QUALITY IMPROVEMENT REVIEW OF RADIATION THERAPY TREATMENT PLANNING IN THE PRESENCE OF DENTAL IMPLANTS

An Undergraduate Research Scholars Thesis

by

HOLLY M. PARENICA

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ABSTRACT

Quality Improvement Review of Radiation Therapy Treatment Planning in the Presence of Dental Implants

Holly Parenica
Department of Nuclear Engineering
Texas A&M University

Research Advisor: Dr. John Ford
Department of Nuclear Engineering

A common problem that arises in radiation therapy treatment planning for head and neck cancers is the streaking artifacts in CT images produced from metallic dental implants (MDIs). These artifacts cause the densities of MDIs and surrounding tissues to appear incorrect on the CT scan, which leads to inaccurate dose calculations for these areas. The purpose of this study is to quantify and compare the effect of metallic dental implants (MDI) on dose distributions calculated with a Collapsed Cone Convolution Superposition (CCCS) algorithm (Pinnacle^3) with a Monte Carlo algorithm (Monaco), with and without correcting for the density of the MDIs. The Monte Carlo dose calculation indicated that PTVs coverage was lower than the Uncorrected Pinnacle^3 plan had calculated. In some cases, the Monte Carlo algorithm indicated that surrounding regions of interest (ROIs) received a significantly higher dose. Not properly accounting for dental implants can impact both the high dose regions and the low dose regions. This study implies that if MDIs and the artifacts are not appropriately contoured and given the correct density, there is potential significant impact on Planning Target Volume (PTV) coverage and doses to surrounding organs at risk.

DEDICATION

I dedicate this research to my parents. I would like to thank my mom for her continuous support and inspiration, as she pushes me everyday to create a better world for those suffering with cancer to live in and find hope in. I would also like to think my father for his continuous support and encouragement and for instilling in me a love for science and work ethic that has helped me to become a better researcher.

ACKNOWLEDGMENTS

I would like to thank Dr. Sotirios Stathakis for his guidance and support and for allowing me to be a part of this research project. I would also like to thank the Cancer Therapy & Research Center at the University of Texas Health Science Center at San Antonio for allowing me to conduct my research using their facilities. Finally, I would also like to thank my advisor, Dr. John Ford, for encouragement and support both in research and in the classroom. Without him, none of this would have been possible.

CHAPTER I

INTRODUCTION

The goal of radiation therapy for cancer treatment is to deliver a prescribed dose of radiation to the affected organ while minimizing the dose of radiation to surrounding organs. It has become evident in the field of radiotherapy planning that metallic dental filling materials can have a significant impact on treatment plan quality and the accuracy of dose delivered in the head and neck region. Metallic dental implants will often produce streaking artifacts on computed tomography (CT) scans and will cause tissue and implant regions to have incorrect CT numbers, or densities.[1] These incorrect densities lead to inaccuracies in dose calculations and can cause the planning target volumes (PTVs) to be underdosed and surrounding tissues and organs at risk (OARs) to receive a higher dose than anticipated. A common issue that arises from overdose to the oral cavity is mucositis: a painful inflammation of the mucus cells.[1] It is clear from this commonly arising issue, that new methods are needed to ensure an accurate and safe delivery of radiation to therapy patients.

Currently, the Pinnacle[3] software from Phillips is a widely used treatment planning software in clinics. This software utilizes a collapsed cone convolution superposition (CCCS) algorithm. The CCCS method models individual infinitesimally small beams of radiation and calculates their effects on surrounding tissue by superimposing each beams effect on one another. Previous research has shown that manually correcting tissue densities in Pinnacle[3] can help with dose calculation accuracy.[2] The Monte Carlo algorithm takes into account the millions of particle histories and is traces these to calculate the dose deposition based on the interactions that can occur in matter.[3] While this method is more accurate, it is not used as often in a clinical setting because of the time required to run the algorithm. Despite this, it is predicted that the Monaco software, which primarily uses Monte Carlo methods, will produce superior plans and will lead to more accurate dosing of PTVs.

CHAPTER II

METHODS

Selection of Patients and Dose Recalculation in Pinnacle[3]

In order to be considered for this research project, head and neck CT scans needed to show a significant amount of streaking artifacts caused by metallic dental implants. Figure 1 depicts a patient's CT scan that was significantly affected by streaking artifacts.

