

# Feasibility of Tracking Head Position Under an Obscuring Immobilization Mask Using a Bite Block and a 3-D surface Imaging System.

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## Abstract

**Purpose:** To assess the accuracy and feasibility of measuring head motion under a thermoplastic immobilization mask when using a 3-D surface imaging system. **Materials and Methods:** Small dome-shaped objects were arranged asymmetrically on a styrofoam platform that was attached to a bite block system. The assembly was mounted on the couch of a linear accelerator to a micromanipulator with slow motion controls. This arrangement is operationally similar to a bite block affixed to the maxilla of a intracranial radiation therapy patient. The micromanipulator allowed for motions with six degrees of freedom. We were able to achieve sub-millimeter translational adjustments of the bite block assembly and angulation. The platform and objects were “tracked” with the AlignRT® 3-D surface imaging camera system (VisionRT, London, UK) in order to compare mechanical translational and rotational movements of known magnitude with the changes reported by the AlignRT system. While translational motions are only reported with millimeter resolution on the computer control screen, we obtained the system records sub-millimeter from stored data file records.

**Results:** Translational agreement between the micromanipulator and the AlignRT system was  $0.1 \pm 0.1$  mm in all three axes. Rotational agreement was within 0.5 degrees for pitch and roll. Agreement for yaw was not determined, however the display for couch rotation is 0.1 degree and has a stability of  $\pm 0.1$  degrees.

**Conclusion:** The AlignRT surface imaging system has superior accuracy that is sufficient for stereotactic radiosurgery guidance using a bite block as we have designed the experiment. Combining a bite block similar to what we designed with the AlignRT 3-D system shows promise in monitoring head position under an occluding immobilization mask.

## Introduction

Thermoplastic masks typically provide 2-3 mm immobilization for the head and neck regions under the best of circumstances. Making an immobilization mask that is very tight to the patient’s face is usually uncomfortable and sometimes unacceptable for patients to wear. However a somewhat looser mask could provide the patient more comfort while encouraging the patient to remain still. Since the patient may be able to move slightly under the mask, a monitoring system that reports the head position directly would be helpful to warn the operator of the linear accelerator when a patient’s position is out of a specified tolerance.

The AlignRT® 3-D surface imaging camera system (VisionRT, London, UK), which is a 3-D surface imaging system, has the potential for tracking the patient’s head. The system consists of a stereo-pair of cameras and a console PC. See Figure 1. However, immobilizing the patient with a mask prohibits the camera from visualizing the patient’s surface directly. If one attaches a surface that can be monitored by the camera directly and rigidly affixed to the patient, such as with a bite block, one can potentially measure the motion of the patient with 6 degrees of freedom by means of this surrogate.

## Materials and Methods

**Design of the Bite Block Assembly:** A standard bite block that can be affixed to the patient’s maxilla with a dental impression was used to support an asymmetric arrangement of dull-surfaced, dome-shaped objects on a styrofoam platform. See Figure 2. For our experiments, the bite block was attached to a micromanipulator through an adaptor, so that the prototype assembly could be accurately moved with six degrees of freedom: translation in three orthogonal axes and rotation about each of these axes. See Figure 3.

**Measurement of motion:** The platform and objects were “tracked” with the AlignRT imaging system. We compared the mechanically applied translational and rotational movements, which were of known magnitude, with the changes reported by the AlignRT system. While translational motions are only reported with millimeter resolution on the computer control screen, we obtained the stored ASCII data file records from the PC that contained the motion data in sub-millimeter resolution.

**Analysis of the data files:** Each ASCII data file is identified by a “.tfm” extension. The file contains a tab-delimited 4x4 homogeneous coordinate transformation matrix of either 4 or 6 degrees of freedom (DOF). Each transformation matrix relates the captured position of the bite block assembly relative to a frame of reference image, which is a previously captured position of the assembly by the AlignRT system. The reference image was captured, by definition, with the couch mount set at its origin and with no rotations. An Excel® spreadsheet (Microsoft, Redmond, WA) was created to import the 6 DOF transformation data file and to extract the translation and rotation information stored therein.

## Results

Figures 4 through 9 show the AlignRT data file information that was captured for different bite block positions. Comparisons were made for over sixty data points for all six degrees of freedom. Agreement of the micromanipulator settings is within a fraction of a millimeter and less than a degree when compared to the captured AlignRT data. Linear trend line fits to the data show excellent correlation with coefficients ranging from 0.997 to 1.000.

In designing the prototype bite block platform, the following design constraints were realized. The dome-shaped or egg-shaped objects were the best for the camera to map consistent surface areas for a variety of angles and translations. More than one object needed to be arranged asymmetrically on the platform in order to avoid degenerate positions. The surface of the objects needed to be roughed so that they were not shiny and were of medium contrast. Hollow objects and a styrofoam platform could be used to reduce the weight of the assembly for patient comfort and perhaps consistency in measured values.

## Conclusion

The AlignRT system can be used to easily monitor patient head position under a thermoplastic mask. Accuracy is better than 1 mm and 1 degree. A clinical design of the bite block system should follow the design constraints found for the prototype version.



Figure 1. AlignRT cameras mounted to the ceiling in a linac room.



Figure 2. (Left) The bite block assembly showing the patient dental adapter; (Right) Attachment to the patient in mask represented by using a phantom.



Figure 3. A view of the bite block assembly when attached to the Leksell frame and couch mount manipulator.

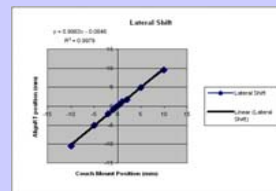


Figure 4. Plot of tracking lateral shifts by AlignRT.

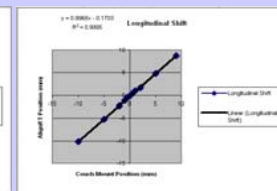


Figure 5. Plot of tracking longitudinal shifts by AlignRT.

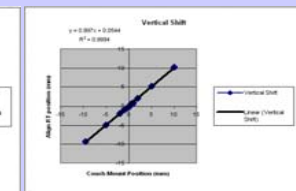


Figure 6. Plot of tracking vertical shifts by AlignRT.

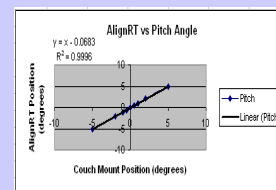


Figure 7. Plot of tracking pitch angle with AlignRT.

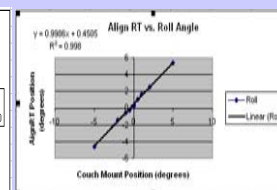


Figure 8. Plot of tracking roll angle with AlignRT.

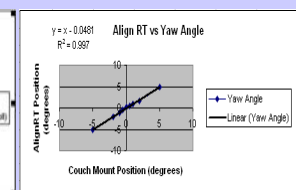


Figure 9. Plot of tracking yaw angle with AlignRT.