

## OPERATION FIELD ILLUMINANCE IN DENTISTRY

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### ABSTRACT

Dental treatment zone and operation field illuminance estimation were made in this study. Treatment zone illuminance was 500 lx under conventional fluorescent lamp based lighting and 1000 lx in a case of additional ceiling light use. Operation field illuminance under a dental operating light varied from 4000 lx to 14000 lx in dependence on an oral cavity zone and a patient position. The maximal illuminance level was achieved at upper incisors in a patient supine position, the minimal one was achieved at upper molars in patient upright position. Using of light emitting diode (LED) headlight increased the illuminance up to 2000 lx in average. The use of intraoral light sources provided adequate operating field illuminance in range (7000–18000) lx in molars area where illumination of dental operating light are not enough.

The study results allow recommendation of ceiling lights and intraoral lights as additional light sources.

**Keywords:** illuminance, operating field, dental office, luxmeter

### 1. INTRODUCTION

In modern dentistry, high-tech treatment methods are widely used providing a broad range of possibilities. At the same time, a dentist mostly deals with extremely small sizes, about (0.1–0.3) mm objects and this fact allows qualification of a dental treatment process as a high precise class

work [1]. However, high precise manipulations require proper operating field lighting. Standard and additional light sources rational using provides high quality treatment and prevents dentist vision disturbance caused by eye strain [2, 3].

Every dental office has general and point source illumination. Fluorescent lamps with good colour rendering index are recommended for general lighting. Moreover, all dental units have operating lights for direct oral cavity illumination. For this task, high brightness LEDs are mostly used as light sources [4].

At present time, operating field direct illumination equipment is widely presented in dental market. It is possible to qualify this equipment with three groups:

- Additional general illumination lights having wide light distribution, for example ceiling lights used for dental unit and treatment area illumination;
- Additional extra oral direct illumination lights, for example different LED based headlights and dental operating microscope light providing additional one dental range (5–6 teeth) illumination;
- Additional intraoral illumination lights used for indirect vision areas illumination, for example LED dental hand pieces, dental mirrors with LED light and suction & lighting systems (Max-Bite, Isolite).

In Russian Federation standard, the dental office overall illuminance is equal to 500 lx [5]. In actual health & sanitation rules the operation field illuminance value isn't established but it's noted that local light level doesn't have to exceed overall one



Fig. 1. The illuminance measurement at the lower molar occlusal surface

in more than 10 times. Basing on this requirement it's possible to suppose that the recommended operation field illuminance value is 5000 lx.

For any activity three illuminance zones exist [6]:

1. Operating zone (in dentistry – oral cavity). Oral cavity illuminance standard value is up to 20000 lx;

2. Transition – middle zone (patient chin). Middle zone illuminance is in range from 6500 lx to 10000 lx;

3. Overall illuminance zone (treatment zone illumination). Instrument table surface illuminance is close to (1500–2000) lx.

According to European Standards DIN5035–3:2006–07 (“Lighting of health care premises”) and DIN EN12464–1:2011 (“Lighting of work places. Indoor work places”) the recommended operating field illuminance value is 5000 lx, the treatment zone one is 1000 lx and overall dental office illuminance is 500 lx [7,8].

According to study made in 2006, dentist instrument table surface illuminance for fluorescent lamps based overall illumination was  $450 \pm 20$  lx, that is lower than standard value, and operating field (oral cavity) illuminance was in range (5280–6140) lx, that is higher than standard value [1]. Basing on study 2013, dentist operating field illuminance in state clinics was  $4930 \pm 8,2$  lx, and in private ones it was  $8850 \pm 7,6$  lx [9].

Treatment zone and operating field illuminance values can be significantly varied in dependence on dental operating light power and on additional light sources used. According to ISO 9680:2014 “Dentistry: Operating Lights”, dental lights must provide adjustable operating field illuminance close to range (8000–20000) lx [10]. In the RF Natio-



Fig. 2. Additional ceiling light

nal State Standard: GOST 26368–90 “Medical luminaires. General technical requirements and test methods”, the maximal operating field illuminance is stated as not more than 2800 lx at recommended distance in range (0.7–1.0) meter (at the patient eyes level – not more than 1000 lx) [11]. Several manufacturer promotional materials announce that dental operation light is able to provide a surface illuminance up to 30000 lx at a distance 0.7 meter. However, it's necessary to note that it's much difficult to provide a direct tooth surface illumination, so a real molar illuminance level usually will be lower.

**The aim** of this study was a dental treatment zone and operating field illuminance determination in dependence on used lighting devices.

## 2. METHOD AND RESULTS OF THE STUDY

The study was performed at the restorative dentistry department of Sechenov University, Moscow.

The treatment zone and operating field illuminance values were measured with luxmeter TKA-PKM (08) (“Scientific & Research company TKA LTD, Russia). The luxmeter includes a measurement sensor, LCD display module and connecting stranded flexible cable. For treatment zone illuminance measurement the sensor was placed at the surface of instrument table. For operating field illuminance value measurement the sensor was protected with disposable digital x-ray sensor sleeve and placed in oral cavity (Fig. 1).

