Development of a High Precision Optical System to Assist Radioactive Seed Placement On Eye Plaques

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Motivation

Customizable I-125 eye plaques are used to treat upwards of 25 patients per year at our institution. A unique plaque is created for every patient, each with varying seed activity, seed position and plaque dimensions. Seeds are attached to the plaque according to the planned coordinates by a physicist, using calipers for guidance. In an attempt to limit potentially dosimetrically significant placement errors, an alternate technique has been proposed for seed placement.

This study has several components:

- First, to verify the significance seed positional deviation has on the dose delivered.
- Next, to evaluate potential dosimetric uncertainties due to current seed placement technique for customizable I-125 eye plaques.
- Finally, propose an alternate method, based upon the development of a high precision optical guidance system, in an attempt to improve the reproducibility and accuracy of seed placement, and therefore patient safety.

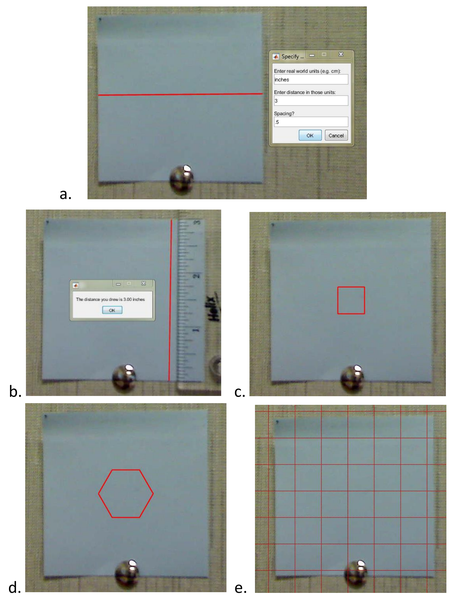
Clinical Significance

An initial study was performed using BrachyVision to model the magnitude of dose deviation which could occur as a result of inaccurate seed placement. The results of this analysis, represented as the percent of prescription dose delivered for a simple four seed arrangement, can be found below.

	.5 mm Shift	1 mm Shift	2 mm Shift
1 seed misplaced	98.6%	97.2%	94.5%
2 seeds misplaced	97.2%	94.4%	89.1%
3 seeds misplaced	95.9%	91.7%	83.6%
4 seeds misplaced	94.5%	88.9%	78.1%

Camera Calibration Prototype

The preliminary optical system was modelled with a webcam which required the development of a spatial calibration method. By measuring the length of an object of known size within the frame, the pixel to distance conversion can be applied across the frame to ensure a uniform, scalable image.

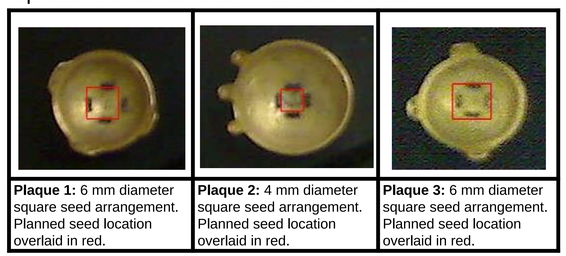


Demonstration of developed optical system with a 3 in x 3 in paper, including (a.) calibration of distance, (b.) verification of measurement, with a ruler included in the frame for reference, (c.) overlaying the outline of a box of user specified dimensions, (d.) overlaying the outline of a hexagon for 6- seed arrangements and (e.) overlaying a .5 inch spaced grid.

Once the calibration is performed, the user then has the ability to input a distance, intended to be used as the seed spacing. This then allows the user to choose how that distance should be projected: as the seed geometry with the designated spacing or as a simple grid. The selected guidance is overlaid on the live video frame to allow for guided, real-time adjustments to be made to the seed position.

Evaluation of Positional Deviation Due to Current Clinical Procedure

An evaluation of the seed placement technique currently in place at our institution was performed. Eye plaques created according to the current clinical procedure were evaluated using the code we intend to implement. Plaques of various sizes were created by multiple members of the department in order to accurately represent uncertainties which could arise.



Plaque 1: 6 mm diameter square seed arrangement. Planned seed location overlaid in red.	**Plaque 2:** 4 mm diameter square seed arrangement. Planned seed location overlaid in red.	**Plaque 3:** 6 mm diameter square seed arrangement. Planned seed location overlaid in red.

By projecting the desired locations, acquired by applying a spatial calibration to the live images with reference to the known plaque diameter, over top over the premade plaque, the offset of each seed was determined. These images were analyzed using ImageJ software to find the displacement of each seed, with negative values indicating a shift closer to the plaque's central axis. The figures above were taken with a low resolution web camera, temporarily in place as the system is being upgraded.

Difference Between Expected and Actual Seed Locations

	Left Seed	Top Seed	Right Seed	Bottom Seed
Plaque 1	-0.28 mm	0.54 mm	0.99 mm	0.18 mm
Plaque 2	0.53 mm	0.73 mm	0.71 mm	0.71 mm
Plaque 3	-1.03 mm	-0.10 mm	-0.52 mm	-0.92 mm

While this example focus's on the most simple arrangement, consisting of only four seeds, it is not uncommon for 6-seed or 8-seed arrangements to be used in order to achieve an ideal dose deposition. Placement guidance is also available for those plans.

Implications for Dose Delivery

The dosimetric impact of actual seed displacement was evaluated using BrachyVision. A preliminary plan was created based on the intended seed location to determine the dose deposited at the prescription point, located in these examples at a depth of 7 mm. A secondary plan was then created to reflect the actual seed positions and the subsequent dose delivered at the prescription point. By comparing these values, it is possible to quantify the impact that inaccurate seed placement can have on the quality of patient care. Another component which should be considered is the variation in dose which could be delivered to sensitive portions of the eye, such as the sclera. As sclera dose should always be minimized, the quantification of this potential variation is ongoing.

Deviation from Anticipated Dose Delivery due to Positional Inaccuracies

	Plaque 1	Plaque 2	Plaque 3
Intended Dose	8525 cGy	8529 cGy	8506 cGy
Delivered Dose	8193 cGy	8078 cGy	9015 cGy
% of Prescription Delivered	96.1%	94.7%	106%

Future Direction

Although the optical guidance system has thus far been used primarily to evaluate premade plaques the next step is to use the system as intended, to guide seed placement. The current setup provides real-time positioning guidance, allowing for much more consistent and accurate seed positioning. The dosimetric improvements due to the implementation of this high precision optical guidance system are currently being evaluated.