



# The factors affecting visual discomfort of dental hygienist



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## ABSTRACT

The objectives of the paper were to analyse the visual behaviour and visual discomfort parameters of dental practitioner at work, introducing the “lighting quality” approach in professional lighting using a suitable measurement methodology able to evaluate all relevant photometric and spectral parameters, not only the standard expected, but also the luminance map of the visual field. Spectral investigations are necessary to evaluate the damage potential of the lighting radiation while the luminance map allows the evaluation of sources of visual discomfort and disability. The “quality of lighting” is a new concept not yet considered in professional lighting but already recognized in road lighting standards. The paper provides also suggestions for new measurement methodology and lighting fixture design and, for dental practitioners, recommendations about position and eye protection system to wear to improve visual comfort and minimize MSD, due to misplaced working position to avoid glare.

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## 1. Introduction

European standard “EN 12464-01:2011 Lighting of work place – Indoor work places” [1], represents the reference standard for lighting of indoor work areas. It specifies requirements (quantitative values of main lighting quantities) and suggestions to ensure visual comfort, accomplishment of visual task and safety of people working in indoor areas.

Visual tasks can be very different depending on the job required; therefore, the European standard provides dedicated tables for 53 different work tasks of which 14 were for Healthcare Premises. Among these, Dental surgeries are included. About Dentists work-place lighting, the standard refers also to “EN ISO 9680:2007 [4] Dentistry Operating Lights” standard, where additional quantitative requirements are considered such as illuminance levels,<sup>1</sup> and

Colour Rendering Index.<sup>2</sup> However, the ISO standard is focused on photometric, electrical and mechanical performances of operating lights. No considerations or prescriptions about lighting conditions or practitioner visual behaviour are given.

During practice, dental practitioners are exposed to very high luminance levels,<sup>3</sup> for long time, while performing crucial visual task, and can therefore experience visual discomfort. As regards visual discomfort, there is no widely accepted definition: usually the presence of visual discomfort is characterized by symptoms (difficulty in performing a visual task, annoyance, stress, and even physical effects such as headaches, pains, sore, itching, and watering eyes) clearly recognizable and associated with a source of the discomfort.

The main parameters able to break visual comfort are generally recognized as [1,17,18,21]:

<sup>2</sup> Colour Rendering Index Ra is the degree of difference in perceiving reference colours, and Ra is a number (1–100) measuring the difference in the colour of 14 reference objects, as rendered by the source used in dentistry lighting and by a source assumed as a reference: 100 means no difference between the rendering capabilities of the two sources. Values lower than 75 identify very strong differences, and higher than 95 identify very small differences. The value Ra is obtained as mean value of the all values (Ri) of the 14 reference samples (one Ri for each coloured sample), and the most relevant samples for this research are as follows: sample 9 (Ri9) representative of strong red, sample 10 (Ri10) yellow and sample 13 (Ri13) representative of the human skin.845-02-61 in CIE 17.4:1987 [6].

<sup>3</sup> Luminance (845-02-35 in CIE 17.4 1987 [6] is the quantity perceived by the human eye, and luminance is the luminous flux reaching the observer's eye, coming from a defined surface (real or imaginary that subtends a solid angle) from a defined direction (measured in [cd/m<sup>2</sup>]).

Abbreviations: CCT, Correlated Colour Temperature; C, intrinsic contrast; FOV, Field Of View; LED, light emitting diode; MSD, musculoskeletal disorders; UGR, Unified Glare Rating; VP, visual performance.

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<sup>1</sup> Illuminance is the amount of light on the area of work, 845-01-38 in CIE 17.4:1987 [6] is measured in [lx].

- The presence of glare from lighting sources or surfaces, especially overhead glare.
- Too low or too high illuminance and luminance levels, related to the visual task.
- Too low or too high luminance uniformities (depending on the level of adaptation).

In this research, the available European Standard for dental practitioner lighting is analysed and a dental workplace unit is characterized for the relevant photometric and visual parameters, in order to provide indications useful for a new approach to evaluate visual comfort [19,17].

It must be clear that the visual task of dental practitioner is very critical: very small details to focus on, crucial colour perception and risk of damaging the patient in case of mistake. Heavy and crucial visual task usually requires high illuminance levels as stated in both standards EN 12464-01 and ISO 9680, but high illuminance levels expose the operator to fatigue and visual discomfort.

This research considers the visual conditions of dental practitioners, especially focussed on dental hygienists although the indications are still valid for every dental practitioner. The paper highlights the main factors inducing visual discomfort during work, provides precautions for practitioner lighting set up and sets first quality criteria for dentistry lighting. Because “Lighting of Quality” doesn’t necessarily means “Lighting of Quantity”.

