International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79. 57 | Impact Factor (2015): 6. 391

A Detailed Study on the Role of Photographic Objective in Dental Photography

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Abstract: ***At present, photography plays a critical role in dental practice. Dental photography assists dentists in treatment planning, communicating with patients and to keep a track on treatment proceedings. To achieve the expected results in each of the above stage, it is important to capture the images with better resolution. The resolution depends upon the selection of lens. Even with best camera and good photographic skills, dental practitioners won't be able to produce a good image without a right lens. This article emphasizes the significance of lens in dental photography. At present, lens plays crucial part in determining the image quality. Recently, lens-less camera which could produce a 3-D image was developed. This study also covers the future of lens-less camera in dental photography.***

Keywords: Dental, Photography, Resolution, Camera lens, lens-less camera

1. Introduction

Photography is an important procedure in dental practice. Dental Photography provides a record of patient's intraoral and/or extra-oral photos for diagnosis, treatment planning, consulting specialist and professional marketing. Dental photograph helps in providing a visual communication to patients, students, colleagues and laboratory personnel. It plays a vital role in Legal documentation and Insurance verification. Above all, dentists use dental photography as a key to self-education, assessment and improvement. Dental photography ranges from a full face photo to specific oral point. The lens of a camera in today's world plays a major role not only in digital dental photography but in all types of photography. But the role of lens in dental photography is inevitable. Selection of lens is an essential process since the quality of image depends on it. Lens affects the focusing, aperture and resolution. The better the resolution the better dentists could express their point of view to the patients. In case of cosmetic dentistry, dental photography plays a major role in marketing. Dentists could easily create awareness among patients about the treatment process with the help of before and after treatment pictures.

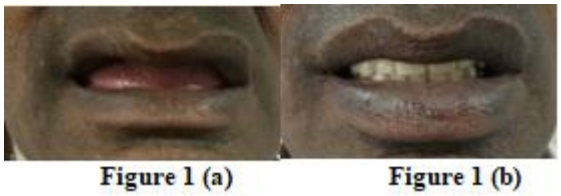

Figure 1 (a) Figure 1 (b)

Figure 1: Complete denture work (a) before treatment (b) after treatment.

The before (left) and after (right) treatment images of complete denture work done by the second author to a 53 years old male patient. It is true that dental practitioners could take a good photograph with a good camera and right photographic skills. But without the right lens, photos won't be of good quality. Intraoral photography was an inconvenient process until there was a considerable growth in close-up lens technology. Recently, Researchers have developed the lens-less camera and took it a step further by producing a 3-D image with it. This study aims at providing the importance of lens and the future of lens-less camera in digital dental photography.

2. Dental Photography

Dental photography is mainly used for two purposes: record keeping and communication. In dental photography, "camera is important, photographic style and technique is more important, but the lens is the most important thing to be considered. "Dental photographs can provide information that is not seen in radiographs. Based on the application, the digital camera used in dental photography is of two types, they are histogram-based camera and through-the-lens[TTL], metering-based system. There are two main types of dental photography based on whether the photograph was taken inside or outside the mouth. They are intra-oral and extra-oral photography. Mirror view is also used to capture dental photographs. The general recommended setting to take a best photograph is

Shutter speed	- 1/125 to 1/200
ISO	-100 to 200
Aperture	-
Extra-oral	: f-8 to f-11
Intra-oral	: f-32
Mirror View	: f-16 to f-19

The settings mostly vary within the above specified range along with white light balance. The aperture value depends on the focal length of the lens. For producing good pictures the shutter speed, ISO and aperture must be in proper combination which is explained by triangular exposure.

Triangular Exposure

The Triangular Exposure is an important concept to be considered in dental photography. By varying Aperture, ISO and shutter speed values photographers could take over, correct and under exposure photographs. Unlike other photographic professionals, dental practitioners can't take photos which are under or over exposed. A dental photograph should be taken with correct exposure settings as

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this plays a major role in providing clarity about tooth shape and color shade information.

