

OSL on Tooth Enamel and Dental Repair Materials - Potential Emergency Radiation Dose Assessment Tools

GEBER-BERGSTRAND T.¹, RÄÄF C.L.¹ & MATTSSON S.¹

¹*Medical Radiation Physics, Department of Clinical Sciences Malmö, Lund University, Skåne University Hospital Malmö, 205 02 Malmö, Sweden*

therese.geber@med.lu.se, christopher.raaf@med.lu.se, soeren.mattsson@med.lu.se

Abstract. The aim of this work is to investigate the optically stimulated luminescence (OSL) properties of parts of human teeth and different dental repair materials. OSL uses harmless low power ($<100 \text{ mW cm}^{-2}$) light to stimulate electrons, which have been trapped following exposure of ionising radiation. Optical stimulation of the irradiated material leads to emission of light with intensity proportional to the absorbed dose. A first step toward *in vivo* OSL in the mouth has been initiated by testing the dose response of tooth enamel and dental repair materials to beta exposure using a Risø TL/OSL-15 reader. To be able to retrospectively determine the absorbed dose of an individual from e.g. a sample of their teeth, would be of great use in emergency triage situations, since teeth are individual and easy accessible.

KEYWORDS: *Tooth enamel, Dental ceramic, Dental composite, Emergency dosimetry, OSL*

INTRODUCTION

A radiological emergency of any kind will necessitate dose assessment of potentially exposed people in order to carry out proper remedial actions and medical treatment. In cases where non-radiological workers are involved, it is unlikely that any of the concerned people carry personal dosimeters. Therefore other ways to estimate the absorbed dose is needed. To be able to retrospectively determine the absorbed dose of an individual from e.g. a sample of their teeth, would be of great use since they are individual and easy accessible. The current method for determining the absorbed dose in teeth is by electron paramagnetic resonance (EPR), which requires the tooth to be pulled out. For obvious reasons avoidance of this would be preferable. Furthermore, EPR analysis of teeth requires that the sample is inserted into a well-defined static magnetic field, making the technique unsuitable for *in vivo* measurements. Optically stimulated luminescence (OSL) however, uses harmless low power ($<100 \text{ mW cm}^{-2}$) light to stimulate electrons, which have been trapped following exposure to ionising radiation. The stimulation leads to emission of light with intensity proportional to the absorbed dose. The first to propose dental enamel as a dosimeter using OSL was Godfrey-Smith and Pass (1997). Even though the OSL technique has been studied extensively for many materials, further studies on tooth enamel have been relatively few (Yukihara et al. 2007, Godfrey-Smith 2008, Meriç et al. 2008, DeWitt et al. 2010, Yüce et al. 2010 and Sholom et al. 2011). Even fewer studies have been made on dental repair materials, i.e. ceramics (Bailiff et al. 2002 and Veronese et al. 2010). All however, present promising results for the different materials.

The aim of this work is to investigate the OSL properties of parts of human teeth and different dental repair materials, i.e. ceramics and composites. This is to find out whether they have suitable properties to serve as emergency dosimeters.

MATERIALS AND METHODS

The samples used were fragments of human tooth enamel, two shades of dental ceramics (Duceram Plus, DeguDent, www.degudent.com) and two types of dental composite; one light cured (XRV Herculite, Kerr, www.kerrdental.com) and one chemically cured (Adaptic, Dentsply, www.dentsply.com). The teeth were cut into smaller pieces using a diamond saw and all visible dentine was removed with a dental hand drill (except for one of the samples, where the dentine was meant to remain). The repair materials were moulded into small 1-2 mm thick brick shapes. The samples were irradiated and measured in an automated TL/OSL reader (TL/OSL-DA-15, Risø National Laboratory, Roskilde, Denmark). Some samples were also irradiated using a ^{60}Co beam or a linear accelerator (Clinacq 2100C/D, Varian Medical Systems, www.varian.com). The TL/OSL reader is equipped with a $^{90}\text{Sr}/^{90}\text{Y}$ source that gives a dose-rate of about 0.9 mGy s^{-1} at the sample position. The stimulation light used is blue LEDs with peak emission at 470 nm and maximum power of 50 mW cm^{-2} . The blue light is filtered with a GG-420 long pass filter to reduce contribution from the low end of the emission peak. The emitted luminescence is detected by an EMI 9235QB photomultiplier tube (PMT), which has maximum detection efficiency between 200 and 400 nm. In front of the PMT is a 7.5 mm Hoya U-340 filter that prevents scattered stimulation light to reach the PMT. During readout the intensity of the blue LEDs were set to 40 % of the maximum stimulation power and were switched on for 100 s. All OSL measurements were performed using continuous stimulation power, i.e. continuous wave OSL. The minimum measurable dose, MMD, was estimated for all samples. This was done by calculating the mean of the background signal from three identical measurements on each sample without any given dose prior to readout. The MMD was then estimated as three times the standard deviation of the mean.

