

COMPARATIVE REVIEW OF DSLR CAMERAS AND SMARTPHONES IN DENTAL PHOTOGRAPHY : INDICATIONS AND LIMITATIONS

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Abstract

This review will cover a historical perspective of dental photography, its major role in dentistry as well as all the indications relative to it. All the camera's set-up and features will be discussed. The role of each component in the camera will be explained, the focus being a theoretical comparison between digital single lens reflex cameras (DSLRs) and smartphones and their use in dentistry. Dental photography has become a must in everyday clinical practice, from patient communication to legal protection to many other utilities. Smartphones are on the fast track trying to replace expensive set ups like DSLRs, which are considered as the best cameras until this day.

Keywords: Dental photography - single lens-reflex 35 mm cameras – smartphones – sensor – lens - image quality.
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EXAMEN COMPARATIF DES APPAREILS PHOTOGRAPHIQUES DSLR ET DES TÉLÉPHONES PORTABLES EN PHOTOGRAPHIE DENTAIRE: INDICATIONS ET LIMITATIONS

Résumé

L'article couvrira un historique rétrospectif de la photographie dentaire, son rôle majeur en dentisterie, ainsi que ses indications relatives. Tous les appareils photographiques, leurs accessoires ainsi que leurs caractéristiques seront discutés. Le rôle de chaque composante de l'appareil photographique sera développé, avec un intérêt particulier portant sur la comparaison des principes théoriques entre les caméras conventionnelles et les téléphones portables ainsi que leurs utilisations en dentisterie. La photographie dentaire est devenue indispensable dans notre pratique quotidienne. Elle facilite la communication avec les patients, sert de preuve et de protection légale en cas de litiges et offre de nombreuses autres utilités. Depuis les récentes avancées technologiques les téléphones portables essaient de remplacer sur le marché les appareils conventionnels, plus onéreux.

Mots clés: photographie dentaire – appareil photographique conventionnel - téléphones portables – capteur – objectif - qualité de l'image.
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Introduction

Digital Single Lens Reflex (DSLR) is considered till this date as the best cameras used to take high quality dental photographs. The main problem with these devices is their high cost. When buying a DSLR camera, one should buy the body, the lens, the flash unit, the polarizer filter and some other accessories. This makes them hard to reach financially by some dentists and especially by students.

Recently, as smartphone technology advances in terms of sensor quality, resolution, and lens sophistication, mobile dental photography has started to gain track in dentistry. The main advantages of smartphones compared to the DSLR are their lightweight, low cost and ease of use, which make them highly competitive with the latter in case they prove to be in line with dental photography indications.

The purpose of this review is to highlight the major roles of dental photography in our everyday clinical practice.

All the camera's set-up and features will be discussed. The role of each component in the camera will be explained, the focus being a theoretical comparison between DSLRs and smartphones and their use in dentistry.

History of dental photography

The history of photography has roots 350 years BC. The Greek philosopher Aristotle was the first to talk about photography. While watching the shape of the partially eclipsed sun between the leaves of a tree and the holes of a strainer, he noticed that the smaller the hole, the sharper the image [1]. His description was the first made of the camera obscura device. Cameras evolved from the camera obscura, and continued to change through many generations of photographic technology, including daguerreotypes, calotypes, dry plates, film, and to the modern day with digital cameras.

Over half a century ago, dentists started looking for a photographic device that could show their patients what they are seeing.

The history of photography and dentistry started in 1840. During this year the world's first photographic gallery was opened and operated by a dentist who turned to be a photographer [2], the first dental college was established and the first dental journal was printed.

The biggest obstacle to taking dental photographs at that time was the incapacity to get light into the dark oral cavity. While the technology of close-up lenses allowed the cameras to take close-up photographs of an intra-oral subject, illuminating the darkness of the mouth was still a problem.

This problem was solved in 1952, when Lester A. Dine invented the first ring flash to be especially used by dentists. Since that time, photography and dentistry have been partners, as photography has become an integral part of a patient's record [3].

