Characterization of an optically stimulated dosimeter for dentomaxillofacial dosimetry

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Objective. The objective of this study was to examine the suitability of optically stimulated luminescent dosimeters (OSLD) for point dosimetry of maxillofacial radiographic examinations.
Study design. The dose response of OSLD nanoDot dosimeters was evaluated over the range of 10 μGy to 4900 μGy x-radiation. The angular dependence of the OSLD nanoDots was examined and compared with that of thermoluminescent dosimeter (TLD) chips. The concordance between OSDL- and TLD-measured absorbed doses at selected anatomic sites in an anthropomorphometric phantom was examined.
Results. OSLD-measured doses were not significantly different from the actual delivered dose, as determined by an ionization chamber. The dose response is linear over the dose response over the examined dose range. Angular variation of OSLD dosimeters ranged from 88% to 109%; however, the magnitude of this variation was not significantly different from that of TLDs. There was a good concordance between OSLD- and TLD-measured absorbed doses.
Conclusions. The OSLD nanoDots dosimeter system performs as well as currently used TLD systems and effective dose estimates using this new system did not differ significantly from current TLD-based dose estimates. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:793-797)**

The basic premise of diagnostic radiology is that the benefit from the examination outweighs potential risks from radiation exposure. The principal detriment from diagnostic x-radiation is radiation-induced neoplasia: the magnitude of this risk increases with radiation dose. Thus, knowledge of the dose delivered by a diagnostic radiographic examination is key for its risk-benefit analysis. Typically, these doses are determined using dosimeters placed at several sites in a tissue-equivalent anthropomorphic phantom to measure absorbed doses at specific organ sites. Thermoluminescent dosimeters (TLDs) are the most widely used dosimeters for such point dosimetry estimates.[1] The most commonly used thermoluminescent material is lithium fluoride doped with magnesium and titanium and the characteristics of this material have been widely studied and are well established.[1] When exposed to ionizing radiation, the dosimeter crystals absorb energy, producing free electrons, which become trapped in a metastable state at sites of imperfections in the crystal lattice structure. When heated, the trapped electrons return to their stable, ground state and the energy differential is released as visible light photons. The intensity of the emitted light is proportional to the absorbed energy, and, thus, serves as a measure of the absorbed radiation dose. TLDs offer several advantages. They are small in size making it convenient to place them on the body or at a specific site in a tissue-equivalent phantom. TLDs are resilient to environmental changes and are reusable. The dose response is linear over a wide range of absorbed doses, approximately 10 μGy to 1 Gy.[2] Disadvantages are that the equipment for measuring the doses absorbed by TLDs is expensive and requires the use of nitrogen gas. Furthermore, calibration of the measurement system and the process to ensure consistent dose measurements, especially in the low dose range, are cumbersome. Before use, the dosimeters are annealed to remove trapped charges. Reproducibility of this annealing regimen is especially important to ensure accurate dosimetry.[3]

Optically stimulated luminescence dosimeters (OSLDs), composed of carbon-doped aluminum oxide, have been used for personnel dosimetry for more than a decade.[4] The basic principles of dose measurement are similar to that of TLDs. Like TLDs, energy from the incident photons produces electrons that are trapped at sites of crystal imperfections; however, instead of heating, the dose readout is performed by controlled illu-

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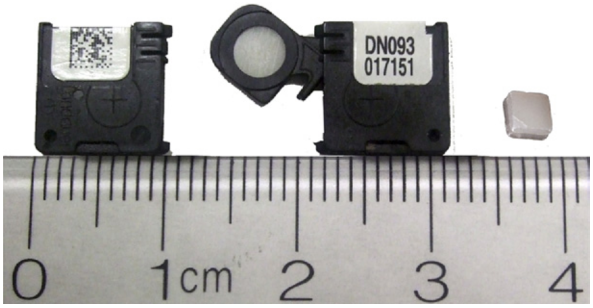

Fig. 1. OSLD nanoDot dosimeter. The 2 sides of an OSDL nanoDot dosimeter are shown. Note the serial number and unique identification bar code. An opened OSLD nanoDot demonstrates the disk of dosimeter material. A TLD chip is shown on the right. Image is available in color at www.ooooe.net.

