ERGONOMIC SOLUTION REGARDING LOCAL ILLUMINATION SYSTEMS IN DENTAL OFFICES

BODEA Renata[1], HULE Voichița[1]
[1]University of Oradea
prod.conf@rdslink.ro

Keywords: ergonomics, illumination, dentistry, dental magnifier, optical design

Abstract: The paper discusses thoroughly the difficult conditions of posture and concentration effort necessary to the dentist. Illumination characteristics have a strong impact both on the quality of medical activity and doctor's health. There is enough room for improvement in this direction. The paper presents a complete design of a dental magnifier, meant to ensure proper magnification and view fields in conditions of ergonomic posture of the physician.

1. CRITICAL ASPECTS REGARDING THE ILLUMINATION OF THE WORK FIELD

The medical dental practice involves muscular and visual fatigue due to continuous effort to keep long-term specific postures and visualization of the work field.

As a result, it develops fatigue of the head, neck, shoulders, back and especially eyes. The work of a dentist requires daily focus and refocus at several thousand times. Also, hard, complex and high precision work reduces blinking frequency (which, at rest varies between 12 and 20 per minute).Low frequency of blinking leads to a reduction below normal of cornea moisture, causing chronic eye irritation and possible infection of the external morphological elements of the eye.

Long effort of focusing and refocusing equivalent to permanent concentration in watching a specific target, causes eye fatigue with decreased visual acuity and general fatigue felt in entire body. In fact, excessive and prolonged stress, imposed by a wide range of professions, including the dentistry, can lead to installation of astenopia, an ophthalmologic disease manifested by fatigue and eye pressure, eye redness, internal-eye pain or extended pain to adjacent areas to the eyeball, blurry sight, headache and occasionally double vision (stereoscopic viewing disability). These symptoms occur in particular due to strong and prolonged concentration, attention and vigilance, leading to excessive contraction of muscles in the anatomical structure of the eye and cause irritation, dryness and ocular discomfort.

Although the dentist is facing a very large number of visual tasks, and therefore, illumination plays a significant role in his work, there is relatively little evidence of standardization in the field. Basically, it is accepted that the relationship between the illumination of the work field and respectively the environment must be around 4. Weaker local illuminations, for the purposes of this report, induce a considerably supplemental nervous consumption expressed in slowing the execution of operations, nervous exhaustion and permanent reduction of vision.

Research has allowed the following observations:

- visibility in field work, as direct effect of illumination affects the performance and efficiency of medical activity
- individual light sources are preferred, as they are manageable in terms of positioning in space and energy characteristics
- adjustable local lighting sources in addition to energy saving advantage, creates to the human operator the sensation of comfort and reduce the degree of difficulty of the carried operation.

Ergonomically speaking, local dental office lighting is correct if it meets the particular requirements of:

- local lamp type
- lamp placement relative to the operator and the working field locations
- size of illumination
- directivity of the source light
- uniformity of the light
- light color.

Elements listed above, in variants or at inappropriate values, create conditions for an unsuitable lighting. This can manifest in several aspects:

- insufficient lighting (luminous flow too low)
- improper distribution of light (operator field must be uniformly illuminated, without shadows and penumbra)
- insufficient contrast (with poor discrimination of details)
- local or global brightness too high (with the effect of reducing the overall visibility and local or global contrast decrease)
- discontinuous nature of illumination (the flicker issue).

Improper lighting, in addition to negative effects on the ergonomic nature over the medical practitioner, promotes errors in diagnosis and treatment, such as:

- omission of early interproximal caries or the deposition of tartar scaling
- disharmony color in restoration with resins materials
- failure depicting small cavities in posterior teeth
- hinder in diagnosis and treatment, in case of using classical mirrors, which reflect the light nonuniformly, even though a source with optimal characteristics emits the light.