Through the 1960's-1970's, the use of photography in dentistry became popular; As this popularity had grown, the use of the 35mm film-based photography became insufficient and considered as limited.

The dentists could take photos of patients in their office, but they couldn't review those photos until the film was developed. Due to this time delay, there was a clear need for immediate photographic results in dentistry.

This need coincided with the invention of instant film cameras. However, these instant film cameras did not provide the same image quality given by the big 35mm film, nevertheless they offered the dentist the ability to take a photograph and see the results within a couple of minutes [3].

In 1975, the first digital still camera was invented by the Kodak engineer Steven Sasson.

In the 1980's, as computers became more advanced, the desire of dentists to computerize their patients' data and photography has increased [3].

In 1981, Sony introduced a prototype of the Sony Mavica. This camera featured interchangeable lenses and a SLR viewfinder. The popularity of intra-oral video cameras leveled off and was replaced by the digital photography.

In 2000, the first real camera phone was produced by Sharp and released in Japan by J-Phone (now SoftBank Mobile) [3]. It is only in the recent years that the use of camera phones has been gaining track in dental photography.

Indications of dental photography

Legal protection

Within a matter of months, dentists and patients tend to forget how the initial situation of the patient was.

To avoid legal disputes, and to remind both the dentist and the patient of the original situation, it is important to have clinical photographs at the patient's first visit. These photos will indicate any preexisting pathology, trauma or any previous treatment done by another dentist [4].

A proper photo documentation of the case is necessary not only to legally protect the dentist, but the patient as well [5]. It may help a mistreated patient, defend a colleague who has provided appropriate treatment, and protect the dentist from any malpractice lawsuit or later financial damages.

Diagnosis and treatment planning

Extraoral and intraoral photographs can be an effective treatment-planning adjunct. In addition to the patient records (medical history, dental history, clinical examination, radiographs, periodontal charting and study models), the attached photos allow the practitioner to see small details that, sometimes, can be missed during a regular clinical examination. This will help him establish the right diagnosis and then put the right treatment planning as if the patient is present [5].

Self-evaluation

As dentists, we should be continually learning throughout our career.

Beside books, conferences and seminars, the best way to a continual education is our self-evaluation and the learning from our own mistakes and experiences.

Quality dental photographs can be an excellent learning device. Due to magnification on a big screen, we can analyze our work and see in clear detail what is wrong and can be improved. The magnified image can highlight imperfections that the clinician may have overlooked, and helps him to improve the quality of care he provides to his patients.

Laboratory communication

In order to fulfill the esthetic demands in prosthesis, the communication between the dental technician and the dentist should be ideal.

The laboratory needs information about the tooth shape, position, dimension and color. Sometimes additional information about the gingiva (texture and shade) are required. This information may demand patients themselves to be physically present. A stone model may accurately provide information on tooth position and shape, but provides NO information on tooth or gingival character, shade, or color.

Maybe one of the most important roles of photography in dentistry today, is the photo that helps us choose correctly the color of our final restoration.

A colored photograph facilitates the communication with the laboratory by providing much needed information to create a final restoration with more accurate hue, value, and chroma. Photographing the shade tab adjacent to the teeth to be restored makes the chances of success higher [5].

Patient communication/ portfolio

Photographs of the patient's initial situation help the dentist educate the patient on diagnosis and proposed treatment, especially when accompanied by a portfolio of before and after photographs of similar, successfully treated cases.

One of the key roles of dental photography is allowing each dentist to build his own portfolio, by taking photos of before/after of his own cases.

Many stock images or animations of teeth and dental practice can be obtained from a dental library or through Internet websites, but it is preferable to use one's own patients' photographs. This way we enhance our new patients' confidence and we increase their acceptance of the treatment plan [5].

Specialist consultation/referral

Dental photography also improves the quality of referrals.

Charting, radiographs, and written reports were the traditional means by which the dentists used to communicate. Nowadays, photographs add an entirely new dimension to our reports.

For example, in the field of oral pathology, where lesions can be ambiguous or completely obscure, a complete history of the patient accompanied by a high resolution photograph may be sufficient enough for an over-the-phone consultation with a pathologist, without the need of the patient's physical presence.