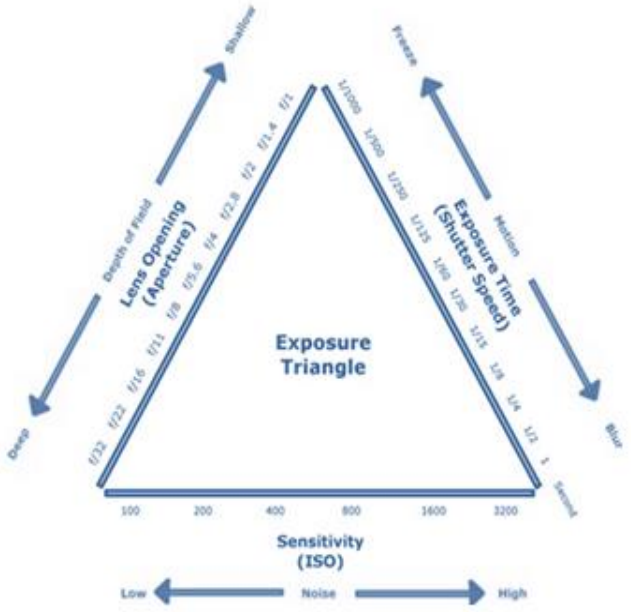

Figure 2: Exposure triangle

From the above triangle, it is understood that by setting any of the right combination of the above values correct exposure photographs could be obtained. But if the focal length of lens is not selected properly, it may result in noise or blur of the image.

Photographic Lens

The camera or photographic lens, also known as photographic objective is composed of assembly of lenses fitted together in a tube known as lens barrel. The lens barrel is usually made up of metal and the lens is made up of optical glass or plastic. The lens used in a camera is convex lens. The parallel rays of light from an object are converged by the convex lens at one point called the principal focus. The distance between the center of the lens and the principal focus is called the focal length.

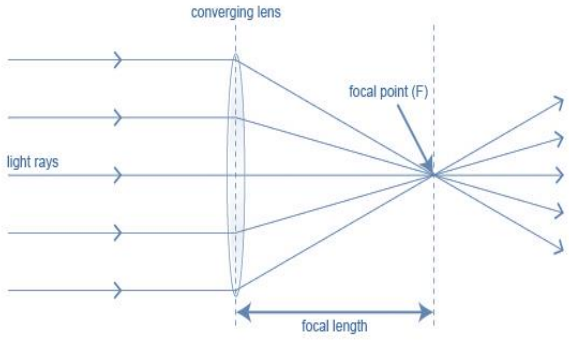

Figure 3: Focal length of a lens

In photography the object is the subject which is to be captured and the principal focus is the film or sensor. The three main types of lenses used in photography are macro, zoom and special purpose lens. The lens which allows enough light to pass through it to produce sharp and bright images with short exposure times is considered as a good lens.

Dental Photographic Lens

The type of lens that is generally used in dental photography is macro lens. Macro type lens is designed to take close up views and has the ability to focus closely on small objects which is essential in dentistry. For dental photography, the focal lengths around 100 mm are considered as the best choice. Focal length is selected as such to reduce face distortion. The focal length of the macro lens is chosen based on the views needed as follows:

Up to 2 teeth	: 100/ 105mm
Up to a quadrant	: 85mm
No smaller than a full mouth	: 60mm

In dental photography, a lens is considered ideal based on two factors. An ideal lens should have shortest minimum focusing distance and must produce minimum distortion. Based on the above factors, 100 mm lens is widely used in dental photography. The selection of lens has a great impact on magnification, focusing distance, depth of field, sharpness, aperture area, image quality, exposure value and shutter speed.

Exposure Calculation

Exposure value is calculated using the shutter speed and aperture setting value. The minimum shutter speed is determined by the focal length. Therefore, the exposure value indirectly depends on the focal length. The intensity of the light for the same f-stop value does not vary with focal length. The equation to calculate exposure value is

$$E_v = A_v + T_v \quad \rightarrow (1)$$

The Aperture value is calculated as follows

$$A_v = \log_2 A^2 \quad \rightarrow (2)$$

The Time value is given by

$$T_v = \log_2 (1/T) \quad \rightarrow (3)$$

Where A is the relative aperture (f-number) and T is the shutter speed in seconds.