In conclusion, one can follow two distinct ways of optimizing the illumination from the standpoint of ergonomics in the dental office, namely:

- improvement of visibility on the work field
- flexible lighting on the work field, both in terms of spatial location and energy characteristics.

2. SOLUTIONS TO INCREASE VISIBILITY OVER THE WORK FIELD OF THE DENTIST

Adequate visibility inside the patient's mouth provides both diagnosis and correct treatment of dental problems. Early detection of cavities or detection of caries placed in shady areas, making treatment of dental roots open channels, proper finishing of dental restorations, involve a very good visual acuity and permanently active, through effort of concentration due to reduced the scale of work areas.

A solution to improve visibility, regardless of the lighting system is using the binocular magnifying glass, which has two major roles:

- forms increased images of details beyond the separation power of the eye. Overall, view of the work area at a larger scale releases the effort of concentration and enables the operator to apply treatment procedures with a higher accuracy than at direct view
- allows viewing of the work area to adjustable distances for the doctor's eye, so that its position should be favored ergonomically. Area can be viewed and submitted to the necessary operations without bending the head, neck and back, which improves comfort and promotes physician's accuracy and efficiency.

Dental purpose binocular magnifier can be designed as a set consisting of two magnifiers, placed parallel, at the pupillary distance of the doctor, with the support goggles, which usually, the doctor wears anyway.

In relation to general purpose magnifiers, the medical purpose magnifier should be a compound lens, providing a magnification of small size, but wide field with a very high image quality (which requires at least spherochromatism and distortion correction).

In principle, the magnifier is an optical instrument used to observe small objects or details.

It is a convergent optical system consisting of one or more lenses. The magnifier forms virtual, increased and erected images of objects placed between the object focus and the principal object plane.
Magnification magnifying is defined as the ratio between the apparent image size and natural apparent size (size of the image formed on the retina when the eye looks through the device, respectively from the minimum distance of clear vision). Magnification magnifying depends on focal length, object distance, but also of the state of accommodation of the eye.

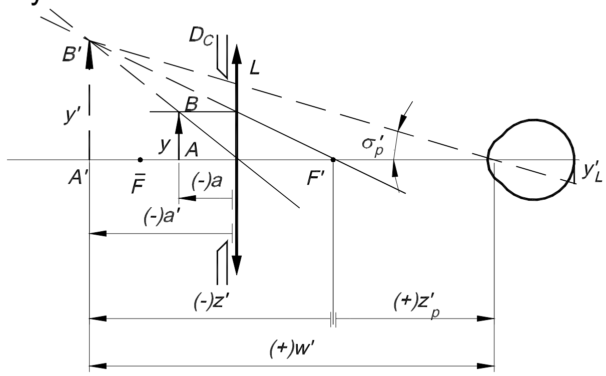


Fig.** 1 **Basic optical scheme of the magnifying glass

Considering an object of height y, located in front of the magnifying glass L (fig.1), its image y', is seen by the eye under the angle σ'_p, the apparent size of the image being y'_L. Eye position before the lens is given by z'_p abscissa and the image of z '. The sum of these distances is denoted by w '.
Eye-lens optical system aperture diaphragm, D_d, is the pupil of the eye that receives the exit pupil role. The entrance pupil is the image of the eye pupil formed by the magnifier. The mount of the magnifying glass plays the role of field diaphragm. The same object, viewed with the naked eye from the minimum distance of clear vision is seen under the angle σ'_o and the natural apparent image size is y'_o (fig. 2).

