Evaluation of a device for attenuation of electron release from dental restorations in a therapeutic radiation field

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Statement of problem. For some patients, radiation treatment is a part of tumor therapy in the head and neck area before and/or after surgery. The oral cavity and teeth are thereby frequently exposed to high doses of radiation. In this situation, electronic backscatter from dental materials may damage the surrounding soft tissue.

Purpose. This study determined the degree of absorption and the backscatter effect of therapeutic radiation used in the presence of 4 different dental materials. The efficacy of a protective stent also was investigated.

Material and methods. The influence of 4 dental materials (a high-gold alloy, pure titanium, amalgam, and a synthetic material) on radiation dose distribution was tested on 2 test models that simulated the presence of teeth. An alanine dosimeter was used to make measurements with and without the presence of a protective stent. To verify the results, one of the test models was compared to a computer simulation.

Results. Backscatter effects on the surface of dental materials caused an increase of up to 170% of the radiation dose measured without the materials. The rate of overdose increased with the atomic number of the dental material. The extent of the backscatter effect was a maximum of 4 mm.

Conclusion. The considerable overdose of 170% found in this study suggests that soft tissue surrounding dental restorations should be protected from radiation. The backscatter results indicate that soft tissue could be effectively shielded with a 3-mm synthetic stent. (J Prosthet Dent 2002;87:323-7.)

CLINICAL IMPLICATIONS

Dental restorations within a therapeutic radiation field produce electrons when radiation is administered. Although electron release may result in soft tissue damage, the results of this study suggest that such damage can be minimized with the use of a simple protective stent.

Interdisciplinary care is required in the treatment of cancer patients with tumors in the head and neck region. In addition to close cooperation between cancer surgeons and prosthodontists, consultation with a radiation therapist is needed.[1,2] Modern radiation therapy allows an accurate dose concentration on the tumor.[3-5] In spite of this accuracy, the position of many oral tumors results in the involvement of the mucous membrane of the entire mouth. Curative radiation therapy applies a total dosage of 60 to 70 Gy. Even when the radiation is divided into several exposures, adverse dental effects (damage to the structure of the enamel and dentin, for example) may still occur.[6]

The radiation dose required to destroy the tumor, as well as its effect on the surrounding healthy tissue, must be closely observed. Even when radiation is properly used, side effects cannot always be completely eliminated.[7,8] Changes can result in caries caused by radiation, intraoral mucositis, xerostomia, and even osteoradionecrosis.[9,10] The side effects of radiation are often combined with great discomfort for the patient. Reactions often appear earlier in the oral mucosa than in other cutaneous regions due to the mucous membrane's greater sensitivity to radiation. The varying sensitivities to radiation in the oral cavity also play a role. Sensitivity decreases from the soft palate, over the floor of the mouth and the mucous membrane of the cheek, to the tongue.[3,10]

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Radiation can also cause changes in the teeth. After a tumor radiation dose of 60 Gy, the structure of the tooth substance is altered, which may engender caries.[10] Moreover, the use of modern radiation equipment with photon energies of 5 to 20 MV does not permit effective shielding of parts of the dentition.[11] When high-dose radiation meets metallic material, secondary electrons detach from the atomic shell of the metallic elements and are backscattered. This effect is known as *electron equilibration*. These electrons can negatively affect on the surrounding soft tissue (by causing mucositis, for example). In this way, metallic dental materials and reconstruction plates may modify radiation fields so that peak doses will expose adjacent mucosae to higher levels of radiation than intended.[12,13]

It is known that when radiation passes through a fringe range of varying density (such as bones or mucous membranes) to metal surfaces, a scattered reflection appears.[14] This is followed by a localized overdose of radiation. The overdose is caused by the large number of electrons in denser material, which triggers a greater backscattering effect. Electron density is particularly high in metals.[15] If the surrounding mucous membrane in this area lies directly against the metal surface, it will be exposed to a considerably higher dose of radiation. Until now, damage to the neighboring soft tissues has appeared to be unavoidable.

The aims of the study were (1) to demonstrate on suitable models how dental materials influence the dose distribution of a high-energy radiation field, and (2) to derive the necessary thickness of protective stents from the extent of the backscattered electrons.

MATERIAL AND METHODS

Two experimental set-ups were designed. In the first model, radiation-modifying factors (dose distribution) were measured on a synthetic plate that contained 4 specimens of the same dimensions (10 mm wide × 10 mm long × 2 mm layer thickness). One specimen was made from each of the following common dental materials: a high-gold alloy (Degulor M [70% Au, 13.5% Ag, 8.8% Cu, 4.4% Pt, 2.0% Pd, 1.2% Zn, 0.1% Ir]; Degussa, Hanau, Germany); pure grade 1 titanium (Rematitan; Dentaurum, Pforzheim, Germany); γ2-free amalgam (Amalcap; Degussa); and a tooth-colored synthetic material for provisional crowns (Protemp; ESPE, Seefeld, Germany).

