Original Article

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Investigating the Effect of Dental Implants on Radiotherapy Dose Distribution Using Mont Carlo Approach

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ABSTRACT

BACKGROUND AND OBJECTIVE: Considering the presence of important organs in head and neck area, treatment of tumors which are existing in this area is very important. The existence of dental implants will effect on dose distribution in radiotherapy. The aim of the present research was to study the effect of dimensions and materials dental implants on radiotherapy dose distribution using the Monte Carlo method.

METHODS: In this research study a Varian 2100 C/D linear accelerator with energy of 6MV was simulated using the Monte Carlo Code (MCNP). Dental implants with length 1.5 cm and diameter 0.4 cm dimensions and length 1.3 cm and diameter 0.7 cm dimensions made of tantalum, steel stainless 3161, zirconium oxide, titanium alloy, oxide aluminum and polytetrafluoroethylene were added to the simulation program. Then, in order to assess the simulation correctness and accuracy, the results of Percentage Depth Dose and the dose profiles obtained from the simulation were compared with the experimental dosimetry.

FINDINGS: Dental implants with larger dimensions increased the dose by a maximum of 5.82%, 5.03%, 4.83%, 4.42%, 3.81%, and 3.54% for each of the six mentioned materials and showed larger changes than the smaller implant, and the tantalum genus produced the greatest heterogeneity over other materials.

CONCLUSION: According to the results of this study, the effect of dental implants on dose distribution in cancer patients under radiotherapy depends on its gender and cross section.

KEY WORDS: *Radiotherapy dose distribution; Monte Carlo simulation; Dental implant*.

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Introduction

Due to the presence of sensitive and important organs in the head and neck area, careful examination of the distribution of radiation dose in these areas is very important. On the other hand, the presence of absorbent materials such as dental implants can disturb the distribution of radiotherapy doses in these areas (1). Cancer can occur near dental implants, including malignant tumors in the nasopharyngeal region, oral cavity, etc. (2).

The presence of dental implants can affect the amount of doses reached in the tumor area. In addition to beam energy, this effect depends on the type, size, and type of the beam (3). The effect of different dental implants on doses was investigated in a study by Serap catli et al. The results showed that titanium alloy implants produced the least dose heterogeneity in the intersection of implants with tissue, due to the lower density and atomic number of titanium alloys compared with to other applied materials (4). In the study of kwoping chang et al. they observed that with increase in the atomic number and the density of the target substance, the dose would increase at the joint border of the implant with the tissue (5).

A variety of metals and alloys, including tantalum, steel stain less 316l, zirconium oxide, titanium alloys, aluminum oxide and polytetrafluoroethylene are used in the manufacture of dental implants. Research has shown that the presence of dental implants with a high atomic number and high density in the therapeutic fields, as a heterogeneous, affects the dose distribution (8-6).

One of the important issues in the treatment with photon rays in radiotherapy is the exact determination of the dose rate and its compliance with the administrated dose, which with heterogeneity (the presence of dental implants) in the beam path, this adaptation decreases (9).

One of the suitable methods to evaluate the distribution of radiotherapy dose is Monte Carlo simulation, which provides acceptable results for the calculation of absorbed dose in radiotherapy (10). Since 6MV energy is commonly used to treat tumors in the neck region, simulation in this photon energy was performed in this study. Since the presence of an implant causes a change in the dose of radiotherapy, these changes should be considered in the design of the patient's treatment. The aim of this study was to investigate the effect of dental implants with different contents and sizes on the distribution of radiotherapy dose of head and neck tumors by Monte Carlo method, as well as accurate dose distribution around dental implants.

Methods

In this research, the therapeutic head of varian 2100 C/D radiotherapy device was simulated precisely using the MCNPX software using device manufacturer information. The main components of the head are linear accelerators for an MV6 photon including: an electron source, a target, a primary collimator, a vacuum window, a flattening filter, an ionization chamber, a mirror, and secondary collimator. Due to the close proximity of the atomic number of water to human body tissue, the phantom was considered to be equivalent to the human body, a cube with dimensions of 50x50x50 cm3 was simulated and placed in the lower cavity of radiotherapy.