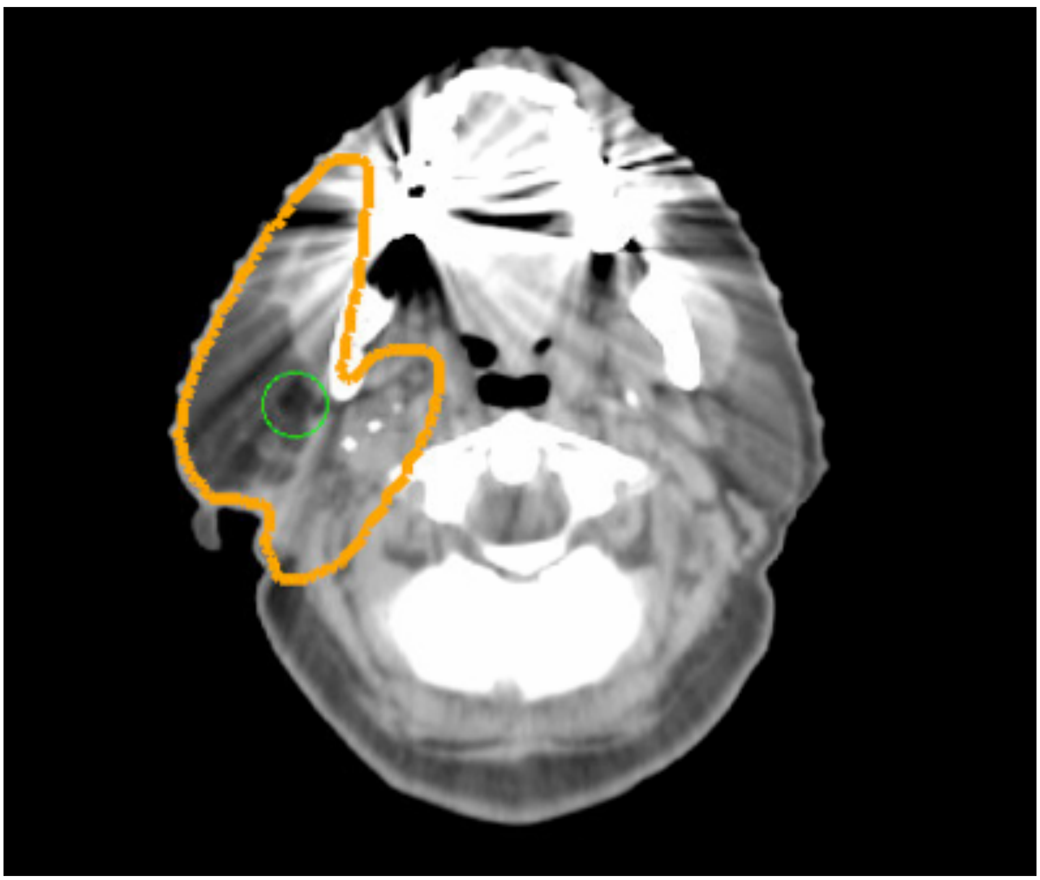

Figure 1. This is a slice of a patient CT scan that shows significant streaking artifacts. This patient was an excellent candidate for this project, as they have isodose lines and PTVs within the vicinity of the dental implants.

Eighteen head and neck cancer patients were initially identified with significant streaking artifacts in their CT scans. Of these 18 patients, seven had either PTVs or OARs near the implants that could potentially see a change in the dose to these areas, and these plans were selected for further observation. These plans were identified using the Phillips Pinnacle[3] Treatment Planning Software. Once these patients' plans were found, copies were made of each plan. For the first copy, the dental implants and surrounding tissues were contoured using the "Contour" tool option. Figure 2 displays a CT scan slice in which both the dental implants and surrounding tissues have been contoured.

