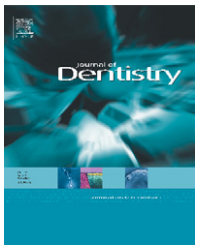
available at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/jden



Monitoring dental erosion by colour measurement: An *in vitro* study

J.B. Krikken, J.R. Zijp, M.C.D.N.J.M. Huysmans *

Department of Dentistry & Dental Hygiene, Academic Center for Oral Health, University Medical Center Groningen, University of Groningen, P.O. Box 196, 9700 AD Groningen, The Netherlands

ARTICLE INFO

Article history:
Received 22 January 2008
Received in revised form
8 May 2008
Accepted 9 May 2008

Keywords:
Dental erosion
Dental colour measurement
CIELab

ABSTRACT

Objectives: The aim of this study was to develop a method to monitor dental erosion by evaluation of the colour change of teeth as a function of enamel loss, and to evaluate the reproducibility of the method used.

Methods: Light reflectance spectra of 12 extracted human incisors were measured using a spectroradiometer and diffuse illumination. From these spectra CIELab colour parameters L^*, a^* and b^* were calculated. Erosive dental wear was simulated by incrementally removing enamel layers. We monitored the change of the colour parameters as a function of the enamel thickness removed.

A clinical situation using a phantom head and ambient illumination was simulated with 8 incisors. In this set-up colour change due to polishing was evaluated. The teeth were immersed in coffee and tea to estimate the effects of nutritional dyes, and so, to determine reproducibility of the method used in clinical situations.

Results: A relationship between tooth colour measured and enamel loss was found, in particular for the b^* value. The relation between the b^*-value and the enamel thickness removed showed a slope of $15 \pm 3\ mm^{-1}$, if the remaining enamel layer had a thickness of less than 0.5 mm.

Polishing of the teeth made them less yellow. Immersion in coffee darkened the teeth, but immersion in tea had no significant effect.

Conclusions: Due to individual variation, it was impossible to use this relationship to estimate the remaining enamel thickness, but the method presented may be suitable for monitoring progression of erosive enamel loss.

1. Introduction

Dental erosion is a growing problem especially among young people.[1] The term dental erosion is used to describe the physical result of a pathologic, chronic, localised and painless loss of dental hard tissue. This tissue loss is caused by chemical etching of the tooth surface by acids and/or chelation processes without bacterial involvement.[2] Erosion may arise if the pH on the tooth surfaces is below 5.5 during prolonged periods of the day.[3] The acids responsible for erosion stem from dietary, occupational or intrinsic sources. Most common causes of erosion are thought to be the use of acidic drinks like cola and fruit juices, and the reflux or vomiting of the acidic gastric contents.[4] Erosion is considered to be one of the types of dental wear, and is often more correctly termed erosive dental wear.[4]

* *Corresponding author*. Tel.: +31 50 363 2995; fax: +31 50 363 2696.
E-mail address: m.c.d.n.j.m.huysmans@med.umcg.nl (M.C.D.N.J.M. Huysmans).
0300-5712/$ – see front matter
doi:10.1016/j.jdent.2008.05.005

In contrast to dental caries, which is usually localised, erosive dental wear is often generalised. Whole surfaces are involved and clear visual signs such as opacities, discolourations and cavities are absent, making detection difficult. Tooth wear is usually assessed using visual scoring systems. These methods lack criteria for distinguishing stages of erosion limited to the enamel. Thus, erosion is mostly diagnosed at a severe stage and is difficult to monitor.[5–7]

Currently two quantitative assessment methods have been described. One method uses inert markers bonded on the teeth.[8] The height difference between a marker and the surrounding enamel determined by making impressions and subsequent profilometry, is a measure for the tissue loss. The other method using ultrasound for monitoring of erosion is in the phase of development.[9,10]

Loss of superficial enamel can be noticed by a yellow colour of the teeth. This is caused by the fact that the thinner enamel layer is more translucent than an intact enamel layer. The yellow colour of the underlying dentine is more visible through this thinner enamel layer.[11–13] We hypothesized that this colour change might be used for the detection or monitoring of erosion.