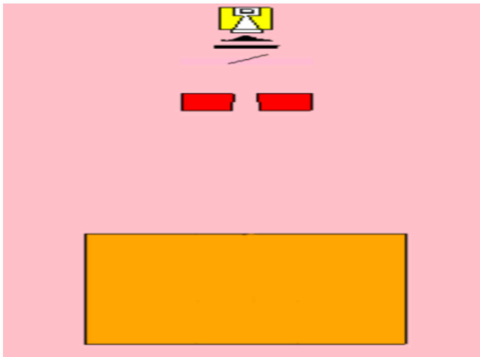

Figure 1. 2100C/D linear accelerator components simulated by the MCNPX code

The device was modeled in a photon fashion with an MV6 energy for 10 × 10 cm2 field. The cut off energy for electron and photon was 0.511 MeV and 0.01 MeV, respectively. In the definition of an electron fountain for a linear accelerator, a Gaussian distribution function was used. In order to validate the model of the simulation of the accelerator, the curve of the dose rate is SSD=100 dB and 10×10 cm2 field, and the dose profiles in the same SSD and field, at a depth of 5 cm in a water phantom with 50x50x50 cm3 dimensions, by using Monte Carlo method was calculated and compared with the measured data in a practical dosimeter. A practical dosimeter was performed with a

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three-dimensional water phantom with dimensions of 50×50×50 cm and with a cylindrical ionization chamber (0.13 cc) with an internal radius of 0.3 cm and a 0.13 cm3 made by ScanditronixWellhofer company. After reconciliation of simulation results and dosimetry, the accuracy of the simulation was ensured, and in the later stages, implants of different types and sizes with no practical dosimetry in the body were simulated.

Phantom Simulation with Dental Implant: In the second phase, two different dimensions of the implant and six different types of materials and alloys used for their construction were considered. In the first case, a cylindrical implant with a length of 1.5 cm, a radius of 0.2 cm, and a second cylindrical implant of tantalum with a length of 1.3 cm, a radius of 0.35 cm, steel stain less 316 l, zirconium oxide, Titanium alloys, aluminum oxide and polytetrafluoroethylene were simulated. Percentage of dose and dose profile at depth of 3 cm along the x axis in water phantom with implant in SSD= 100 cm and 10×10 cm2 field were calculated and the results of simulation calculations, in both cases, with and without the presence of implants were compared. To perform the calculations, the * f8 was used and the number of 109 particles was simulated.

The number of particles was calculated using the variance reduction method. The calculation error was calculated by the simulation software, and at the end of each run, for each cell, it was declared below 2%. The binomial test was used to compare the qualitative parameters between dosimetry and simulation, and the t-test was used for quantitative parameters and p <0.05 was considered significant.

Results

depth dose percentage curves and dose profiles calculated by the Monte Carlo method with measurements in dosimetry was performed.

Calculations of dose changes due to dental implants in water phantom: Dosage distribution in water phantom with and without dental implants with six different genera was investigated. Depending on the percentage of the depth dose percentage for a cylindrical implant with a length of 1.5 cm and a radius of 0.2 cm, the maximum dose increase was 5.4%, 3.2%, 2.72%, 2.29%, 2.11% and 1%, and reduction of dose of 30.29%, 4.73%, 4.36%, 1.75%, 0.65% and 0.62% for tantalum metal implants, steel stain less 316l, zirconium Oxide, titanium alloys, aluminum oxide and polytetrafluoroethylene. The highest dose reduction was obtained based on the dosage profiles, 13.29%, 4.54%, 3.99%, 2.84%, 2.8% and 2.78%, respectively, for all six genera. Also, the percentages of depth dose percentages for cylindrical implants with length of 1.3 cm and radius of 0.035 cm, the maximum dose increase was 5.82%, 5.03%, 4.83%, 4.42%, 3.81%, and 3.54% and dose reduction was 66.94%, 31.66%, 28.33%, 22.68%, 14.5% and 10.09%, respectively, for all six genera. The maximum dose reduction was based on the dosage profiles, 14.5%, 7.56%, 6.07%, 5.12%, 5.08%, and 3.91%, respectively, for each of the six different genera of the implant. The findings of this study showed that the effect of dental implant on dose distribution is a complex function of the genus and the dimensions of the implant. The higher atomic number of the material and the larger implant and larger dimension result in greater dose heterogeneity and should be considered in the design calculations of the patient's treatment (Fig. 6-1).