Marketing/ advertising

The importance of digital marketing is increasing every day.

While still viewed negatively by some, and still illegal in some countries like Lebanon, marketing by dentists is becoming a necessary part of today's modern dental practice. It has a tremendous capacity to help any dental practice grow more effectively through internal and external marketing.

The former includes all forms of stationery, business cards, appointment cards and practice brochures, while the latter includes social media, journals, magazines or web pages. For many dentists, marketing has simply become part of the monthly overhead.

Well-written descriptions of the dental practice and the services of the dental office are important in the marketing efforts, but patients' before/after photos remain the most powerful tool

that can motivate and excite patients to pursue a treatment plan.

These photos can be easily purchased from many practice websites, but their quality in term of contrast, saturation and resolution is obviously poor.

Original photographs, taken by the dentist for his own cases, better enhance marketing with superior color accuracy/saturation, sharpness, and high resolution [5].

Professional instruction/publications

Photography is a key part of academic in many ways.

It can be used for the following purposes:

1) To prepare university lectures: pictures are essential in the field of education, enabling the student to have a clear image of the topic explained.

2) To publish books or articles: pictures help the lecturer in understanding the text and effectively visualize what the written passage is about.

3) To prepare conferences or poster presentations: up to now the most common way of education is through presentations, which are supplied with plenty of pictures and videos [4].

In the three cases high standard photographs are required.

For publications, many dental journals show strict publishing criteria for images.

For the lectures and conferences, after taking pictures and storing them, an accurate editing is essential to create clear and explicative presentations. Here it is important to remember that dental images are dento-legal documents, therefore, editing should be kept to a minimum, where the edited photo will not alter the original image that reflects the clinical situation in the oral cavity.

Photo editing or photo manipulation is possible through specific computer tools included in all the picture visualization programs. The use of the cropping, rotation and zooming tools is ethically acceptable in dentistry; it's even desirable to visualize what is

only needed in the photo by framing it and removing all the extraneous items such as saliva ejectors, cheek retractors and cotton rolls.

An important point to mention is that after each editing, the image quality will decrease even with the highest format, that's why the original picture issued directly from the camera should be of a good quality with a high resolution [6].

Digital smile design

Since patients became increasingly seeking dental and medical treatments for esthetic purposes, dentists have been more aware of the powerful impact of a good communication with their patients.

This communication evolved from a verbal explanation of the treatment planning, to some images of patients treated in similar cases, to a design wax-up [7].

In recent years, with the drastic improvement of digital dental photography and computer softwares, clinicians are able to predictably plan a smile design and communicate anticipated results to patients and ceramists alike.

Today, the DSD Concept is considered the most modern powerful tool for showing patients the possibilities for enhancing their smiles.

This concept is based upon the analysis of the patients' facial and dental proportions by studying the relationship between teeth, gums, lips and smile with the facial features in motion and with emotion.

In order to accomplish this analysis and plan a case with DSD, few but high quality series of digital photographs are required [8].

Different camera types used for dental photography

Intra-oral camera

Used to capture images very quickly and display them immediately for the patient.

It is a good tool for a quick intra oral tour, showing patients defective restorations, cavities or any type of pathology [9].

Their disadvantage is that they give an image of a very small area, and their image quality does not fulfill the minimal requirements of a dental photograph.

These cameras are not recommended for dental photography [10].

Compact "point and shoot"

Point-and-shoot cameras have better image quality than intraoral cameras, but still not suitable for dental photography. Their flash and lens are not interchangeable as they are built in. These cameras produce some image distortion due to their lenses which are not suitable for close up photography [9].

Mirrorless camera:

Mirrorless cameras do not use a mirrorbox or pentaprism; as a consequence they do not use an optical viewfinder. This gives them the advantage to have smaller camera bodies and more compact lenses. Their size is comparable to a compact camera, but with a larger image sensor that enable them to take better quality images. Their Flash and lens units are modifiable but with limited choices. They have similar capabilities to a DSLR in a smaller package. They can be used in dental photography.