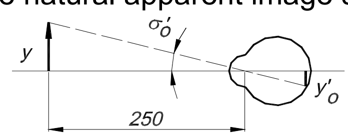


Fig.** 2 **Object seen with naked eye

Magnification ratio can be written as [1], [2]:

$$\Gamma = \frac{y'_L}{y'_o} = \frac{tg\sigma'_p}{tg\sigma'_o} = \frac{y'}{w'}\frac{250}{y}. \tag{1}$$

Ratio y'/y - β - is replaced by its expression -z'/f'. Magnification becomes:

$$\Gamma = \beta\frac{250}{w'} = -\frac{z'}{f'}\frac{250}{w'} = \frac{w'-z'_p}{w'}\frac{250}{f'}. \tag{2}$$

The final expression for the magnification takes the form:

$$\Gamma = \frac{250}{f'}\left(1-\frac{z'_p}{w'}\right). \tag{3}$$

Relationship (3) reveals the magnification dependence of focal length f', eye position by z'_p and object position by w'. Commercial magnification is defined while the eye is accustomed to infinity ($w'\to\infty$) and the object stands in the focal plane:

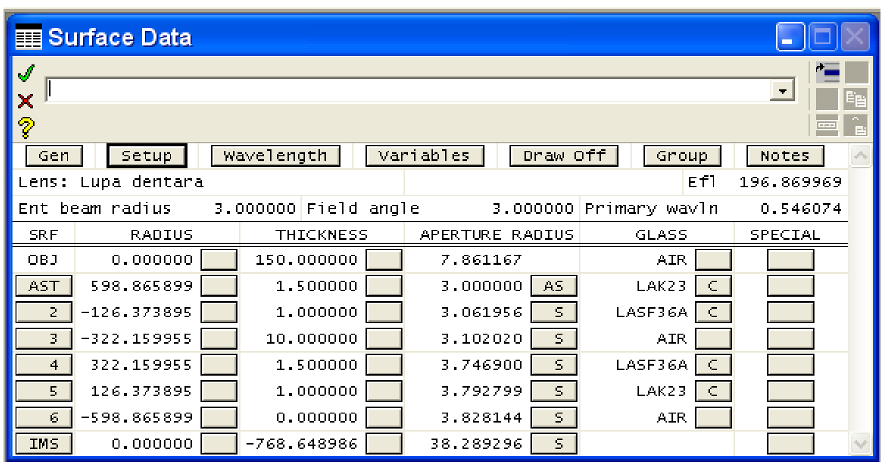
$$\Gamma_c = \frac{250}{f'}. \qquad (4)$$

Commercial magnification is entered on the magnifying glass mount as digits followed by the sign "X" (e.g. 3X, 5X, etc.). Real and commercial magnification are equal if the eye is in the focus ($z'_p=0$) and the eye is emmetropic. Real magnification greater one unit to the commercial one if the image is formed at the minimum distance of clear vision (w '= 250) and the eye is very close to the lens ($z'_p \cong -f'$):

$$\Gamma = \frac{250}{f'}\left(1 - \frac{-f'}{250}\right) = \Gamma_c + 1. \qquad (5)$$

For eyes with ametropiae, the expressions determined for magnification are not valid, because the minimum distance of clear vision is different than 250.
From functional point of view, magnifying glasses fall into two categories:
- ❑ observation magnifiers, for viewing small objects or details of these
- ❑ measuring magnifiers equipped with reticules or graduated scales, to measure the observed details.

Dental magnifiers are only instruments for observation. Associated optical systems are designed for low magnification (<5X). According to relationship (3) magnification can be easily changed by varying the object distance, respectively approaching or removing the tool from the field under observation.
It comes, further, a magnifier model of two achromatic doublets. The Surface Data of the system show very small axial dimensions (~15 mm) - fig. 3 - to a field object of ~16mm (fig. 4). At a distance of ~ 200 mm, the magnification is 4.8X (fig. 5). The image formed by the lens proves very good quality as shown in the statistical analysis of wavefront (OPD PV and RMS OPD - fig. 6) and Fourier PSF parameter, whose value is close to unit (fig. 7).