The measurements of treatment zone illuminance were made under natural light, under standard fluorescent lamp based lighting and with additional ceiling light for dental office. The operating field illuminance was measured under following light sources:



Fig. 3. Dental unit operating light



Fig. 4. LED headlight



Fig. 5. Colour filter for LED headlights

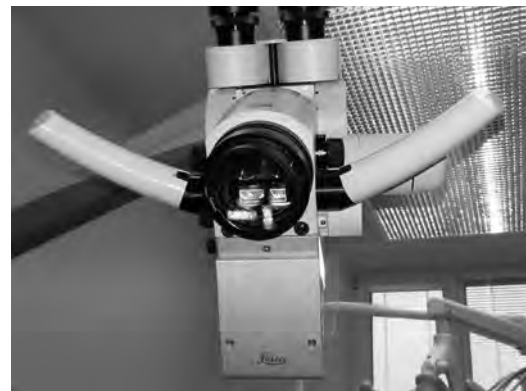


Fig. 6. Dental operating microscope

- Conventional fluorescent lamp based lighting;
- Additional ceiling light for dental office D-TEC (manufacturer listed the illuminance value 5800 lx at the distance of 1.2 m) (Fig. 2);
- Dental operating light of the dental units: A-DEC200, A-Dec Int., USA (according to manufacturer, LED light provides the illuminance value 8000–17000 lx) and Darta 1605 M, Russia (according to manufacturer, LED light provides the illuminance value 3000–35000 lx) (Fig.3);
- LED headlights: Crystal LED Light and NOW. CLIP (NOW, China), providing the maximal illuminance 35000 lx (Fig. 4); colour filter for LED headlights DK – Cap (DKH Dr. Kim, Republic of Korea) (Fig. 5);
- Dental operating microscope with LED light Leica M 320 Hi-End (KaVo, Germany) (Fig. 6);
- Dental mirror with LED light LumiEst (Geosoft, Russia-Israel) (Fig. 7);
- LED dental turbine handpieces: SYNEATG – 98 L (W&H Dental Werk, Austria) (Fig.8) NTKsd – 300 (BX-Taifun, Russia);
- Intraoral suction & lighting system MaxBite (China) (manufacturer listed the illuminance value 5000 lx) (Fig. 9).



Fig. 7. LED dental mirror

The intraoral measurements were performed in upright and supine patient positions. The sensor was positioned at the upper incisors vestibular surfaces, lower molars occlusal surfaces and upper molars occlusal surfaces. In the each area 2 measurement series were performed under different light sources. Each series included 5 measurements. Totally it was performed 50 series of 5 measurements. Further illuminance average values and their standard deviations were calculated. Treatment zone illuminance values are presented in Table 1.

**Table 1. Dental Office and Treatment Zone Illuminance Value**

Light source	Illuminance, lx
Natural light* (by the window)	805±15
Natural light* (treatment zone)	232±20
Conventional fluorescent lamp based lighting	470±25
Additional ceiling light for dental office	1000±15

\* the measurements were carried out at 11 a.m. in a cloudy autumn weather



Fig. 8. Dental LED turbine handpiece



Fig. 9. Intraoral suction&lighting system MaxBite

Natural light is not enough for adequate illumination of dental treatment zone (232±20) lx, so it's not recommended to examine the patient under natural only. Though some authors recommend determining patients' teeth shade under natural light when direct or indirect esthetic restoration is planned. In that case it would be better to determine teeth colour near the window, where illumination is better (805±15 lx) and near the daylight.

Under conventional fluorescent lamp based lighting treatment zone illuminance was lower than recommended level (470±25) lx. The illuminance was depending on instrument table position. The maximum illumination level was achieved when the instrument table was positioned directly under the light source. Under additional ceiling light the treatment zone illuminance was (1000±15) lx and corresponded to European standards.

The operating field illuminance depends of the oral cavity zone, Table 2. When dental operating light is used, the maximum illuminance is determined on the upper incisors' vestibular surface (12300±2500) lx at upright position and (13200±1200) lx at supine position). So, there is no need to use any additional light sources to perform dental treatment in this area. Illuminance on the lower molars also depends on patient's position.

When the patient is in the supine position, the dental operating light can be placed directly above the oral cavity (light incident angle is close to 90°), so the illuminance value can be up to (10000±1000) lx. In the upright patient's position the light incident angle is less than 90° and illuminance value decreases to (54000±500) lx. However, this illuminance value is more than 10 times higher than treatment zone illuminance level, provided by standard fluorescent lamp based lighting. The minimum illuminance was determined on the upper molars' occlusal surface in the patient's upright position, (2500±300) lx.

During dental treatment the tooth surface can be shaded with dental handpiece or any other instrument, so the illuminance level can decrease significantly. In the presented study when turbine handpiece was positioned in the oral cavity the illuminance value at the lower molars' occlusal surface was 250 lx in upright patient's position and 300 lx in supine position.

When additional light sources are used, the operation field illuminance varies from 2300 lx up to 12500 lx (Table 3).