mination of the dosimeter with 540-nm light photons.[5] The doses can be read repeatedly with only a 0.05% decrease in signal intensity.[4] Alternatively, illuminating the OSLD with a 150-W tungsten-halogen light will discharge more than 98% of the signal.[4] Recently, Landauer, Inc. (Glenwood, IL) introduced the OSLD nanoDots: a commercially available OSL dosimeter for single-point radiation measurements. These dosimeters contain a disk of aluminum oxide encased in a small plastic sleeve (Fig. 1). OSL-based dosimeters offer several advantages over currently used TLDs for point dosimetry measurements. First, the dynamic range of OSLDs is 10 μGy to 10 Gy,[5] which is broader than that of TLDs. Unlike TLDs, the dosimeters do not require an annealing process to prepare the dosimeters for use. Dose readouts are quick and nondestructive, allowing for dose verification and analysis of total dose accumulation and for immediate reuse of the dosimeters. In contrast to TLD systems, instruments used to measure OSLD absorbed dose are small, and portable versions are available. Importantly, the commercially available OSL nanoDot dosimeters are provided with an engraved bar code that encodes the dosimeter sensitivity and a unique identification to allow for efficient and accurate tracking of dose.

Several studies have used TLD dosimeters to estimate the effective dose from maxillofacial radiographic examinations.[6-12] Given the advantages of OSLDs, it is likely that their use for dosimetry of diagnostic and therapeutic radiation techniques will increase. In this study, we examined the suitability of the OSL nanoDot dosimeters for dosimetry of diagnostic maxillofacial radiographic examinations and compared their performance relative to the widely used TLD chips.

MATERIAL AND METHODS

Dosimeters and readers

OSL nanoDot dosimeters were purchased from Landauer, Inc. Following exposure, OSLD-absorbed doses were measured on a light photon counter (MicroStar InLight Reader, Landauer, Inc.). The readout was determined approximately 20 minutes after radiation exposure. The OSLD readers are calibrated for 80 kVp. To account for energy dependence of the dosimeter, correction factors were applied to the measured doses following the manufacturer's instructions. The correction factors were 1.0 for a 70-kVp beam and 1.2 for a 120-kVp beam. TLD-100 chips were supplied and analyzed by Landauer, Inc. Exposed TLDs were analyzed within 36 hours after radiation exposure. OSLDs were exposed within 24 hours after radiation exposure. Radiation exposures measured with a calibrated ionization chamber (RadCal, Monrovia, CA) served as control. Ion chamber doses measured in mR were converted to mrad using a conversion factor of 0.95 and were subsequently converted to μGy.

Determination of the dose response for OSLD nanoDots

To examine the relationship between radiation exposure and the measured doses, OSLD nanoDots and an ionization chamber were exposed to radiation from a dental x-ray unit (JB70, Progeny Dental, Linconshire, IL). Exposure parameters were 70 kVp and 7 mA. The source film distance and the exposure times were varied to provide a dose range of 10 μGy to approximately 4900 μGy, as determined by the ionization chamber. Separate OSLD nanoDots were used for each exposure setting and 2 independent exposures were made for each setting.

Determination of signal fading

Two OSLD nanoDots were exposed to a 70-kVp x-ray beam. The absorbed doses from OSLD nanoDots were determined 20 minutes after exposure. The dosimeters were then stored at room temperature for 1 month and the absorbed dose was remeasured. Three sequential readings were made for each dosimeter.

Determination of angular dependence

OSLD nanoDots, TLDs, and an ionization chamber were used to measure the x-radiation dose from a dental x-ray unit (JB70, Progeny Dental). Exposure parameters were 70 kVp, 1.4 mA, and a source-dosimeter distance of 30 cm. Dosimeters were exposed at the following beam incident angles: 0°, 15°, 30°, 45°, 60°, 75°, and 90° (where 90° represents the angle at which the central ray of the x-ray beam is perpendicular to the largest surface area of the dosimeter). Separate OSLD