Digital Single Lens Reflex cameras (DSLR)

DSLR is a digital camera that uses mirrors to direct light from the lens to the viewfinder, (the hole that we look through to see what we are taking a picture of).

The scene that we are taking a picture of, passes through the lens in a form of light into a reflex mirror that sits at a 45 degree angle inside the camera chamber; the reflex mirror then forwards the light vertically to an optical element called a "pentaprism. The pentaprism then converts the vertical

light to horizontal by redirecting the light through two separate mirrors, right into the viewfinder (Fig.1). This means theoretically that what is seen in the viewfinder is identical to that recorded on the resulting image.

A DSRL has 3 components: a body, a lens and a flash system.

The main advantage of a DSLR is the interchangeable lenses, which are selected according to the type of photographic application, which means that any number of "interchangeable lenses" with different focal lengths can be fitted, to suit the photographer's needs and requirements.

Different flash systems can be associated to a DSLR like a ring flash, twin flash and a studio flash.

DSLR cameras are very suitable for dental photography [9].

Smartphone cameras

Smartphones' cameras, like all cameras available on the market, comprise two main components: a sensor and a lens, which are built in the device.

As they get better each year, for lots of people, they have replaced the point and shoot cameras for everyday photography, due to their smaller size and ease of access. During the last few years, as smartphone cameras are continuously improving in terms of sensor quality, megapixels, aperture, and resolution, Mobile Photography has been introduced to the dental field and became useful by some dentists.

DSLR or Smartphone camera?

Ideal camera for dental photography

Whether it's DSLR or smartphone camera, in order to talk about an ideal camera for dental photography, we must begin with what we should expect from this camera.

Besides being affordable price and lightweight, the ideal camera should fulfill all the indications of dental photography mentioned above.

Even though a good image quality is a common trait among all the indi-

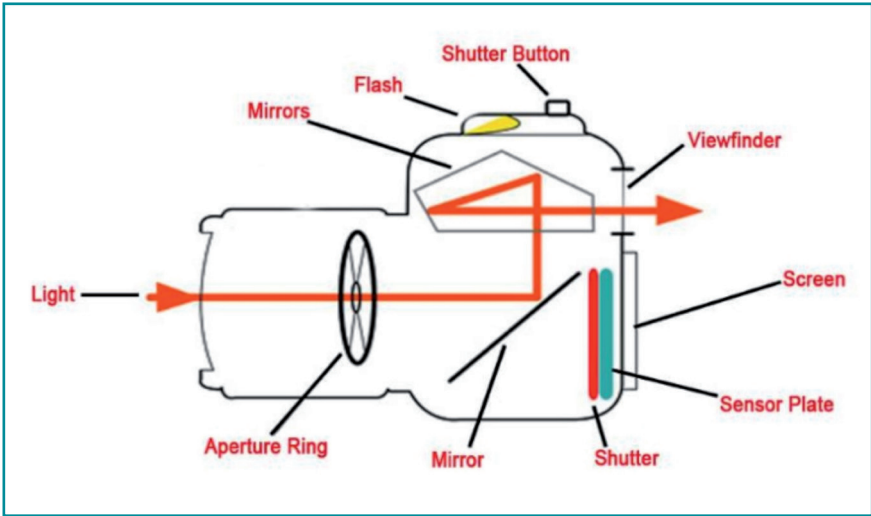


Fig.1: DSLR camera illustration.