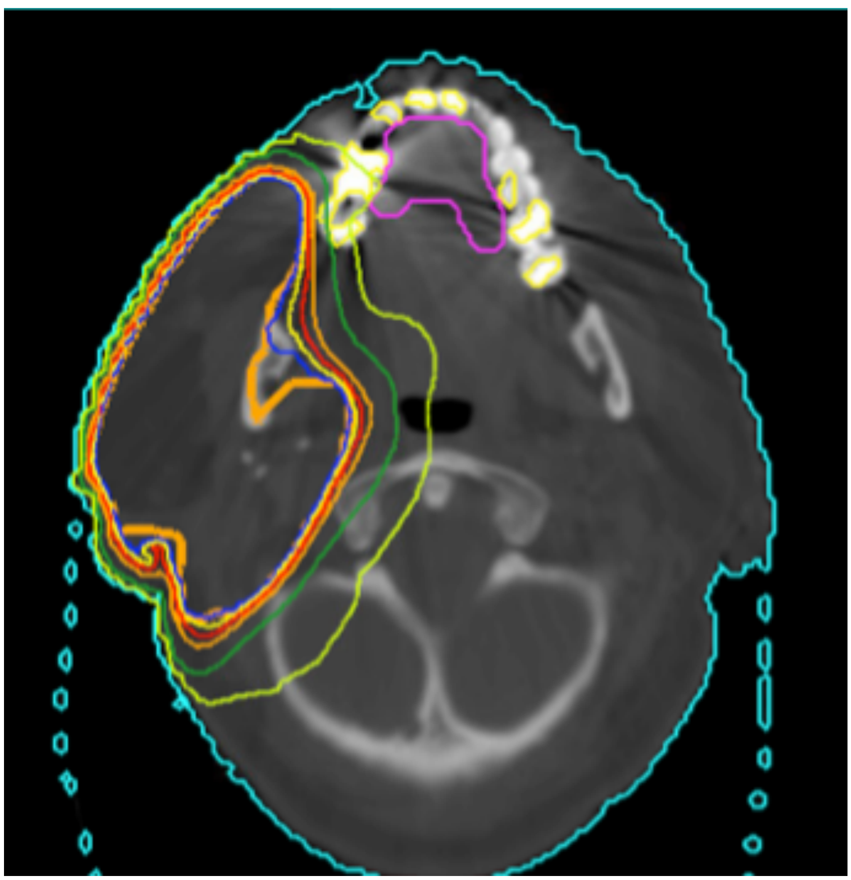

Figure 2. This is a slice of a CT scan showing how dental implants and surrounding tissues were contoured. The implants are contoured in bright yellow on the patient's teeth and the surrounding tissues are contoured in bright pink just inside the patient's teeth.

In order to see which regions were most affected by the artifacts, the CT numbers were studied and compared to known densities of tissue and dental amalgam. To more easily identify the dental implants, the "Window/Level" setting was changed to the "Bone" preset. The densities for these structures were not changed. This plan served as the "uncorrected plan", or the control for this experiment. Copies were made of each uncorrected plan and the densities to the dental implants were forced to be 12 g/cm^3, and the surrounding tissues were assigned a density of 1 g/cm^3 because tissue can be treated as water for the purpose of calculating radiation dose. Following these corrections, doses were recalculated in Pinnacle^3 using a CCCS algorithm.

Dose Calculations in Monaco

Following the CCCS calculations done in Pinnacle^3, both the corrected and uncorrected treatment plants were transported to the Monaco Treatment Planning System. As in the Pinnacle^3 corrected plans, the dental implants were assigned a density of 12 g/cm^3 and the surrounding tissue was assigned a density of 1 g/cm^3. The densities for the uncorrected plans were not changed. The doses were recalculated using a Monte Carlo algorithm in Monaco.

Comparison of Treatment Plans

After all dose calculations were complete in Pinnacle^3 and Monaco, the treatment plans were exported to the Velocity Treatment Planning System in order to be compared with one another. The two plans of interest were the Uncorrected Pinnacle^3 plan and the Corrected Monaco plan. In order to see the change in dose, the doses from the Uncorrected Pinnacle^3 plan were subtracted from the doses in the Corrected Monaco plan. After creating this new "plan", the changes in dose were studied using a dose volume histogram and isodose distributions.

CHAPTER III

RESULTS AND DISCUSSION

In 6 of the 7 patients that were reviewed, the Corrected Monaco plan showed a decrease in dose in PTVs as well as ROIs surrounding the metallic dental implants. A summary of the Uncorrected Pinnacle Doses subtracted from the Corrected Monaco Doses for various organs can be seen in Fig. 3. Negative values indicate that the Corrected Monaco plan calculated a lower dose than the Uncorrected Pinnacle^3 plan.

