic space | Difficulty of inserting or removing the device |
| Perioral cone positioning devices | External beam therapy for superficial lesions of the floor of the mouth, the hard and soft palate, sinuses, tonsils and nasopharynx | Polymethylmethacrylate resin | Immobilization of the perioral cone during radiation | Patient discomfort |
| Introral positioning device for stereotactic radiotherapy | Stereotactic body radiation therapy | -Tungsten<br>-Polymethylmethacrylate resin | Verification of the accuracy of cranial positioning in the stereotactic space | Complex fabrication technique |
source to calculate the dosimetry of these transporters before the proper treatment [21].

These devices have the advantages of bringing the radioactive source to the treatment site and allowing repositioning and stability during processing. In addition, they minimize the exposure of adjacent tissues due to the speed of the drop in radioactivity.

**Leaded protective devices: (Fig. 1)**

It is a gutter associated with a protective radiopaque material (Cerrobend or lead, etc.) to reduce radiation induced side effects [19]. Its position and design vary depending on the clinical situation [8]. It can be applied alone or in combination with the positioning stents;

The Cerrobend alloy is preferred because of its low melting temperature (70°C) as it prevents transmission of the electron beam. It is the best fitting method when the patient is intended to receive a one-sided dose of radiation. During the manufacturing of this device, a hollow cavity of the required thickness is made, the Cerrobend alloy is then heated and poured into the hollow cavity and it is sealed with acrylic resin [19]; indeed, the concerned site by the protection is dug from a cavity at the thickness of the resin (using a resin cutter), like a tunnel. At this cavity, the metal will be poured. A second technique consists in placing a block of the chosen alloy and arming it with transparent acrylic resin if the case allows. The thickness of this block must be at least 2 mm. This protocol is simulated and illustrated via Fig. 2.

After the realization phase, the prosthodontist teaches the inserting and removing methods to the patient or his /her companion (if the patient fails). The leded protective device is used during the radiotherapy sessions. The radiotherapist should ensure its good positioning (according to the initial verified position).

The advantage of these stents is that they allow the protection of healthy tissue due to the use of lead or cerrobend, which allows the radiation to be absorbed and thus further minimizes unwanted complications.

The disadvantage of this type relates to its weight which could be a source of patient discomfort treatment. Moreover, it requires a completion time that can be significant in some urgent cases.

**Tongue depressing devices: (Fig. 3)**

Tongue depressing devices are commonly used in unilateral radiation therapy to the neck to reduce unnecessary doses to adjacent non-target structures [22]. They help to depress the tongue, position the mandible and prevent exposure of the parotid glands. They are designed as a resin base with an occlusal index that extends to the tongue and a flat plate to depress the tongue. This design allows patient comfort [19].

**Displacement devices or removal devices are used to move the vital structures from the radiation field. They are used in the treatment of tumors involving the mandible, tongue, and oral mucosa. The stents are designed to separate the maxilla from the mandible [19]; A lower position of the tongue and the mandible allows the radiotherapist to move the radiation fields and therefore spare much of the salivary glands from irradiation. The height of the interocclusal base depends on the degree of the oral opening (1/2 to 2/3 of the oral opening) [8 23]. Finally, this position must be reproducible during radiotherapy sessions.**

The use of this type of stent reduces the dose of radiation to the tongue, the grade of radiculitis, and the use of opioids during RT [24]. This allows the distance of the mandible from the field of irradiation by the wedge interposed between the two arches, and maintains a reproducible distance during the treatment. It is an association that we have optimized by making the device illustrated in “Fig. 4”. It allows to protect the maxilla by the leded gutter and at the same time to move the mandible away from the irradiation field and therefore its protection.

The limit of this technique, in our experience, is the difficulty of inserting and removing the devices in patients with oral opening.

**Fig. 1. Leaded protective stents: A case of a carcinoma of the lower lip candidate for external radiation beam therapy.**

**Fig. 2. A – Simulation of the alloy incorporation protocol in the gutter, B – View of the leaded gutter after sealing the cavity (pedagogical models).**

The realization protocol comprises taking maxillary and mandibular impressions, mounting the two primary models on an articulator. The resin bases are made differently depending on whether the patient is dentate or edentulous. Then two layers of resin base are attached to the mandibular registration base to form the part of the stents that will support the tongue. An occlusal index must be incorporated into the registration bases to ensure the stability of the splint and the correct positioning of the mandible [8]. It is possible to add a hole in the anterior segment in which the tip of the tongue is placed to establish a reproducible position [19].