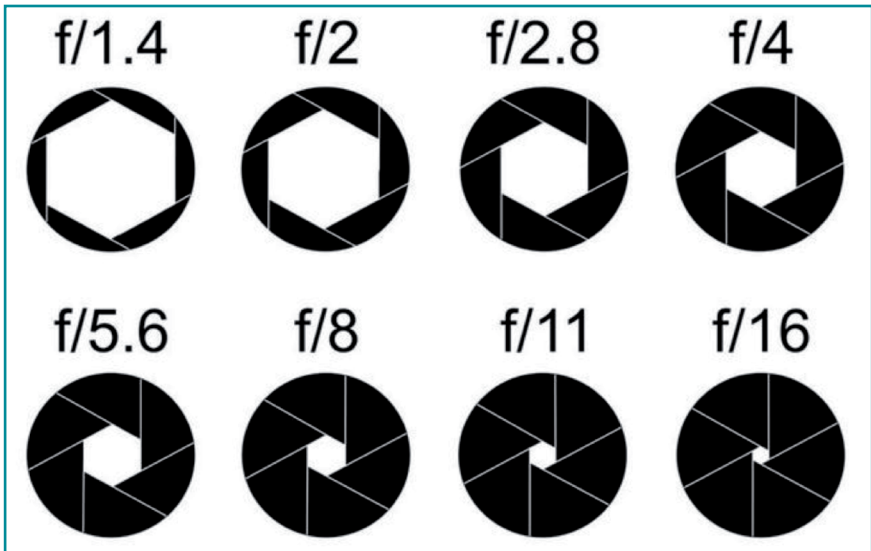


Fig.2: Different f stops diameters.

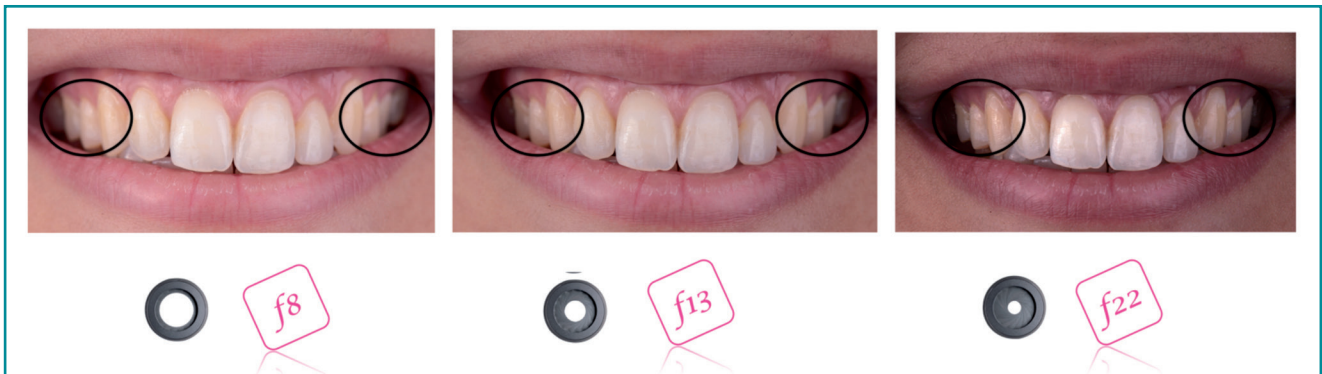


Fig.3: Different f stops effect on the pictorial outcome.

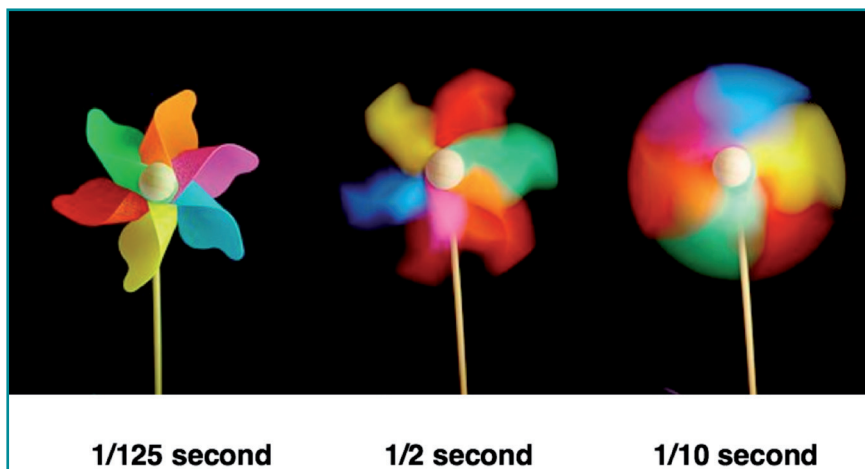


Fig.4: Different shutter speeds' effect on the pictorial outcome.