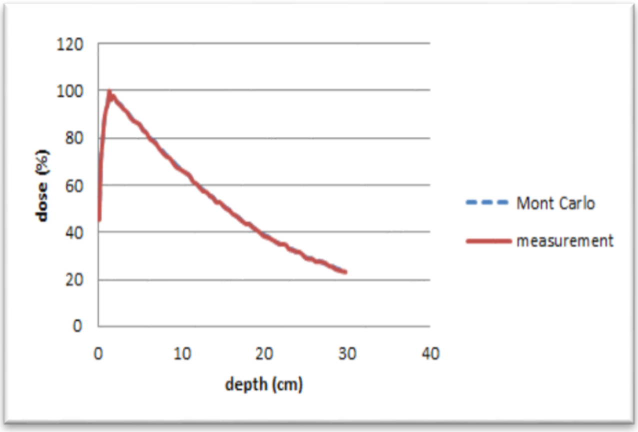

Figure 1. Depth dose rate curve calculated by simulation and measured by dosimetry

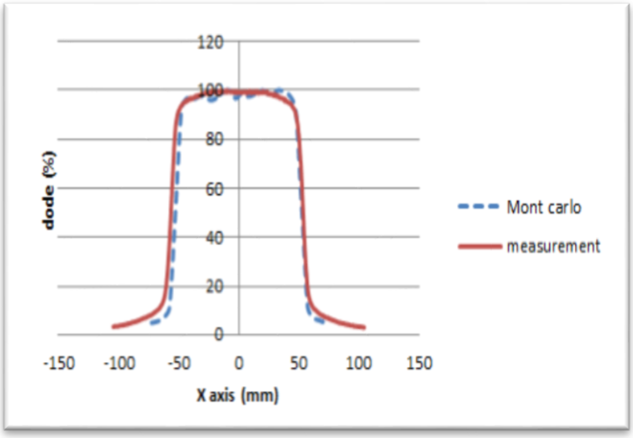

Figure 2. Profiles computed by simulation and measured by dosimeters

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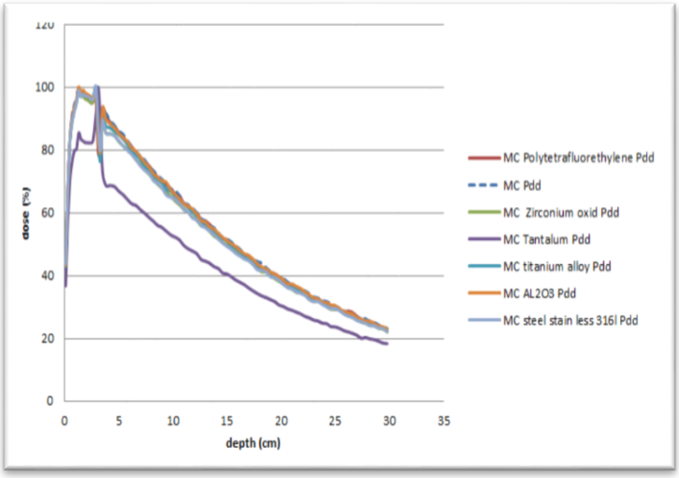

Figure 3. Depth dose rate curve resulted of simulation with and without the presence of an implant with a length of 1.5 cm and radius of 0.2 cm, with six different genera.

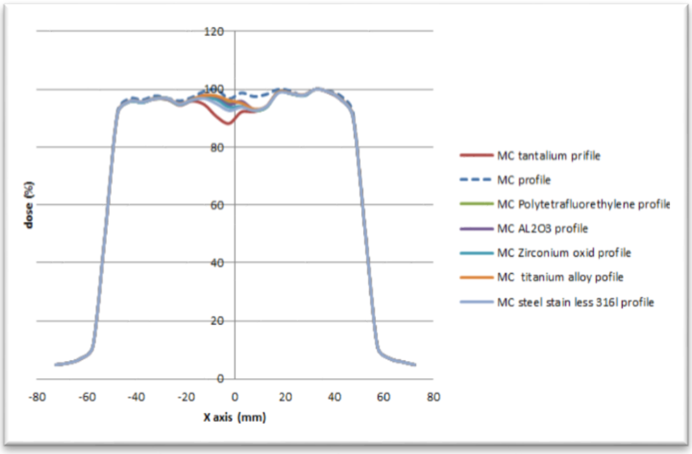

Figure 4. Dosage profile curve obtained by simulation with and without the presence of an implant with a length of 1.5 cm and a radius of 0.2 cm, with six different genera.