RESULTS AND DISCUSSION

After irradiation in a ^{60}Co beam the tooth fragment that consisted of both enamel and dentine exhibited a distinct difference in the dose-response, depending on whether the dentine or enamel side of the sample was oriented towards the stimulation light during OSL-readout, see figure 1. This clearly shows that the dose-response for dentine is much lower than for enamel. A similar difference has been demonstrated earlier using electron paramagnetic resonance measurements (Onori et al. 2008). Knowledge of this difference is important since the thickness of the enamel varies over the tooth surface and can in places be so thin that the OSL signal is affected by the signal from the dentine. This has been discussed as a possible cause of low signals also in OSL (Godfrey-Smith 2008).

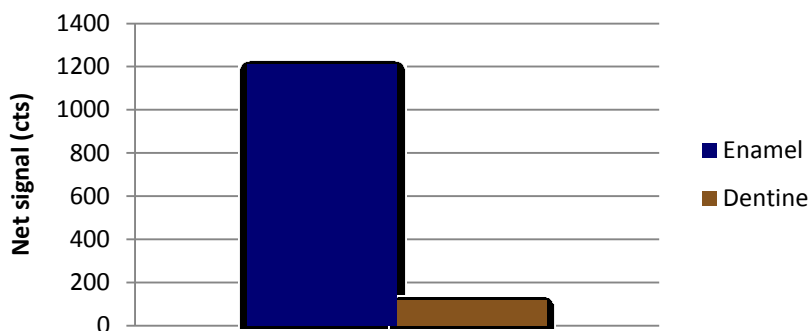


Fig. 1 Net signal in counts from an irradiated fragment of teeth being read out with the enamel and dentine side up respectively. The sample was irradiated with 10 Gy, using a ^{60}Co source, prior to each readout.

A clearly linear dose-response can be seen for the different tooth fragments (fig. 2). All fragments are from the same tooth and all dentine have been removed and yet a distinct variation between the fragments can be seen. This is consistent with previous work from DeWitt et al. (2010). The reason for this is most likely the variation in enamel thickness over the tooth surface. The MMDs for the different fragments also varied widely (table 1). The MMD for the enamel was considerably lower than many previously reported MMDs for tooth enamel (DeWitt et al. 2010, Godfrey-Smith 2008, Yüce et al. 2010), but in the same order of magnitude as a study on multiple-teeth samples (Sholom et al. 2011).

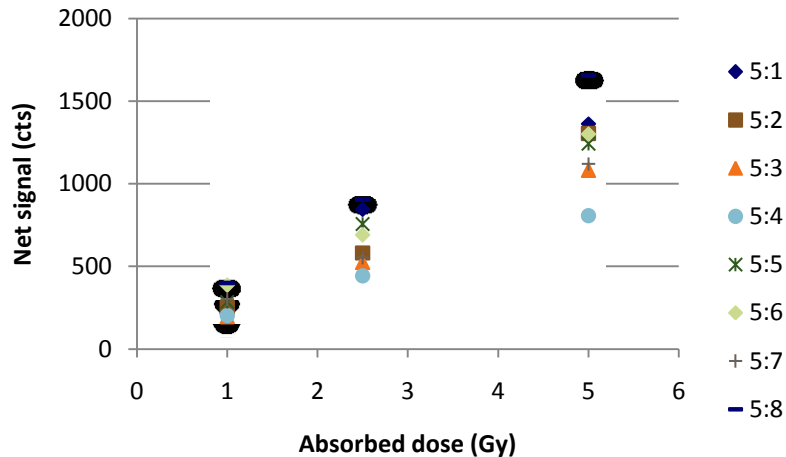


Fig. 2 Dose-response for eight different fragments of enamel from the same tooth irradiated with a $^{90}\text{Sr}/\text{Y}$ source.

