Development of a new laser alignment device with Winston-Lutz phantom in radiotherapy

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1. Introduction

An accurate and reproducible patient positioning is required in modern radiotherapy because the precise delivery of radiation to a patient depends on the accuracy of patient setup. The first step of patient alignment generally relies on the lasers in the treatment room. Therefore, the lasers must be aligned precisely to the radiation isocenter. According to the report provided by the American Association of Physicists in Medicine (AAPM) Task Group 142, the localizing lasers should be aligned to within ±2 mm of radiation isocenter for non intensity modulated radiation therapy (IMRT), ±1 mm for IMRT, and less than ±1 mm for stereotactic radiosurgery (SRS) on a monthly basis [1].

In this study, we developed and tested a new laser alignment device adopting an accurate, reproducible and straightforward alignment method in radiotherapy. The device consists of two laser alignments parts: the first part is an optical alignment part, and the second is a radiation alignment part. In the radiation alignment, a Winston-Lutz (W-L) phantom which was installed in the device was used [2-5].

2. Methods and Results

2.1 Fabrication of a new laser alignment device

The device for aligning the patient-setup lasers was fabricated, and the laser alignment procedure consisted of two functional steps, optical alignment and radiation alignment. The device is cube-shaped with the dimensions of 30×30×30 cm^3 and contains a metal bottom plate and five transparent acrylic plates. There are a total of four cross hair lines (CHLs) inscribed, one each on every plate except the front and back (i.e., top, bottom, and two lateral sides). On the front plate, a single vertical line inscribed exists. It also contains a W-L phantom in which a metal ball is mounted for radiation alignment. The phantom is micrometrically movable along three orthogonal axes. A light emitting diode (LED) positioned on the longitudinal central line of the bottom plate can illuminate both the CHL of the top plate and the single vertical line of the front plate to create shadows on the ceiling and the wall facing to the front plate simultaneously. There are two high accuracy spirit levels installed on the bottom plate along the two orthogonal directions. The horizontality of the bottom plate is adjustable by three level feet. The device was manufactured with a machining accuracy of less than 20 μm and an assembly accuracy of about 0.1 mm. The device is shown in Fig. 1.

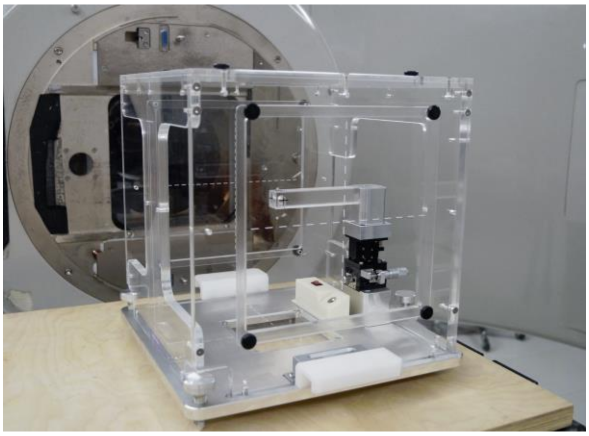

Fig. 1. A photograph of new laser alignment device placed on the patient table.

2.2 Laser alignment workflow

First, the fabricated device is placed horizontally on the patient table close to the isocenter position. The horizontality of the device is critical and can be achieved using two orthogonal high accuracy spirit levels and three level feet on the bottom plate. In the next step, optical alignment for the lasers is carried out, and then radiation alignment is performed at the last.

2.3 Performance test of the laser alignment device

We tested the performance of the laser alignment device for five medical linear accelerators (linacs, 4 Varian linacs and 1 Elekta linac) and one simulator. For five linacs, at first, their patient-setup lasers were aligned using conventional alignment method. After the alignment, W-L test was performed to measure the coincidence between the lasers and the radiation isocenter. In the test, the images of the W-L phantom were obtained for the gantry angles, 0°, 90°, 180°, 270° with an Electronic Portal Imaging Device (EPID). The images were analyzed to get the quantitative deviation between the laser center and the radiation isocenter. For each gantry angle, two images were obtained at two opposed collimator angles, 90° and 270°, and the two images were combined to remove the potential asymmetry of the collimator. Finally, the combined image was analyzed with an evaluation software, DoseLab Pro. The same measurement was done using the device after the optical alignment and after the radiation alignment, respectively. We compared the quantitative deviations for the conventional alignment, optical alignment, and radiation alignment, each other.

3. Results

Table I: Deviation between the laser center and the radiation isocenter

	Conventional Alignment		
Direction	x	y	z
Average	0.152	0.223	-0.549
SD	0.632	0.729	0.685
Max.	1.38	1.49	-2.07

	Alignment with new laser alignment device					
	After Optical Alignment			After Radiation Alignment		
Directon	x	y	z	x	y	z
Average	-0.222	0.445	-0.051	0.005	0.029	-0.027
SD	0.408	0.716	0.577	0.341	0.325	0.334
Max.	-1.01	1.92	1.06	-0.55	-0.63	0.56

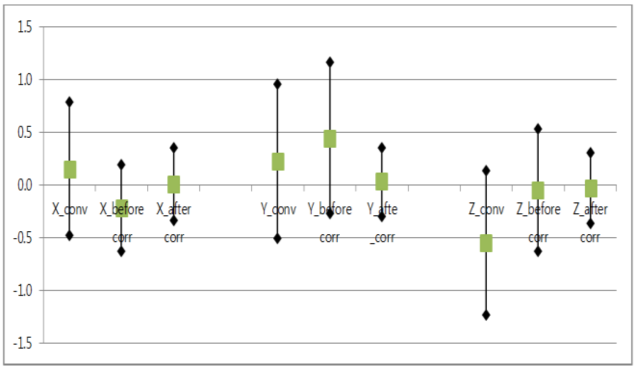

Fig. 2. Comparison of the alignment accuracy between the alignment methods: conventional, optical, and radiation alignments.

4. Conclusions

In this study, we developed a new laser alignment device with a W-L phantom for radiotherapy. Its performance was also tested in a conventional medical linac and a simulator. It was revealed that the device could align the patient-setup lasers in the treatment room accurately, precisely, and fast. We expect the device can be used as a quality assurance tool daily and monthly.

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