The side facing the radiation source had, as is customary in dentistry, a high-luster finish. An alanine dosimeter system was used. Alanine foils of 0.1 mm thickness were placed directly on the surface of the material specimen. Alanine tablets of 0.5 mm thickness were used 0.5 to 5 mm away from the dental material surface. In order to simulate the soft tissue situation, a 1.0-cm–thick layer of bolus material was placed in the direction of the radiation between the specimens and the radiation. The radiation set-up was covered with polystyrene to guarantee the recording of all possible scatter fractions.

Radiation physical measurements were verified with a computer program. The American Monte-Carlo-calculation method is particularly suitable for this purpose, as it allows simulation of radio-physical processes. For the set-up described above, Monte-Carlo calculations with the code MCNP-4A were performed; the geometry of the measurement set-up and all radiophysical conditions (central beam, material composition, layer thickness of the material, dose, distances) could be simulated.[16]

A second, more clinically relevant set-up was established with the aid of a simulated row of side teeth fixed in a plaster base. This model included a natural, unprepared tooth (first premolar, tooth A); a synthetic (phantom) tooth (second premolar, tooth B); a natural tooth prepared for an interchangeable, duplicated crown (first molar, tooth C); a natural tooth with an amalgam filling (second molar, tooth D); and another natural, unprepared tooth (third molar, tooth E). The prepared first molar (tooth C) contained 3 replaceable crowns of the same form made of varying materials (a high-gold alloy, pure titanium, and a tooth-colored synthetic material). This model was covered with removable protective stents that covered the teeth and were made of a synthetic material (Erkoloc; Erkodent, Pfalzgrafenweiler, Germany). This protective device was deep-drawn and had a layer thickness of at least 3 mm. On this model, the alanine dosimeters were positioned on the surface of the protective stent. Comparative measurements with and without the protective stent were made.

Both experimental set-ups were radiated with the use of a linear accelerator (Linac Mevatron KD 2; Siemens, Concord, Calif.), a common device in radiotherapy. The photon energies used were 6 and 15 MV. A radiation dose of 60 Gy, which is typical for the treatment of squamous epithelia carcinoma in the mouth, was delivered in a single exposure. The selected field size of 20 × 20 cm^2 guaranteed that the entire experimental set-up was included. The direction of the radiation and the radiation dose were the same in all experiments. All experimental measurements were repeated 6 times and analyzed by only 1 person. The maximum error of the system was 7%.

RESULTS

Figure 1 illustrates the relationship between the radiation dose and the distance relative to the dental material. For example, the dose increase in front of the materials was a maximum of 30%, 60%, and 70% for pure titanium, amalgam, and the high-gold alloy, respectively. The synthetic material Erkoloc had no

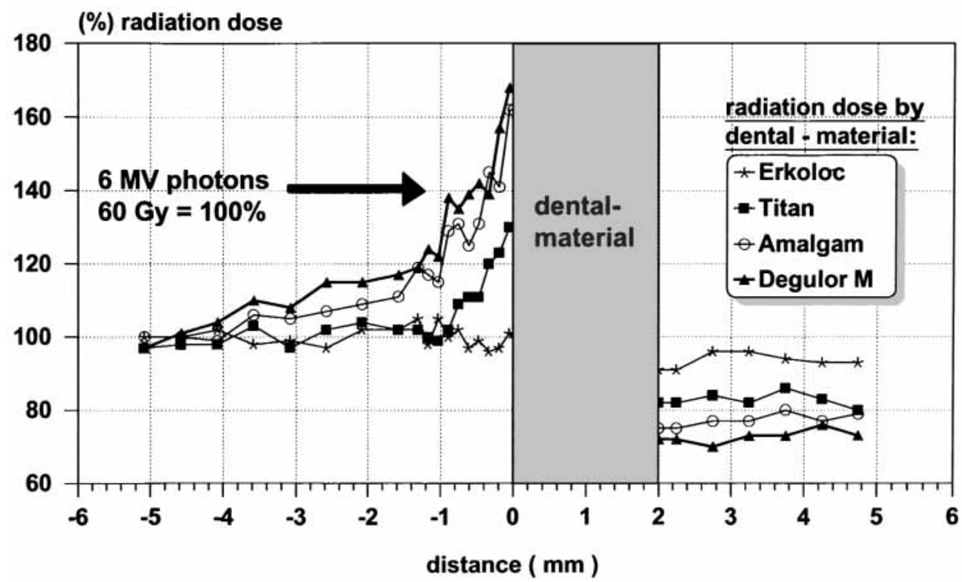

Fig. 1. Radiation doses measured with use of 4 dental materials (each 2 mm thick) with photon radiation at 6 MV. When beam was directed from left to right, backscattering in front of dental material led to dose increase of up to 170%; no dose increase occurred behind dental material.

