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Radiation-Free Patient Surface Modeling Using a Hand-Held 3D Scanner for Custom Lead Shield Fabrication

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ABSTRACT

Purpose: To evaluate the feasibility and accuracy of generating patient-specific 3D surface models using a low-cost hand-held optical 3D scanner as a radiation-free alternative to CT-based modeling for lead shield fabrication in skin cancer treatment.

Methods: A head phantom was scanned using both computed tomography (CT) and a hand-held optical 3D scanner (CR-Scan Ferret, Creality, Shenzhen, China). The optical scan data were processed using CrealityScan software to generate stereolithography (STL) models, and MeshMixer was used for model refinement, preparation for 3D printing, and geometric comparison with CT-derived models. Scan acquisition time, model quality, and geometric agreement between the two methods were evaluated.

Results: The hand-held 3D scanner acquired a complete surface scan in approximately 1–2 minutes while providing real-time visual feedback on scan coverage. Compared with CT-based modeling, optical 3D scanning produced higher-resolution surface models with comparable geometric accuracy. The technique was cost-effective, repeatable, and eliminated the need for CT imaging and associated ionizing radiation exposure. Geometric differences between CT-derived and optical 3D models were minimal, supporting the accuracy of the hand-held scanning approach for patient-specific lead shield fabrication. In addition, 3D printing enabled the development of customized molds for Cerrobend casting, demonstrating the potential to further streamline the manufacturing workflow.

Conclusions: Hand-held optical 3D scanning is a practical, accurate, rapid, and radiation-free alternative to CT-based modeling for the fabrication of patient-specific lead shields in skin cancer treatment. The technology also shows promise for broader radiation therapy applications, including custom bolus design, cutout fabrication, and other patient-specific treatment accessories.

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INTRODUCTION

To eliminate unnecessary radiation exposure and streamline patient-specific lead shield fabrication for skin cancer treatment, this study evaluates the feasibility of generating a 3D patient surface model using a low-cost hand-held 3D scanner. The accuracy of the hand-held scanner–derived model was compared with a conventional CT-based 3D model.

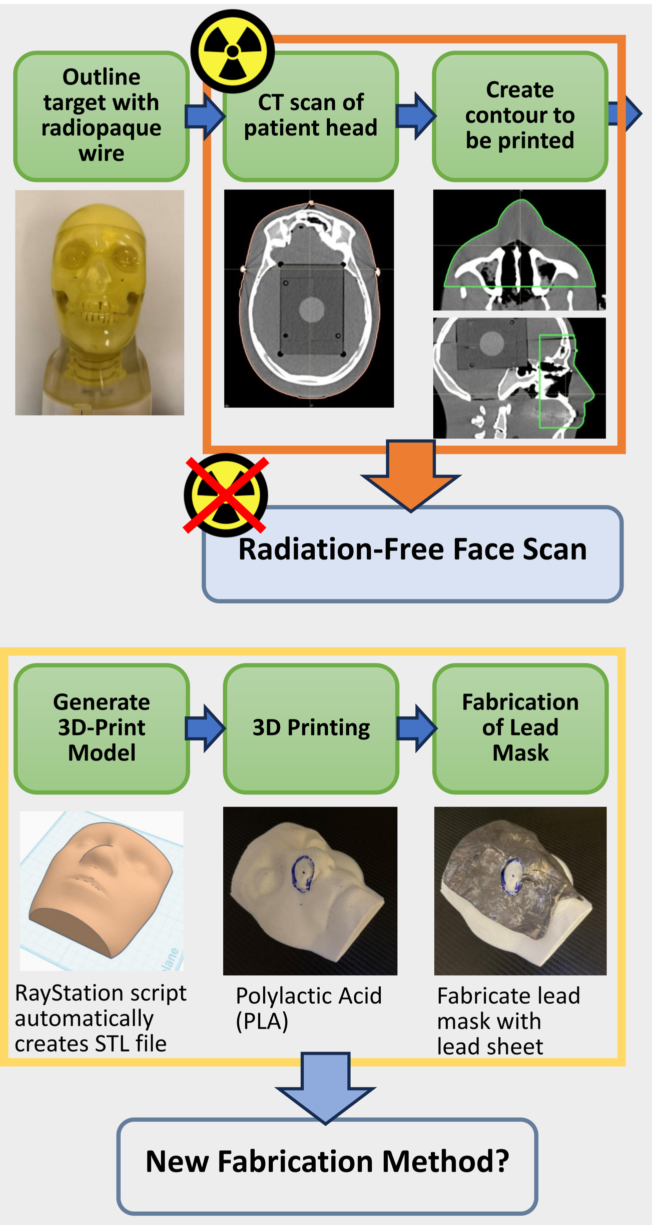

Figure 1. Lead shield fabrication using a 3D printed custom model based on CT scan and Radiation-Free hand-held 3D scanner

METHODS AND MATERIALS

Topographical mapping of the patient face using optical 3D scanning has been proposed as an alternative to CT imaging to avoid additional radiation exposure and imaging costs. Although a gantry-mounted optical 3D scanner was previously introduced for lead shielding fabrication, CT-based modeling remains in use at our institution. With recent advancements in 3D scanning and printing technology, affordable hand-held scanners are now available.