From (1), (2) and (3)

$$E_v = \log_2 (A^2/ T) \quad \rightarrow (4)$$

Also,

$$(A^2/ T) = (ES/ C) \quad \rightarrow (5)$$

$$E_v = \log_2 (ES/ C) \quad \rightarrow (6)$$

$$E_v = \log_2 (LS/ K) \quad \rightarrow (7)$$

Where E is the illuminance
C is the incident-light meter calibration constant
S is ISO arithmetic speed
L is the average scene luminance
K is the reflected-light meter calibration constant

The f- number (also known as focal ratio, f-ratio, or f-stop) in a camera is the ratio of focal length to the diameter of the effective aperture.

$$N = f/D \quad \rightarrow (8)$$

Where f is the focal length and D is the diameter of the effective aperture. The f-stop scale is approximately obtained by a geometric sequence as follows

$$N = f/ (\sqrt{2})^n \quad \rightarrow (9)$$

Where n = 0, 1, 2…
The area of aperture is given by

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$$\text{Area} = \pi (D/2)^2 \quad \rightarrow (10)$$

From equation (8) & (10)

$$\text{Area} = \pi (F/2N)^2 \quad \rightarrow (11)$$

The intensity of the light is inversely proportional to the square of the distance travelled. Thereby, the intensity can be calculated as follows,

$$I \alpha (1/D^2) \quad \rightarrow (12)$$

$$I = \text{Area}/D^2 \quad \rightarrow (13)$$

Shutter speed vs. Focal length rule of thumb states that "the shutter speed value in seconds should be the less than the inverse of focal length in millimeters. "

$$T \geq 1/f \quad \rightarrow (14)$$

3. Calculation for Dental photography

A 100 mm lens is widely used in dental photography. The 100mm here indicates the focal length. Therefore, according to Shutter speed vs. Focal length rule of thumb, the minimum value of shutter speed should be 1/100. The general ISO setting for dental photography is 100. The typical value of K is 12. 5. Assuming the luminance available for capturing the subject as 1000 cd/m^2, the following results are obtained.

Parameter	Symbol	Value	Unit
Exposure value	E_v	13	EV
Illuminance	E	20480	Lux
Relative aperture	A	8	Nil
Shutter speed	T	1/125	sec
Aperture diameter	D	12. 5	mm
Aperture area	Nil	122. 72	mm^2
Light intensity	I	0. 0123	Nil
Aperture value	A_v	6	Nil
Time value	T_v	-7	Nil

Lensless Camera

Lens is used to focus light in a specific direction. Lensless camera, as the name indicates can take photos without lens. It has a permeable film instead of lens. The focus can be adjusted after capturing the image and signal processing is used to reconstruct the shadow image formed by the permeable film. Also an imaging chip which can produce image from light sensors has been developed. Researcher took it a step further by producing a 3-D image from 2-D image thus formed. The hardware is simple and inexpensive, but there is a loss in resolution. The features of a lensless camera are thin, compact, inexpensive and robust.

4. Future Scope

In dentistry, lensless camera could provide an invaluable service especially in capturing intraoral photographs due to its thinness. But the images captured by the lensless camera have low resolution and there is slight variation in color. In dentistry (specifically in esthetic dentistry), the details and color shade matching is important for treatment planning, record keeping and communication. In future, modifications in chip receivers and aperture array could enhance the resolution of the image produced.

5. Conclusion

Thus from the above study, it is clear that the photographic objective plays an important role in dental photography. It is clear that the lens should be selected properly to attain the expected results. The lensless camera is expected to come into practice in 2018. As per the present studies, the lensless camera has lower resolution compared to conventional camera. Cosmetic dentistry primarily focuses on improvement of dental aesthetics in color, position, shape, size, alignment and overall smile appearance. Therefore, lower resolution may negatively affect the professional marketing in dentistry. But with modification in chip receivers and aperture array, it may be the future of dental photography.

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