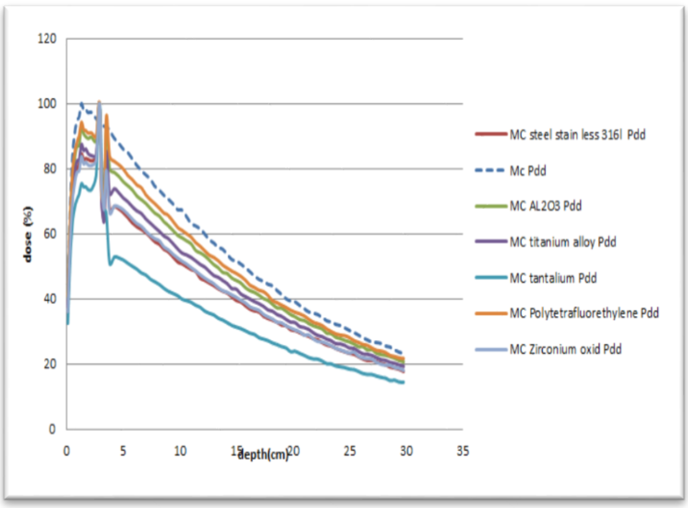

Figure 5. Depth dose rate curve resulted of simulation with and without implant

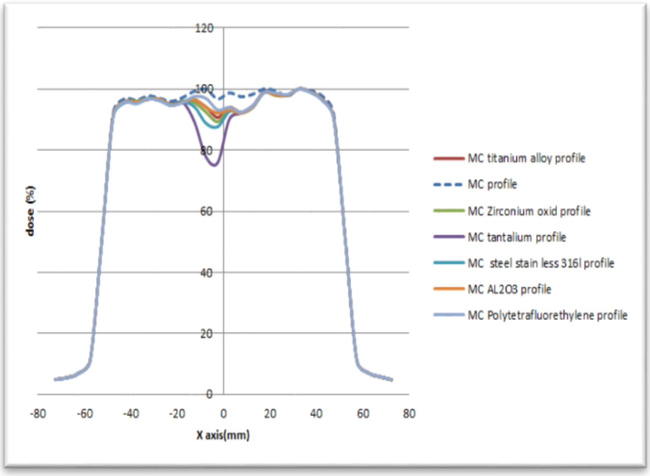

Figure 6. Dosage profile curve of simulation with and without implant with length of 1.3 cm and radius of 0.35 cm with six different genera.

Discussion

In this study, the effect of genus, type and dimensions of dental implants on radiotherapy dose distribution was investigated so that for tantalum implants with length of 1.3 cm, radius of 0.35 cm, this effect cannot be neglected and should be calculated in the design calculations of the patient's treatment. The presence of metallic dental implants in radiotherapy fields causes disturbances in doses in surrounding tissues. If the cancerous area is in the vicinity of the metal, turbulence will occur both in magnitude and in the decrease. Comparing the dose distribution in the water phantom with dental implants showed that the dose reduction due to the weakening of the beam by the metal in the terminal region of the implant as well as the increase in the dose at the boundary between the metal and the tissue (phantom of water) at the metal entrance to the metal, caused by the electron Post-breaks have been created. The severity of dose reduction and increase of dose is dependent to the density, atomic number, and the dimensions of the implant.

By increasing the size and density of the implant, dose disturbance increases in the surrounding area. In study of Serapcatli et al., a titanium alloy implant on the joint border of the implant with tissue increased the dose by 6.3%, which was less than the other materials used in implant simulation, due to the lower density and atomic number of the Titanium alloy used in other materials (4). These results were consistent with our research results. Wang and colleagues observed that the titanium alloy implant increased the dose by 27% at the joint level of the implant with the tissue. They observe that materials with high density produce more dose heterogeneity (8), and these results are consistent with our research results. According to the results, the use of materials that have a lower density compared with other materials, such as polytetrafluoroethylene is recommended. It is also recommended that when designing treatments for patients with dental implants, radiation should be diverted as far as possible so that the implant is not exposed to radiation paths to minimize the heterogeneity of the dose.

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