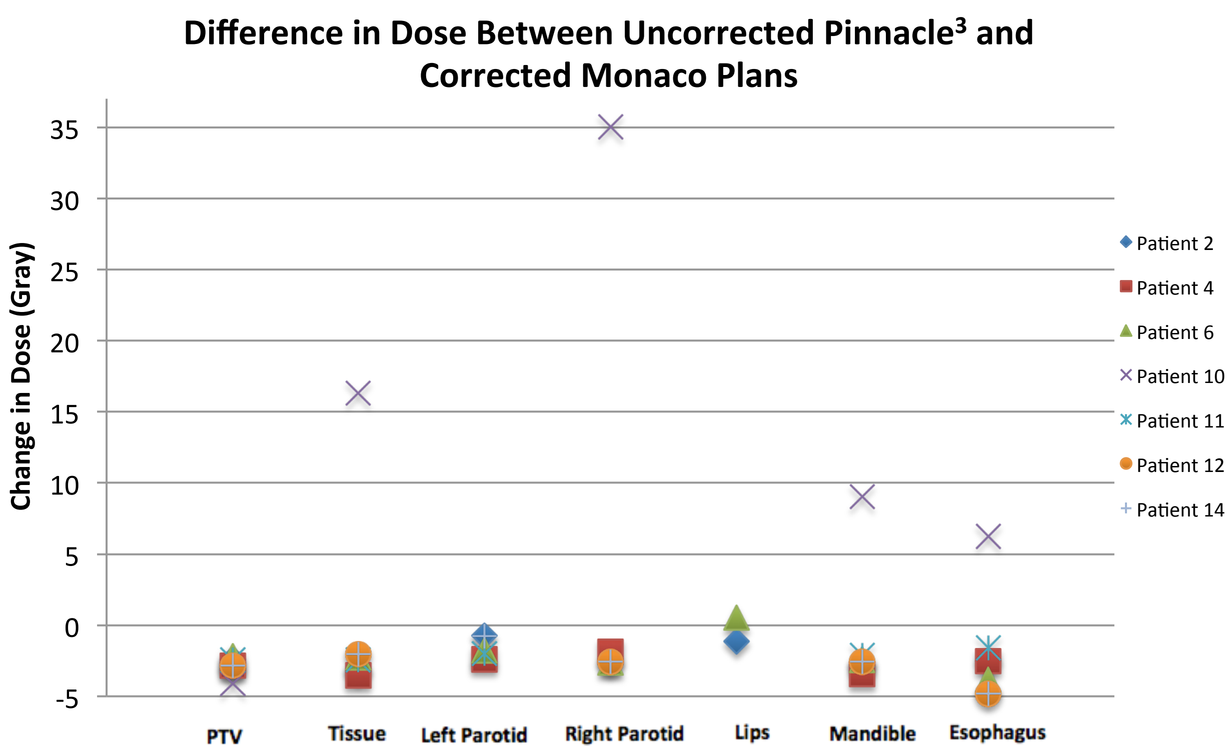

Figure 3. This graph depicts the doses calculated in Pinnacle^3 (uncorrected) subtracted from doses calculated in Monaco (corrected) for PTVs and other ROIs for the seven patients selected for review from the initial 18 patients.

One patient showed a significant increase in dose to ROIs near the implants and a simultaneous decrease to PTVs. Figure 4 compares the dose distributions in the regions surrounding the implants. Areas with warmer colors (i.e. red, orange, and yellow) indicate regions of higher dose as compared with areas in blue that indicate low dose regions. Figure 1a displays the dose distribution calculated with the uncorrected CCCS algorithm in the regions surrounding the implants. As seen in Fig. 1b, the Monte Carlo algorithm with corrected densities shows higher doses to surrounding organs and tissues. Figure 1c displays the dose distribution of the Uncorrected Pinnacle^3 dose subtracted from the corrected Monaco dose. As seen in this comparison, the Corrected Monaco calculation indicated that regions surrounding the implants received significantly higher doses than the Uncorrected Pinnacle^3 plan had predicted. In particular, the right parotid received a much higher dose than anticipated.