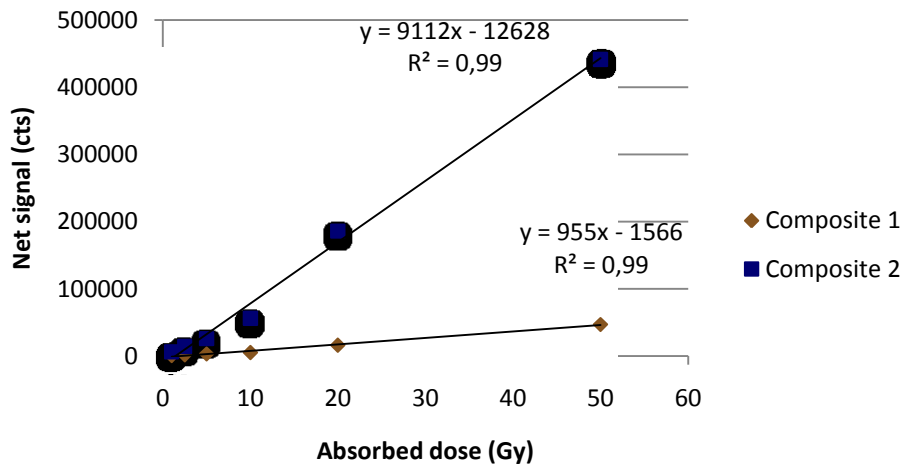


Fig. 3 Dose-response for two different composite materials. Irradiated with a $^{90}\text{Sr}/\text{Y}$ source for doses up to 10 Gy and a linear accelerator (10MV) for doses above 10 Gy.

In figure 3, a clear proportionality in the dose-response can also be seen for the composite materials. However, the sensitivity, in terms of net signal per unit absorbed dose, is much higher than for the tooth fragments and the calculated MMD is therefore lower, see table 1. Neither the composite materials nor

the ceramics show the same variability between different samples of the same piece as does the tooth, suggesting that a more solid calibration can be made for these materials. The ceramics are composed mainly of feldspar, which is known as an excellent OSL material (Bøtter-Jensen et al. 2003). The composites in turn consist of ZnO, which is also known for its good OSL response to ionising radiation.

Table 1. Minimum measurable dose (MMD) for different materials connected with human teeth. Calculated for eight different enamel samples and four different samples each for the other materials. Given are the average and the range for all measurements.

Material	MMD (mGy)
Tooth enamel	393 (40-1097)
Ceramic 1	125 (100-150)
Ceramic 2	376 (345-414)
Composite 1	110 (16-221)
Composite 2	68 (52-82)

CONCLUSIONS

All studied materials show promising properties to serve as dosimeters. The intra-sample variability is smaller for the composites and ceramics and thus calibration curves for these materials will be easier to obtain than for teeth. The major advantage of teeth is that they are present in the mouth of almost everyone. However, most of the adult population have some kind of dental repair material. That, together with the fact that the MMDs for these materials are lower than for other biodosimetric methods, as yet need extensive optimisation regarding the read-out process, makes them very interesting for accident dosimetry.

Before any *in vivo* dosimeter can be developed, further studies have to be made concerning the signal stability of teeth, in order to obtain a reliable calibration curve. Otherwise some kind of *in vivo* calibration will be necessary. A possible alternative for such calibration could be a very small X-ray tube with appropriate shielding so that only a small part of the tooth will be exposed. Further studies also have to be made on what part of the tooth and also what sort of tooth, i.e incisors, canines, premolars or molars, that is most suitable for OSL readout.

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