This device should be placed before each radiotherapy session, the radiotherapist should control its repositioning and the position of the tongue.

The advantage of this technique is to allow repositioning of the tongue to limit its mobilization during the treatment and therefore best possible repositioning of the site to be irradiated. In addition, this device protects the tongue from radiation and therefore prevents post-radiation complications mainly candidiasis, and radiomucitis.

The large size of this type of device can constitute a limitation, especially when the patient develops mucositis with increased radiation doses [31].

**Positioning devices: (Fig. 4, Fig. 5)**

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limitations. In this case, the design of other types of stents with different technics and materials must be studied.

Perioral cone positioning devices: (Fig. 6, pedagogical models)

These devices serve to direct the beam to the target area while minimizing the movement of the perioral cone during the radiation phase. They are indicated for superficial lesions mainly involving the floor of the mouth, the hard and soft palate, the sinuses, the tonsils and the nasopharynx [19]. The most commonly used intraoral cones vary from 3 to 4 cm in diameter.

The manufacturing protocol of this device consists of winding the aluminum around the perioral cone. It is used as a separator for the acrylic resin which will then be applied to it (ring 5–6 cm in length), the cone is attached to the maxilla registration base if the patient is edentulous or to an occlusal index if the patient is dentate. The treatment cone is inserted into the positioning device showed in Fig. 5 for the verification of its position [10].

Dosimeter positioning devices: (Fig. 7)

The dosimeter is a device that measures the amount of dose...
administered to a lesion and the amount to be delivered. Lithium fluoride capsules are generally used as dosimeters for their accuracy and efficiency.

These capsules are wrapped in aluminum foil which is wrapped with acrylic resin [19], and constitute a dosimeter positioning device.

Intraoral positioning devices for stereotaxic radiotherapy

Stereotaxic body radiation therapy (SBRT) is a high-precision radiotherapy technique that involves administering a high ablative biological dose in 1 to 5 high-dose fractions [25].

The advantage of intraoral positioning devices is the placement of the head in a reproducible manner in the stereotaxic space [19]. This is an interesting non-invasive technique for verifying the accuracy of cranial positioning.

Regarding the procedure for making these devices, the primary impressions (using irreversible hydrocolloids) are made. Then the models are mounted on an articulator with an increase in the vertical dimension of occlusion from 2 to 3 mm.

The transparent resin is placed at the level of the hard palate and the occlusal surfaces. Then the articulator is closed to have the engagement of the mandibular teeth in the resin.

Then six tungsten spheres (3 mm) are included in the palatal region so that they are placed at least 2 mm apart and positioned so that they do not overlap in the anteroposterior or lateral view. The next step is covering the spheres and adjusting the occlusion [26].

Oral protection devices (customized)

Personalized mouth devices are made in the form of flexible trays to protect against painful mucosal edema characterizing post-radiation mucositis. They are intended for daily application of fluoride gel in the mouth for 10 to 15 min three times a day which eliminates hypersensitivity in 4 to 6 weeks [19].

3D printed stents maintain mouth opening and depress the tongue (MOTD)

3D printed stents maintaining mouth opening and depressing the tongue (MOTD) provide better advantages over other standard stents, noting reproducible positioning and similar movement of soft tissues [27], [Fig. 8].

In these types of designs, diagnostic imaging affects the accuracy of these intraoral devices during treatment with RT.

The choice of materials used in making 3D printed oral stents must be meticulous, it must also be sufficiently rigid, non-deformable, biologically inert, and non-toxic [28].

Modeling and fabrication of intraoral stents with a 3D printer using MED610 polymer resin allow high precision in terms of size and volume under optimal image processing conditions [29].

Conclusion

Intraoral protection, positioning, and removal devices represent efficient tools to provide invaluable assistance to head and neck radiotherapy. Their use during radiotherapy should be systematic if indicated with the concertation with the oncological team. Collaboration between the maxillo-facial specialist and the radiotherapist/oncologist guarantees good treatment for cancer patients.

CRediT authorship contribution statement

W. El Hawari: Conceptualization, Writing. O. Bentahar: Supervision, Reviewing and Editing.
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Consent for publication

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