The colour of an object observed is the result of three combined factors: the spectrum of the light source, the spectral reflectivity of the object, and the spectral sensitivity of the eye.[11,14] The CIELab (1976)-system was introduced to describe colour as a result of these three factors. This system is a three-dimensional space, with coordinate axes L^*, a^* and b^*. L^* denotes the lightness of the colour ($L^* = 0$: black, $L^* = 100$: white), a^* represents the green–red axis (a^* negative: green, a^* positive: red), and b^* represents the blue–yellow axis (b^* negative: blue, b^* positive: yellow). Each object colour can be represented as a set of values for L^* a^* and b^*, and so as a point in this colour space.[14,15]

The aim of this study was to determine the colour change of teeth as described by L^*, a^* and b^* as a function of enamel loss. Also we evaluated the reproducibility of this method both in a highly standardized and in a simulated clinical set-up. We determined colour changes caused by other processes in practice, such as polishing and exposure to coffee and tea.

2. Materials and methods

Human incisors extracted for prosthetic reasons were collected from several clinicians, who stored them in a 5% sodium hypochlorite solution immediately after extraction. Twelve incisors without restorations or buccal discolourations were selected. These were glued upon microscope object slides with the buccal enamel surface facing up and plane parallel to the glass surface. This allowed for precise repositioning of the buccal surfaces for colour measurement.

Erosive dental wear was simulated by removing consecutive enamel layers with sandpaper (220 grid, Siawat, Bern, Switzerland) using tap water for cooling and lubrication. During grinding, the glass slides were put in a PMMA holder in order to keep them plane parallel with the original enamel surface. The slide surfaces were also used as reference planes to measure the amount of enamel removed. After removing a layer of about 70 μm, the teeth were superficially dried with a paper towel. Eight thickness measurements and four spectral reflectivity measurements were performed immediately. Means of these measurements were used in the analysis. The process of grinding, thickness measurements and reflectance measurements was repeated until the enamel–dentine junction was reached, usually after about 13 cycles. Thickness measurements were performed using an electronic micrometer (Magnascale LY-101, Sony, Japan). The thickness of enamel removed was determined as the difference between the thickness of the whole tooth before and after grinding. By visual inspection we determined whether the enamel–dentine junction was reached, passage of the junction could be observed as an increased surface dullness. Reflectivity measurements were performed with a spectroradiometer (PR650, Photo Research, Chatsworth, CA), in a hemisphere set-up, providing diffuse illumination of the teeth during measurement (Fig. 1). Each spectral reflectivity measurement consisted of two parts, measurement of the spectral reflectivity of a white standard $L_W(\lambda)$ (Spectralon, Labsphere, North Sutton, NH) followed by the measurement of the tooth $L_S(\lambda)$. The ratio of these two spectra was considered as the reflectance spectrum of the tooth.

From these spectra, both in $W/(m^2\ sr^{-1})$, we calculated the colour coordinates L^*, a^*, and b^* in CIELab (1976) colour space for D_{65} illumination according to a standard method.[14] For these calculations we used tabled values of $E_{D_{65}}(\lambda)$ which is the relative spectral irradiance distribution of the CIE standard illuminant D_{65}, and $\bar{x}_{10}(\lambda)$, $\bar{y}_{10}(\lambda)$, and $\bar{z}_{10}(\lambda)$ as the spectral tristimulus values according to CIE 1964. In the tables used[16]

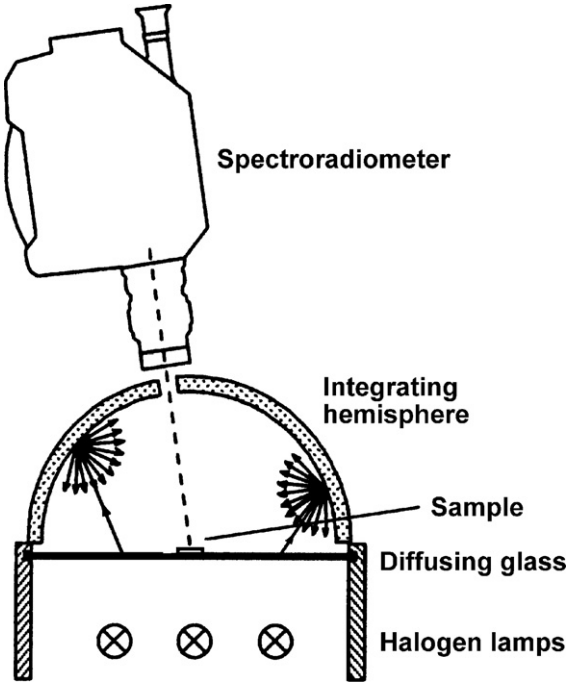


Fig. 1 – Hemisphere set-up as used for colour measurement. At the bottom is a box with lamps, these illuminate the opaque glass window at the top of the box. Over the box is a white integrating hemisphere that leads to diffuse illumination of the sample which is on top of the centre of glass window. The spectroradiometer is aimed at the centre of the sample.