Surface Data
Gen | Setup | Wavelength | Variables | Draw Off | Group | Notes
Lens: Lupa dentara — Efl 196.869969
Ent beam radius 3.000000 Field angle 3.000000 Primary wavln 0.546074

SRF	RADIUS	THICKNESS	APERTURE RADIUS		GLASS		SPECIAL
OBJ	0.000000	150.000000	7.861167		AIR		
AST	598.865899	1.500000	3.000000	AS	LAK23	C	
2	-126.373895	1.000000	3.061956	S	LASF36A	C	
3	-322.159955	10.000000	3.102020	S	AIR		
4	322.159955	1.500000	3.746900	S	LASF36A	C	
5	126.373895	1.000000	3.792799	S	LAK23	C	
6	-598.865899	0.000000	3.828144	S	AIR		
IMS	0.000000	-768.648986	38.289296	S			

Fig. 3. Geometry and reference characteristics of the designed magnifying glass

By scaling a reference system when the quality parameters are appropriate, it is easy to obtain a family of magnifiers with lower magnifications and longer working distances. Optimally, the magnification is correlated with the linear visual field size. Their recommended values are:
- ❑ magnification range (2... 3.5)x
- ❑ working distance (200...500)mm
- ❑ object field size: (9...15)mm.

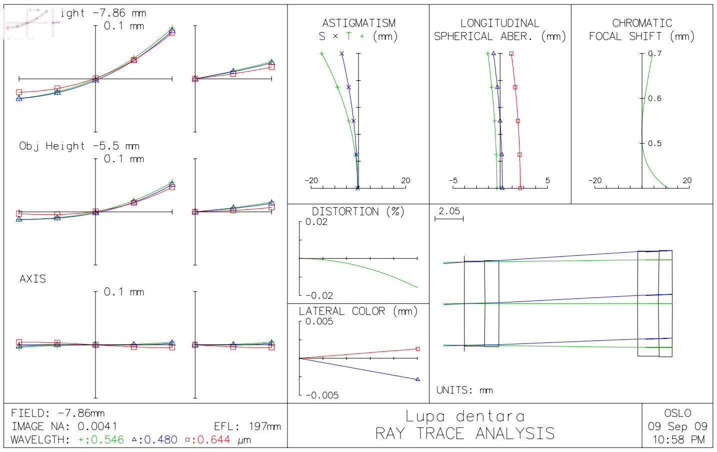


Fig. 4. Geometric and chromatic aberrations of the system at a linear object field of ~ 16 mm

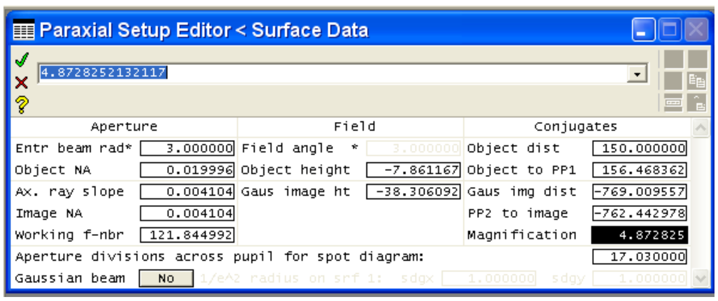


Fig. 5. Reference characteristics (magnification 4.8X)

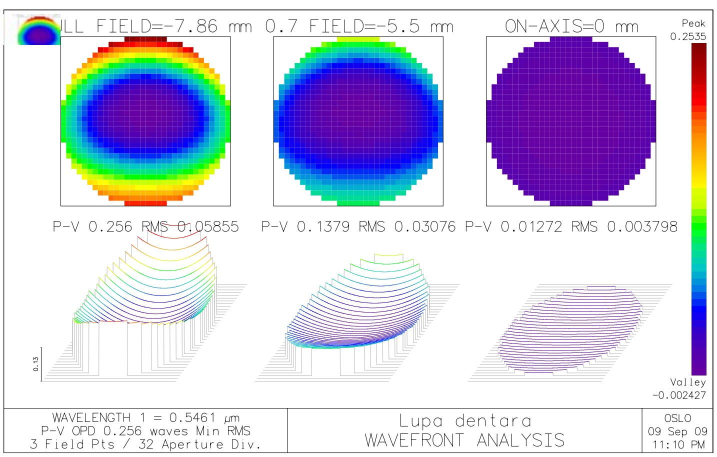


Fig. 6. Wavefront analysis (P-V<0.2λ and RMS < 0.07λ indicate a diffraction limited system)

Figure 8 presents two models of dental binocular magnifying glasses attached to protection goggles (without frames, respectively, mounted in titanium frame).

