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"Image analysis-based quality assurance of ^{125}I seed plaque assembly for ocular brachytherapy with the aid of 3D-printing"

BACKGROUND: Ocular brachytherapy is a radiation therapy for ocular melanomas and retinoblastomas. It involves the deposition of radiation into eye tumors using low-energy and low-dose rate (LDR) sealed sources arranged on gold plaques. These plaques are sewn onto the eye over the tumor and left in place for a period of four to seven days depending on tumor size and type. At Thomas Jefferson University Hospital and Wills Eye Hospital, ^{125}I seed sources are placed in custom arrangements on gold plaques to optimally target the tumor volume. In the existing procedure for plaque construction, the medical physicist glues seeds onto the plaque while visually following a printout of a simulated plaque from the treatment plan. For quality assurance (QA), a second medical physicist checks that the final seed placement visually matches the plan. Overall, these procedures rely heavily on physicist experience for both accurate seed placement and QA. The existing quality checks confirm that the total number of seeds is correct, but it is unclear if seed placement and orientation is accurately assessed. Thus, there is a need for a QA method that provides both qualitative and quantitative feedback regarding the accuracy of seed placement.

PURPOSE: The purpose of this project was to design and demonstrate the utility of an image analysis program to compare actual seed placement on the plaque with the seed arrangement of the treatment plan.

METHODS: Model plaques were 3D printed (Formlabs Clear Resin) and painted gold to mimic the clinical plaques used in brachytherapy cases. Non-radioactive ^{125}I seeds were glued onto the plaques following the seed pattern from clinically relevant treatment plans (six 15-mm round and six 22-mm notched plaques). After construction, the plaques were photographed using a DLSR camera with micro lens (Nikon D90 with 60mm focal length) mounted on a vertical stand and 3D-printed plaque holder to ensure image reproducibility. Images were processed in Lightroom (v. 12.4, Adobe). An image analysis program developed in MATLAB (v. 2023a 9.14.0) was used to compare actual seed placement with the treatment plan and provide quantitative analyses of each seed's orientation and distance displacement from the intended seed position. Five actual plaques that were used for patient treatments were also photographed and analyzed with the program to verify the practical utility of the software.

RESULTS & DISCUSSION: The image analysis program was able to detect sub-millimeter scale differences in seed position with 2.31% error. The average seed displacement was 1.31 mm, with a max displacement of 2.95 mm. The average orientation difference was 5.27 degrees, with a max orientation difference of 27.95 degrees. While the program was initially developed with 3D printed plaques, testing revealed that image analysis can be performed for actual golden plaques with radioactive seeds for routine QA.