## 2. Materials and methods

The available normative documents about lighting for Dentistry (EN 12464-01:2011 [1] and ISO 9680) were analysed. Thereafter, a typical dental hygienist workplace, equipped with dental lighting fixture standard ISO 9680 compliant, was characterized in terms of relevant photometric quantities, and visual discomfort parameters using a dedicated INRIM methodology as described by Rossi et al. [17,18,21] and Iacomussi et al. [13], as standardized methodology was not available. To evaluate parameters of visual discomfort a luminance map of the practitioner field of view in different practitioner positions, was acquired using a luminance calibrated Charge Couple Device (CCD) detector [20,13].

### 2.1. Reference standard analysis

European standard “EN 12464-01:2011 [1] Lighting of Work Place – Indoor Work Places”, specifies the requirements needed to ensure visual comfort and to perform visual task and safety in different working places, including Healthcare Premises for Dentist (table 5.48 of EN 12464-01:2011 [1]).

The European Standard considers four areas with different lighting parameter requirements: the room general lighting, the lighting at the patient, the operating cavity lighting and the lighting for teeth matching. The relevant parameters are (Table 1):

- Maintained illuminance ( $E_m$ ), the quantity of light incident on a surface (definition 845-01-38 in CIE 17.4:1987 [6]).
- Unified Glare Rating (UGR), a number identifying the amount of discomfort glare suffered by a subject: the higher the value, the higher the glare [7,20].
- $U_0$ , the minimum illuminance uniformity, that identify the ratio between the maximum and the minimum value of Illuminance in the area of interest.
- Ra, the minimum value of Colour Rendering Index (definition 845-02-61 in CIE 17.4:1987 [6]).

It is to note that glare requirements are provided only for premises general lighting or for the patient, while for the

practitioner area (i.e. operating field) no UGR value is provided; nevertheless, practitioner is subjected to high glare levels. Indeed the practitioner Field Of View (FOV) is the patient mouth: no lighting fixture is in the FOV; however, it doesn’t mean that the practitioner is free from glare or he doesn’t see (in his field of view) glaring sources.

The most important area to be lighted is, obviously, the patient’s mouth (Operating Cavity), where the visual task is. For Operating Cavity and teeth matching, “EN 12464-01:2011 [1]” doesn’t specify reference lighting parameter values and refer to “EN ISO 9680:2007 [4]”.

However ISO 9680:2007 is a technical standard about dental lighting fixtures: it specifies requirements and test methods for electrical, mechanical and photometrical performances of lamps designed to illuminate the oral cavity of patients. ISO 9680:2007 is not a standard about lighting, but about performance of lighting fixtures, it does not provide any useful information about the lighting nor methods or attentions to be paid to reach good quality of technical lighting.

Instead EN 12464-01:2011 [1] is a standard about lighting: it suggests, as a good practice common to all workplaces, lighting design criteria to ensure the proper visual comfort in terms of luminance distribution, intrinsic contrast C (the relative difference in luminance between an object and its background) and several other parameters that fit well for interior lighting, but not for technical lighting. Dentistry lighting is a very technical lighting and common lighting design criteria can hardly be applied.

Obviously both standards do not adopt a “lighting quality” approach and refer to quantitative parameters for performances that can’t be applied to dental lighting or situations with workers exposed to high intensity lights for long time a day.

Technical lighting requires the definition of some parameters values, and the most important parameter is illuminance: it necessary to provide enough light to achieve defined visual performances. Indeed being able to execute a task does not assure the visual comfort and safety of the practitioner nor the best lighting conditions for task execution. It is necessary to define new parameters focused to improve the quality of lighting: no accepted definition for lighting quality is available. The quality of light is a subjective experience, depending on several aspects related to the subject, and usually is judged according to comfort, activity and level of performances needed.

An approach based on quality parameters is already applied in interior lighting [14] and road lighting EN 13201-4 [2,3] with measurand related to parameters able to describe human interaction with light. These parameters are mostly related to spectral distribution of light (Ra and CCT), intensity distribution in the field of view (uniformity and glare), but it is not possible to define a single parameter to assure “lighting quality” because lighting scenario and users must be considered too. Several lighting quality indexes have been proposed, some of them are related only to the lighting source properties [15], and others are also based on Environmental Psychology like the VBE Index (Visual, Biological, Emotional Index) [23] but is of difficult application in lighting standards. However EN12464-01:2011 already considers some quantitative parameters related to visual comfort, but not in sections dedicated to dentistry and other technical lighting: to introduce a quality metric approach for dentistry lighting it is absolutely necessary for a deep analysis of the dental practitioner visual condition, including field measurements of normative and qualitative parameters.

### 2.2. Analysis of the visual task of a dental hygienist practitioner

The visual system assignment is to extract information from the environment, its performance, VP, is measured by the speed and accuracy with which a particular task is performed CIE 145:2002

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