Besides the advantage of improving the viewing, the doctor is ergonomically favored because of the possibility of acquiring a suitable model in terms of working distance – fig. 9 – (which depends on the characteristics of operator's eye, of his stature, anthropometric dimensions such as arm length etc.). In figures 10 and 11 are compared doctor's postures without, namely with the use of dental magnifiers.

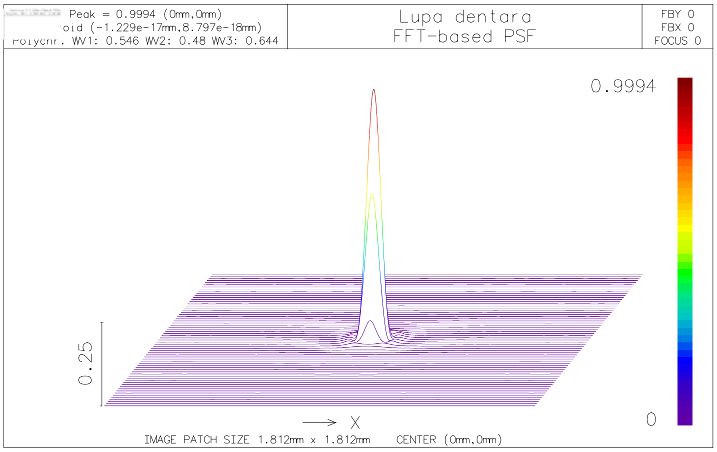


Fig. 7. PSF of the optical system associated to the dental magnifier

Fig. 8. Dental binocular magnifying glasses attached to protection goggles [3], [4]

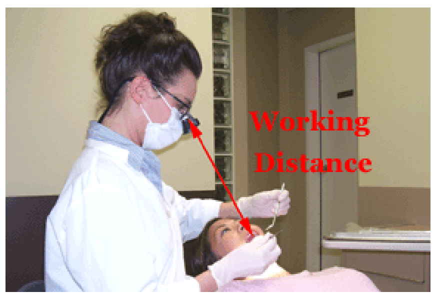


Fig. 9. Use of dental magnifier allows a normal posture of the physician

Fig. 10. Traditional posture [3]

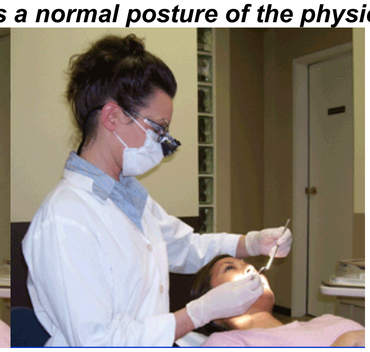


Fig. 11. Ergonomic posture [3]

3. CONCLUSIONS

Working in a dental cabinet is very stressing from different points of view, including the illumination conditions. The dental magnifier is a solution for ergonomic posture of the physician. Magnification and field are specific for such applications. A complete range of magnifiers may be developed from the solution designed in the paper.

REFERENCES

[1] Gruescu, C, *Elemente de optică tehnică şi aparate optice*, Ed. Orizonturi universitare, Timişoara, 2000
[2] McCluney, R., *Introduction to Radiometry and Photometry*, Artech House Inc., Norwood, MA, 1994
[3] http://www.loupedirect.com/?gclid=CNeE6KrA4pwCFdMWzAodx0P1kQ
[4] http://yts-dental.ro/ochelari.html#dios