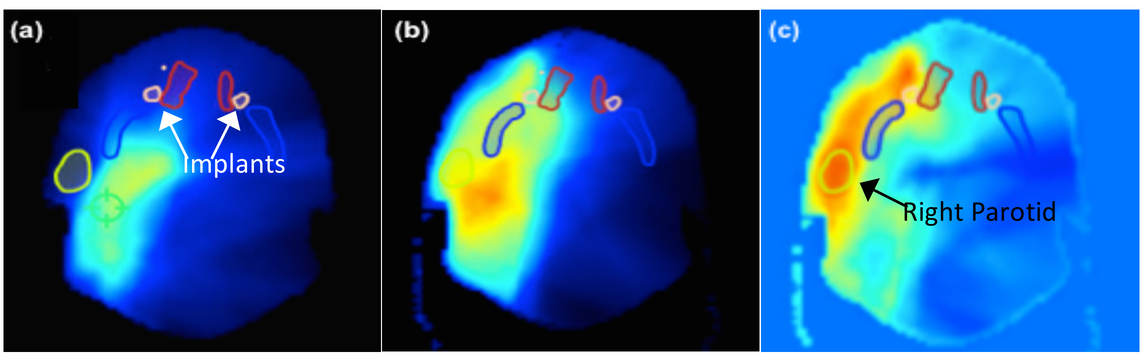

Figure 4. These are pictures of the dose distribution in regions surrounding implants for (a) Uncorrected Pinnacle^3 dose, (b) Corrected Monaco dose, and (c) Uncorrected Pinnacle^3 dose subtracted from the Corrected Monaco dose.

In contrast to this patient's ROIs surrounding the dental implants, the Corrected Monaco plan indicated that the PTVs received less dose than the Uncorrected Pinnacle^3 plan had calculated. Figure 5 displays the dose distributions in PTVs for (a) Uncorrected Pinnacle^3 dose calculation, (b) Corrected Monaco dose calculation, and (c) Uncorrected Pinnacle^3 dose subtracted from the corrected Monaco dose. As seen in Fig. 5c, the Corrected Monaco plan indicated a decrease in dose to the patient's PTVs.

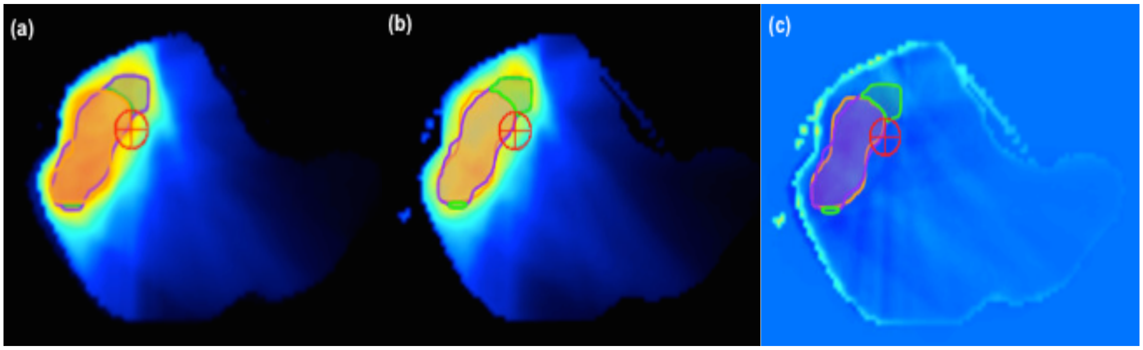

Figure 5. These are pictures of the dose distribution in the PTVs for (a) Uncorrected Pinnacle[3] dose, (b) corrected Monaco dose, and (c) Uncorrected Pinnacle[3] dose subtracted from the Monaco dose.

A tabulation of the changes in minimum, mean, and maximum doses from the Uncorrected Pinnacle[3] calculation to the Corrected Monaco calculation is displayed in Table 1. The primary focus in these values is the change in mean dose. On average, the Corrected Monaco plan indicated a decrease in PTV coverage. However, the change in dose to PTVs was minimal when compared to the increase in dose to ROIs surrounding the dental implants. The Corrected Monaco plan indicated that the mean dose to the right parotid was actually 35.00 Gy higher than was originally thought. The mandible and tissue surrounding the implants also received higher doses than what was initially calculated.

