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The effect of ultraviolet induced fluorescence on visually perceived tooth color under normal light conditions

Sascha Hein[a,*], *Jaap J. ten Bosch*[b]

[a] *Private dental laboratory, Freiburg im Breisgau, Germany*
[b] *University of Groningen, The Netherlands*

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ABSTRACT

Objective. Restorative and prosthetic materials should provide an appearance similar to natural teeth under all light conditions, including UV-rich environments and daylight. Various studies claim that UV-induced fluorescence makes teeth whiter and brighter in daylight. The aim of this paper is to determine experimentally the significance of tooth fluorescence in natural sunlight on perceived tooth color.

Methods. A total of 35 extracted, hydrated teeth without restorations or endodontic treatments were evaluated in an experimental setup. A UV/VIS spectrometer using a reflectance/backscattering probe was used to collect the reflected spectrum. Unfiltered and filtered sunlight was used for irradiation of the samples so as to use the combined ultraviolet and visible spectrum (UV/VIS) and the visible spectrum (VIS) exclusively. Color coordinates for each group were measured using the CIE $L^*a^*b^*$ 1976 system, averaged, and compared.

Results. The average color difference between both groups (UV/VIS and UV) was ΔE^* 0.527. The average tooth color for the VIS group was L^*_{VIS} 72.21, a^*_{VIS} −2.42, and b^*_{VIS} 22.35, and for the UV/VIS group was $L^*_{UV/VIS}$ 72.00, $a^*_{UV/VIS}$ −2.47, and $b^*_{UV/VIS}$ 22.44.

Significance. UV induced fluorescence from sunlight does not make teeth whiter and brighter.

Contents

* *Corresponding author at*: Rennweg 17, 79106 Freiburg i.Br., Germany.
E-mail address: saschachristianhein@me.com (S. Hein).

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1. Introduction

Fluorescence, by definition, is the absorption of light by a substance and the spontaneous emission of light in a longer wavelength, within 10^{-8} s of activation. After the absorption of a photon, an electron of the fluorophore is excited to a higher energy level. After a slight relaxation due to vibrational and rotational energy losses within the excited state, the electron falls to its ground state, thereby releasing a photon. The vibrational and rotational energy is released as heat. Thus, the photon has a slightly lower energy than that which caused the excitation [1].

There are 3 types of tooth fluorescence: blue fluorescence, which is excited in the near ultraviolet (UV) region; yellow/orange fluorescence, which is excited by the blue and green wavelengths; and fluorescence in the far red and near infrared [2,3]. Yellow–orange fluorescence can be used for the diagnosis of dental caries [4]. Blue fluorescence, which is excited by near ultraviolet radiation, is relevant in the optical appearance of teeth. This type of fluorescence is clearly visible under illumination that is relatively rich in ultraviolet radiation. It is therefore of importance to a large part of the general public who visit environments such as nightclubs and entertainment shows [5]. Accordingly, because restorative and prosthetic materials should provide an appearance similar to natural teeth, the fluorescence of such materials is also very important, and consequently much research has been devoted to this field [1].

There is a widespread belief that ultraviolet-induced fluorescence in daylight noticeably affects tooth color [6–12]. Although studies [1,14] using the standard illuminants A and D65 as defined by the International Commission on Illumination (Commission Internationale de'L'eclairage, or CIE) [15] did not provide evidence for an influence of fluorescence induced by daylight, such studies were only artificial as sunlight was not used.

The aim of this paper is to determine experimentally the significance of tooth fluorescence in natural sunlight on perceived tooth color.

2. Materials and methods

2.1. Specimen selection

A total of 78 extracted teeth were obtained from a private periodontal surgery in Perth, Western Australia over a period of 12 months. Immediately after extraction, the teeth were stored in 10% buffered formalin. Teeth containing restorations, endodontic treatment, or having caries lesions were excluded from the study. Four intact mandibular anteriors were considered too small in size to yield accurate measurement results and were hence excluded. Thirty-five remaining teeth were included (Table 1). All suitable specimens were cleaned and stored in distilled water at 4 °C. The apical tips were cut off.

2.2. Standardization

To allow for standardized evaluations, a small disc (WS-1-SL, Ocean Optics, Dunedin, FL, USA) made of white, non-fluorescing, and diffusely reflecting packed polytetrafluoroethylene (PTFE) was used. For precise repositioning, all samples and the holder were fixed to acrylonitrile butadiene styrene (ABS) polymer blocks (Brick 2 × 2 and 2 × 4, LEGO, Enfield, CT, USA) using cyanoacrylate adhesive (Loctite Super Glue Gel, Henkel Australia, Thomastown, VIC, Australia) and cure-catalyst spray (Accelerator Spray, Zirkonzahn, Gais, Italy).

2.3. Color measurements in sunlight

In order to obtain color measurements using sunlight, a custom-made box (Fig. 1) was built with an open top that could be completely covered with either of two filters. The bottom of the box was lined with an ABS polymer grid (Item 626, LEGO, Enfield, CT, USA). A 5.0-mm-thick sheet of clear UV-resistant polycarbonate (Sunlite, Welshpool, WA, Australia) was used as a UV-blocking filter (VIS). The other filter (UV/VIS) was a 6.0-mm-thick UV-grade fused silica window (Knights Optical, Harrietsham, Kent, UK) (Fig. 1) that attenuates the solar spectrum in the same way, but allows passage of the ultraviolet portion of the solar spectrum (Fig. 2).

Reflected emissions including fluorescence were collected by a reflectance/backscattering probe (EOS-676969, Ocean Optics, Dunedin, FL, USA), with a fiber thickness of 600 μm and with an acceptance angle of 25.4°. The other end of the probe was attached to a spectrometer (USB-650 Red Tide, Ocean Optics, Dunedin, FL, USA). The distance from the buccal/labial surface of the teeth or the reflection standard, respectively, was 10 mm.

Measurements were conducted in Perth, Western Australia, under sunlight incidence of approximately 80° to the labial/buccal surface of the specimens between the hours of 12:00 and 13:00 when the UV levels were recorded highest during the day; UV index = 4 (100 mW/m^2).

Each tooth was measured with the box covered with the UV-blocking lid and immediately thereafter with the UV-transmitting lid. To detect malfunctions, the instrument was

Table 1 – A total of 35 teeth were used for the experiment.

Maxillary centrals	Mandibular centrals & laterals	Maxillary molars	Mandibular molars	Maxillary premolars	Mandibular premolars	Maxillary canines
7	5	5	6	7	4	1

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