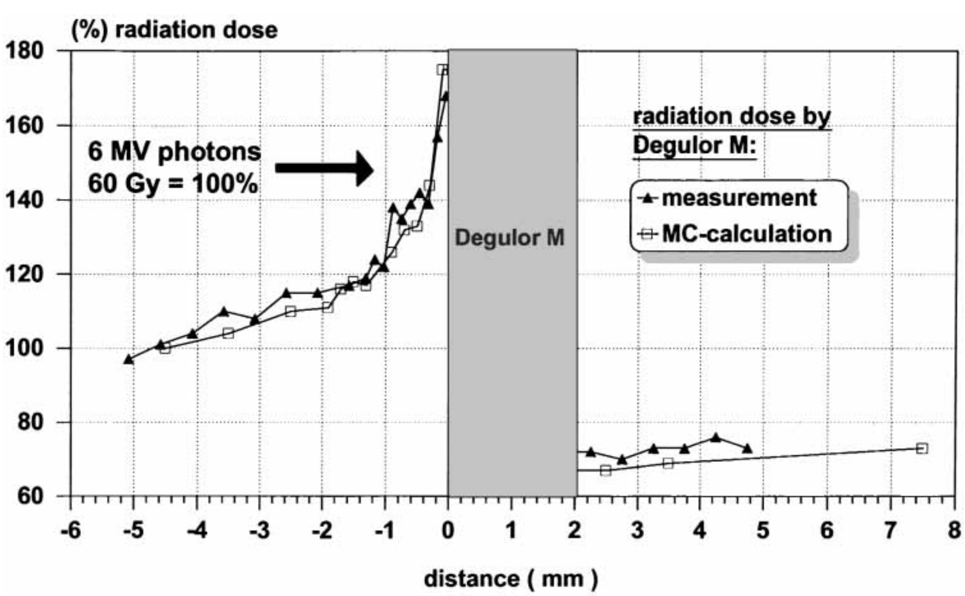

Fig. 2. Comparison of measured and calculated radiation doses, with high-gold alloy used as example (standard deviation for calculation: 3%). Correspondence of methods confirms measurements results for Degulor M in Figure 1.

influence on the dose distribution. These values were used as references. The highest dose increase was measured at a distance of 0.1 mm in front of the material surfaces. At a distance of 3 mm, overdose decreased to less than 10% for the high-gold alloy. For pure titanium, no dose increase could be measured at this distance. In the forward direction of the radiation (behind the dental material), absorption prevailed. Absorption increased with the atomic numbers of the metals (Fig. 1) and was more marked for the softer 6 MV radiation than for the 15 MV radiation.

The results of the Monte-Carlo calculations and the obtained readings corresponded. Figure 2 compares the calculation results with the measurement results, using the high-gold alloy as an example. A dose increase of 170% was measured 0.1 mm in front of the alloy, but at a distance of 3.5 mm, the overdose decreased to 104%.