Table 1. Minimum, mean, and maximum doses for PTVs and ROIs surrounding dental implants in Uncorrected Pinnacle^3 dose subtracted from Corrected Monaco dose.

Region of Interest	Minimum Dose (Gy)	Mean Dose (Gy)	Maximum Dose (Gy)
PTV 59-69	-26.39	-0.91	22.88
PTV 5940	-26.52	-2.49	22.88
PTV 6996	-16.24	-4.00	19.48
Mandible	-16.24	9.04	44.31
Right Parotid	1.13	35.00	55.81
Tissue	7.28	16.35	35.03

The dose volume histogram (DVH) for the difference in dose between the Uncorrected Pinnacle^3 plan and the Corrected Monaco plan can be seen below in Fig. 7. This graph clearly displays the discrepancies in dose between the two plans and highlights the severe overdose to the regions surrounding the implants.

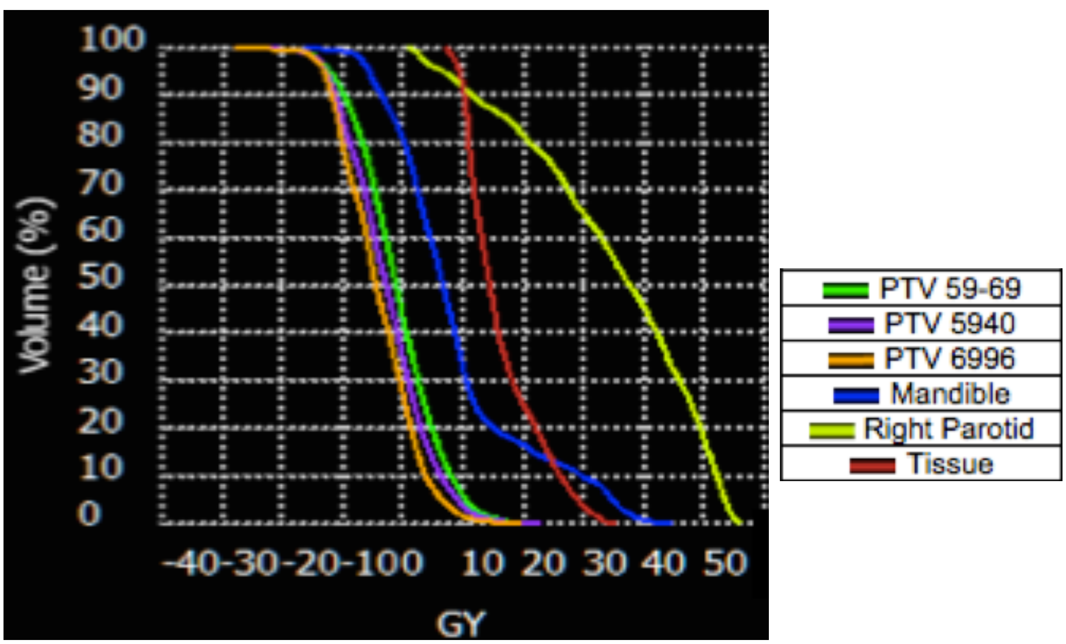

Figure 7. This is a dose volume histogram obtained from Velocity for PTVs and ROIs surrounding dental implants in Uncorrected Pinnacle^3 dose subtracted from Corrected Monaco dose. A legend is included.

A likely cause for the large increase in dose to this patient's tissues surrounding the implants is the orientation of the beam in the area around the implants. Figure 8 depicts the beam's eye view for this patient. It is evident that the beam passed near or through the implants, which could have resulted in increased photon scattering. An increase in photon scattering could have resulted in a higher dose to the regions surrounding the implants.