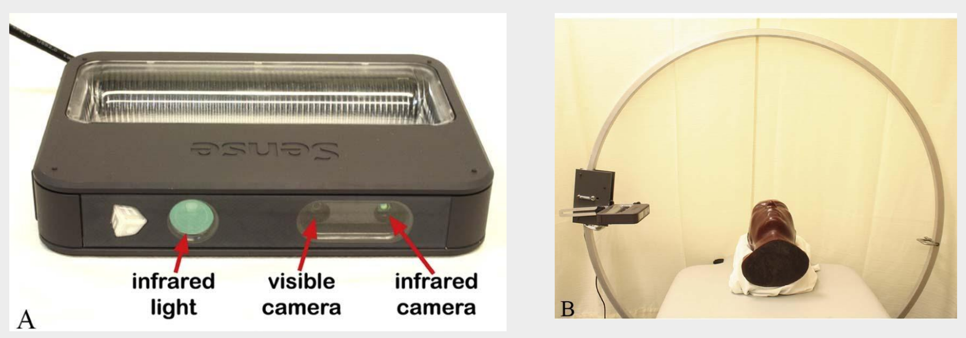

Figure 2. Gantry-guided optical scanner at University of Manitoba, Winnipeg, Manitoba, Canada (Sharma *et al.* 2018)

In this study, a handheld 3D scanner (CR-Scan Ferret; Creality, Shenzhen, China), with a stated accuracy of 0.1 mm and a spatial resolution of approximately 0.16 mm, was evaluated. A head phantom was scanned using both computed tomography (CT) and the hand-held 3D scanner. The optical scan data were processed using CrealityScan software to generate AI-enhanced stereolithography (STL) models. MeshMixer (Autodesk, San Rafael, CA, USA) was used for model refinement, preparation for 3D printing, and geometric comparison between CT-derived and optically derived STL models.

Figure 3. A hand-held 3D scanner and a head phantom used for surface acquisition. High-resolution 3D surface scan of the head phantom.

RESULTS

The hand-held 3D scanner (CR-Scan Ferret, Creality) required approximately 1–2 minutes to acquire a complete surface scan of the phantom in the supine position. During the scanning process, the CrealityScan software provided real-time visual feedback, displaying the percentage of the surface area successfully captured.

Compared with CT-based modeling, hand-held 3D scanning offered several advantages, including higher surface resolution, comparable geometric accuracy, lower cost, repeatable image acquisition, and elimination of additional hardware requirements such as a CT gantry system. Most importantly, the hand-held scanning technique avoided exposure to ionizing radiation.

Geometric differences between the CT-based and hand-held scanner–based 3D models were minimal, demonstrating the feasibility and accuracy of hand-held optical scanning for fabrication of patient-specific 3D-printed lead shields.