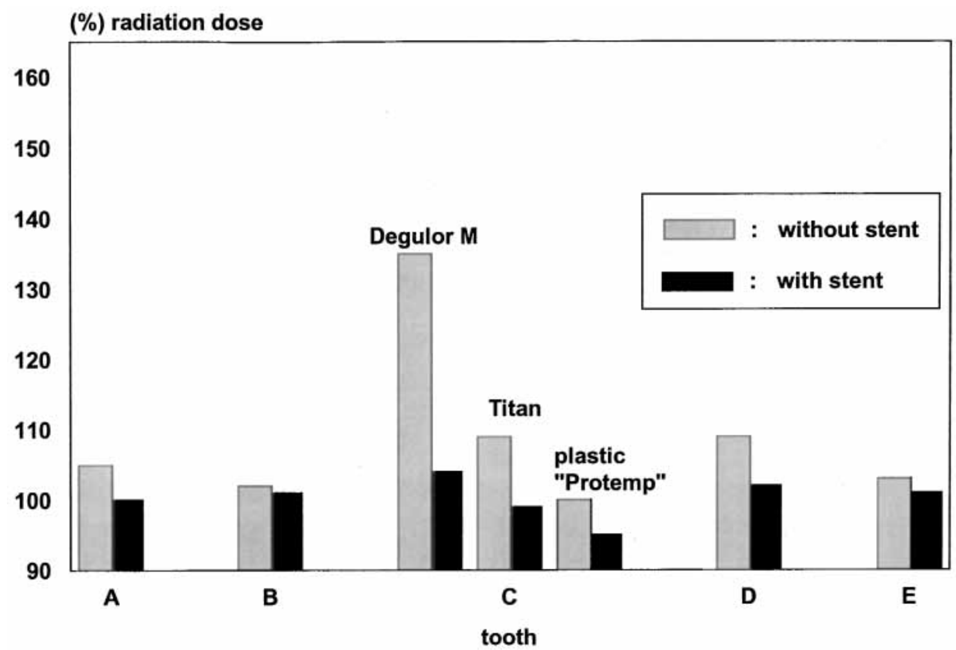

Fig. 3. Maximum dose increase measured for 1 row of teeth with and without stent. Row included natural, unprepared tooth *(A)*; synthetic tooth *(B)*; natural tooth with interchangeable crowns *(C)*; natural tooth with amalgam filling *(D)*; and natural, unprepared tooth *(E)*.

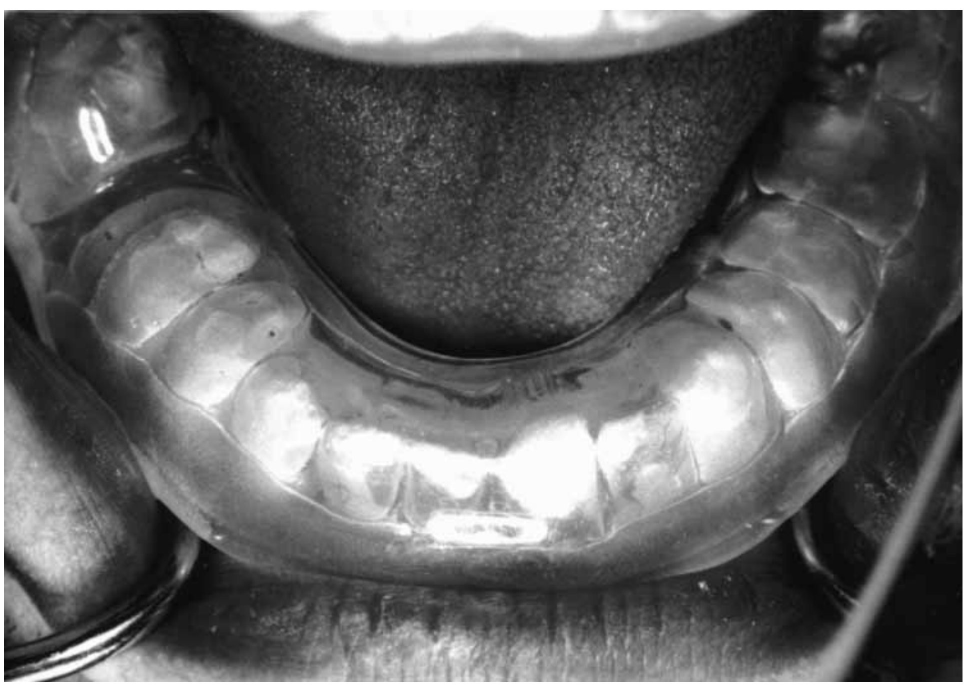

Fig. 4. Stent in place.

With the aid of the clinically oriented set-up (row of simulated teeth), it was shown that the highest overdose (30%) occurred when the high-gold alloy was used. This means that in the selected arrangement, 80 Gy could be measured directly on the surface. As expected, this value was lower for the more radiolucent pure titanium (Fig. 3). The use of a protective stent at least 3 mm thick (Fig. 4), independent of the restoration material used, effectively reduced the radiation overdose.

DISCUSSION

Ionized radiation affects various tissues in the oral cavity, even when the radiation field is localized precisely. In this study, the composition of the restoration material influenced radiation penetration. Wang et al[13] examined permeability in their study of implant materials, and Melian et al[12] studied reconstruction plates made of titanium and vitallium, which are used in the surgical treatment of tumors. A low backscattering effect for titanium also was demonstrated in these experiments. The effect of absorption was demonstrated by Farahani et al[15] for selected materials such as amalgam and a Ni-Cr-dental alloy. Their results confirm the present finding that absorption is less relevant than the effects of backscattering. The results of the present study indicate that when a stent of appropriate thickness is used, a considerable reduction in backscattering can be achieved.

CONCLUSIONS

When a high-gold alloy or amalgam restoration is present, backscattering of electrons in front of the dental material may result in a considerable overdose of radiation to the adjacent soft tissue. With a simple stent, the soft tissue can be effectively protected from such an overdose. It is recommended that a stent be fabricated with high-gold or amalgam dental restorations for any patient who must undergo intraoral radiation therapy.

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