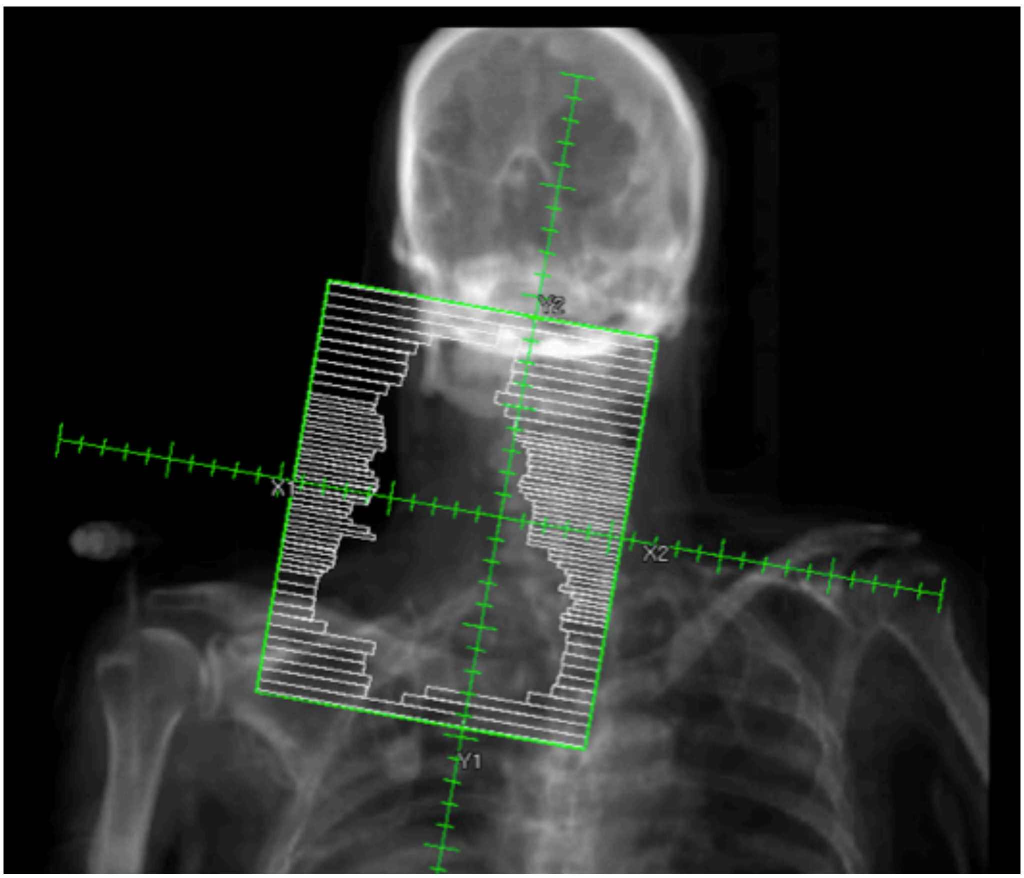

Figure 8. This is a picture of the beam's eye view for the patient severely affected by streaking artifacts. The beam likely passed near or through the metallic implants which caused an increase in photon scattering, which, in turn, could have the increase in dose to surrounding ROIs.

While only one of the patients was severely affected by the streaking artifacts, it is crucial that CT scans affected by streaking artifacts be closely examined for severe discrepancies in dose. In order to ensure effective patient care, plans affected by streaking artifacts should be carefully monitored for large changes in dose, and plans should avoid projecting the beam through the implants, if possible. These changes can help to ensure non-tumorous regions are not receiving unnecessarily high doses and could potentially spare patients from problems associated with overdose, such as mucositis.

CHAPTER IV

CONCLUSION

The results of this study imply that if metallic dental implants and the resulting streaking artifacts are not appropriately contoured and given the correct density, there is the potential for a decrease in PTV coverage and a significant overdose to regions surrounding the implants. The Corrected Monaco dose calculation (using Monte Carlo methods) indicated that some PTVs received a lower dose than the Uncorrected Pinnacle^3 plan (using a CCCS algorithm) predicted. In some cases, the corrected Monaco plan indicated that surrounding ROIs received significantly higher doses. Not properly accounting for dental implants can impact both the high dose regions (PTVs) and the low dose regions (areas surrounding the implants). Because each patient is unique, and dental implants can vary widely between each person, the effect of streaking artifacts can affect each plan differently. In order to prevent a large overdose to areas surrounding the implants, each plan should be carefully reviewed and checked for discrepancies in dose to such regions. Precautions such as avoiding the projection of the beam through the implants should be taken to ensure patient safety and prevent overdose to non-tumorous regions.

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