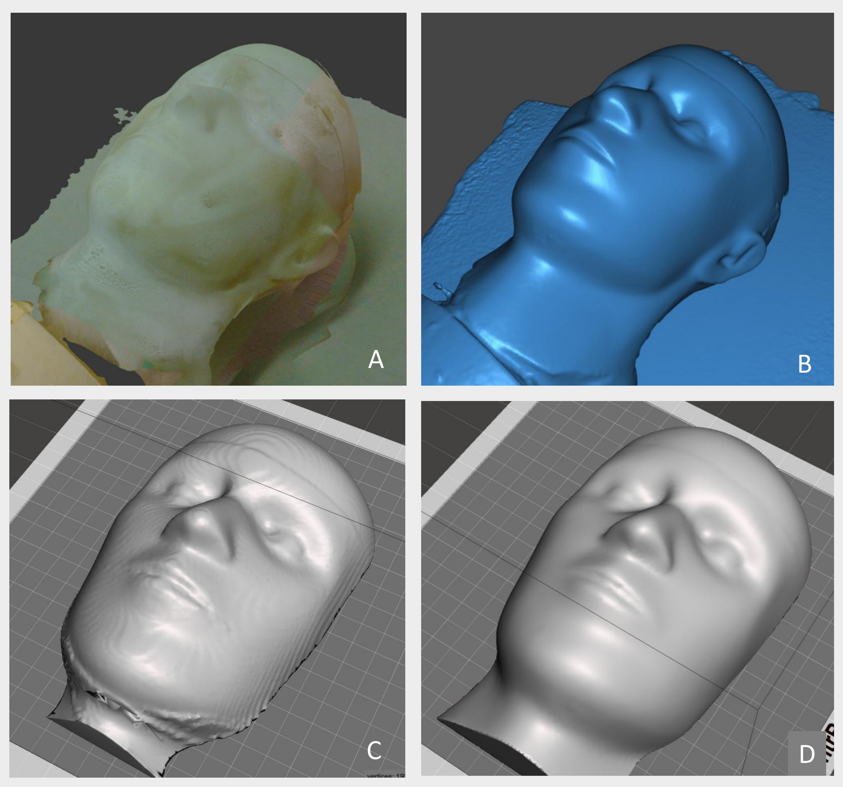

Figure 4. (A) Phantom (B) Optical Scan (C) 3D model from CT scan (D) 3D Model from Optical scan

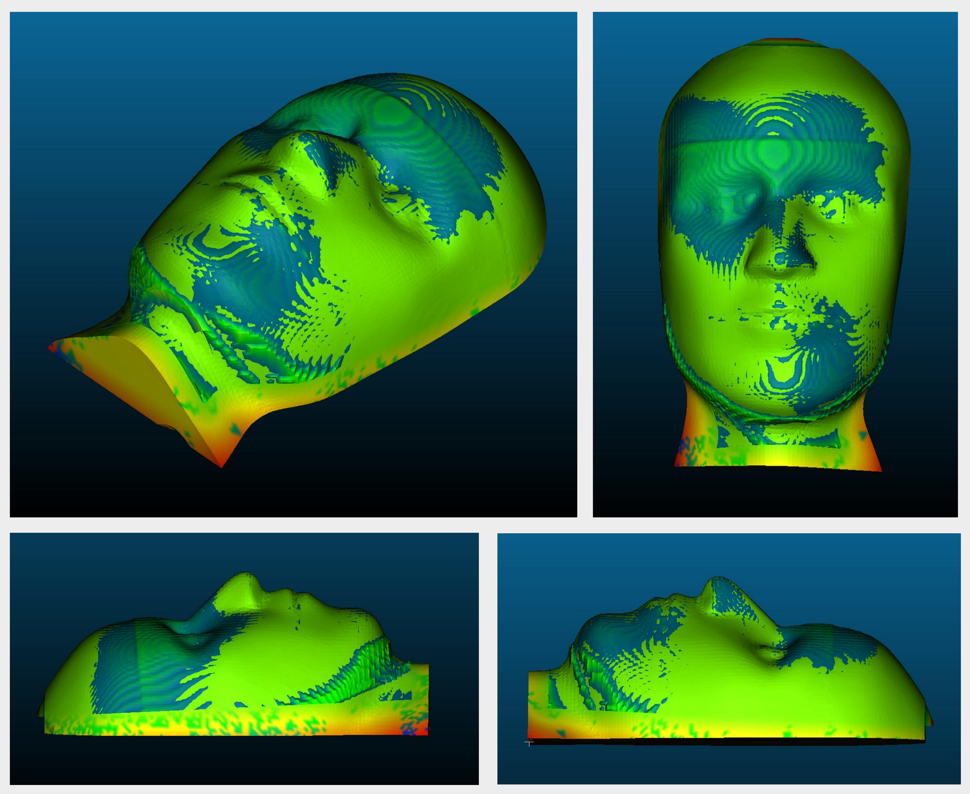

Figure 5. Difference between meshes obtained with CT and Optical scans

DISCUSSION

Although the use of a 3D-printed patient-specific model improves the accuracy of lead shield fabrication, the process still relies on conventional techniques, including cutting and hammering lead sheets to match the model surface. Advances in 3D modeling and printing provide alternative fabrication methods, such as producing customized molds for Cerrobend casting. A prototype Cerrobend shield fabricated using this approach was developed, demonstrating the feasibility of integrating 3D printing into the shield manufacturing workflow.

Figure 6. A prototype Cerrobend mask fabricated with 3D printed molds

CONCLUSIONS

Hand-held optical 3D scanning provides a practical, rapid, accurate, and radiation-free alternative to CT-based modeling for the fabrication of patient-specific lead shields in skin cancer treatment. This technology also offers significant potential for broader clinical applications, including custom bolus design, cutout fabrication, and other patient-specific radiation therapy accessories.

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