LED operating light alone provides the illuminance in lower molars area (2300±30) lx. When LED head light and dental operating light are used

**Table 2. Different Zones of Oral Cavity Illuminance Value, Provided by Dental Operating Light (the distance is 70 cm)**

	Patient is in upright position, lx	Patient is in supine position
Upper incisors' vestibular surface	12300±2000	13200±1200
Upper molars' occlusal surface	2500±300	3900±500
Lower molars' occlusal surface	5400±500	10000±1000
Lower molars' occlusal surface (the operation field is shaded with dental hand-piece, positioned in oral cavity).	250±5	300±10

**Table 3. The Operation Field\* Illuminance with Additional Light Sources**

	Dental operating light is off, lx	Dental operating light is on, lx
LED headlight	2300±300	12100±300
LED head light with colour filter	101±4	Not used
LED light source of dental operating microscope	6800±500 (40 cm distance)	12500±300

\* The measurements were performed at lower molars' occlusal surface

**Table 4. Operation Field Illuminance Provided with Intraoral Light Sources**

	Dental operating light is off, lx	Dental operating light is on, lx
Dental mirror with LED light	950±12	11200±200
LED turbine handpiece	5200±500	6800±300
Intraoral suction & lighting system MaxBite*	Min* 3000±500 Max* 8000±500	Min* 13000±1500 Max* 18000±2100
* dimming		

together, the illuminance is (12100±300) lx, which is more than 20 times higher than treatment zone illuminance, provided by standard fluorescent lamp. However, the problem of operation field shading during dental treatment is not dissolved.

When direct tooth restoration is performed, the use of LED headlight can lead to composite resin premature polymerization due to high intensity blue spectra region [4]. So, for resin composite modelling special colour filter is recommended. In that case, operation field illuminance decreases up to 101 lx.

Nowadays endodontic treatment, microsurgery and many other procedures are performed under high magnification with dental operating microscope. Built-in LED light source provides the operation field illuminance value (6800±500) lx when used alone and (12500±300) lx when used together with dental operating light.

Intraoral light sources put the light directly to the operating field and provide a high illuminance value (Table 4).

Dental mirror with LED light provides illuminance (950±12) lx when used alone and (11200±200) lx when used together with dental operating light. So, with dental mirror with LED a good illumination of operation field can be reached even in zones of indirect vision.

When LED dental handpiece is used, the light beam is directed exactly to the tooth surface, but the handpiece itself partially obstructs the light from dental operating lamp. In this situation the operating field illuminance was (6800±300) lx, which was much better comparing to the dental handpiece without LED light, (300±10) lx.

Intraoral suction & lighting system MaxBite can provide the operating field illuminance from (3000±500) lx up to (5000±500) lx when

used alone and in range from (13000±1500) lx to (18000±2100) lx when used together with dental operating light. The system is fixed opposite to operating field (when the treatment is on the right side, MaxBite is on the left side), so the light can be partially obstructed with instruments used during dental treatment.

The results of the study demonstrate that the conventional overall illumination with fluorescent based lamps is not enough for adequate lighting of treatment zone. Recommended by standards illuminance value 1000 lx can be reached, when additional LED ceiling light is used.

The operation field illuminance depends on oral cavity area and patients position. The best illuminance level was achieved in patient's supine position. The dental operating light can provide illuminance values from 12000 lx up to 14000 lx at the incisors and from 4000 lx up to 10000 lx at the molars. So, the difference between treatment zone and operating field illumination can be up to 12–14 times. During the working time, the dentist has to switch attention from operating field to instrument table many times. The significant difference between illuminance values leads to eye fatigue due to frequent adaptation to varying light levels [2]. This can have adverse effect on the vision of the dentist and assistant [12]. According to T.F. Danilina et al., 86.7 % of dentists note eye fatigue after the working shift [13]. According to A.V. Nemaeva et al. after the working shift 60 % of dentists note blurred vision and 20 % have eye redness [14].

The use of LED headlights together with dental operating light allows increasing illuminance up to 2000 lx. However, the dental operating light alone can provide illuminance relevant to European standards. So, there is no need to use LED headlight for conventional dental treatment, especially on the zone of indirect vision. Headlights have narrow angle light distribution. If a dentist turn his head to the instrument table and back during a treatment, it's necessary to refocus a headlight. Headlights using is the most efficient at long treatment procedures requiring a maximal dentist attention and high illuminance level (for example, endodontic surgery). It's also important to take into account that in cool white LEDs a royal blue band light intensity is significantly higher than yellow-green band one that is a cause of additional dentist eye strain [15].

It's necessary to note that maximal illuminance level is achieved only in front teeth group area.

In molar area the illuminance is significantly lower. At first, it's impossible to provide a direct lighting in lower molar and especially upper molar area. At second, instruments shade the operating field in this region. In these cases intraoral light sources providing adequate operating field illuminance even in indirect vision zones are the most efficient.

The results, which were obtained in the upper research, allow recommending ceiling lights and intraoral light sources (dental mirrors with LED lights, LED dental handpieces and intraoral suction & lighting systems) as additional lighting in dentistry.

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Fig. 1. The illuminance measurement at the lower molar occlusal surface



Fig. 3. Dental unit operating light



Fig. 5. Colour filter for LED headlights



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