Fig.5: Different ISO effect on the pictorial outcome.

cations, some require more or less quality than the others.

Image quality

Image quality refers to the faithfulness with which a picture represents the imaged object.

There are many factors that affect directly the image quality. Listed below are some of them:

*Sharpness

Determines the amount of detail an image can convey. Sharpness is affected by the lens (design and manufacturing quality, focal length, aperture, and distance from the image center) and the sensor in the camera body.

*Image noise

Noise in a digital picture can be seen as a lot of oddly colored dots or grains in the image.

It produces undesirable effects such as artifacts, unrealistic edges, unseen lines, corners, blurred objects and disturbs background scenes [11].

*Exposure

Exposure is the measuring and balancing of light in the image. If there is too much light, the picture will appear too bright or overexposed with loss of details being obscured by excess light. If there is not enough light, the picture will be too dark or

underexposed. The factors that affect the exposure are aperture (f-stops), shutter speed and ISO settings known as exposure triangle. Besides having all a direct effect on the amount of light received by the sensor, each factor has an additional practical effect on the image [12].

a) Aperture

Aperture is the hole in the lens through which light enters and reaches the sensor.

Various sizes of apertures are called f-stops or f-numbers and ranges from f- 1.4-f32.

The diameter of the aperture in millimeters is calculated by dividing the focal length of the lens by the f-stop number [12].

Effect on the light: Larger is the f-stop, smaller will be the aperture (Fig. 2) and less will be the amount of light that reaches the sensor and vice-versa.

Effect on the pictorial outcome: Aperture is the deciding factor for 'depth of field'.

Depth of field determines the zone of sharpest focus around the subject (front or back) upon which the lens is focused.

The smaller is the aperture the greater is the depth of field (Fig. 3).

Aperture is adjustable in DSLR, but almost all smartphone cameras come with fixed aperture lenses.

b) Shutter speed

The purpose of the shutter is to protect the sensor or the film from light until the chosen moment. The shutter speed is the length of exposure time (how long the shutter stays open). It can range from 1:5000 sec to B (Bulb mode) keeping the shutter open as long as required [12].

Effect on the light: The faster is the shutter speed, the shorter will be the exposure to light.

Effect on the pictorial outcome: Shutter speed is the deciding factor of how blurred or frozen the motion appears in the picture.

Slow shutter speed= motion appears blurred;

Fast shutter speed= motion appears frozen (Fig. 4).

Shutter speed is adjustable in DSLR, but almost all smartphone cameras come with fixed shutter speed.

c) ISO

ISO is the sensitivity of the sensor to the light.

The ISO is measured in numbers and can range from 24-128000 [13].

Effect on the light: Lower setting implies less sensitivity and higher setting more sensitivity.

Effect on the pictorial outcome: ISO is the deciding factor of how noisy the image is.

Lower the number less is the noise and higher is the image definition, and vice-versa (Fig. 5).

ISO is adjustable in DSLR cameras and only recently in some new smartphones.

High ISO number

Low ISO number

*Lens distortions

Lens distortions are also known as geometric distortions because they affect the way geometrical shapes are depicted by a lens.

The cause of geometric lens distortions is the design of the lens and the way it bends the light that passes through it.

There are various types of lens distortions:

Barrel distortion is when straight lines appear as curved at the edges of the photo. It occurs because the magnification of the image decreases the farther the object is from the optical axis of the lens; the magnification greater at the center of the lens than at the edges. Most lenses with barrel distortion are wider-angle lenses (short focal length) that squeeze a very wide scene onto a narrower sensor.

Pincushion distortion is when straight lines appear as curved towards the center of the photo. This happens as a result of the magnification being greater at the edge of the lens than at the center. Pincushion distortion usually occurs with the longer focal length end of zoom lenses.

DSLR's vs. Smartphone camera's components.

Camera body

When referring to the camera body, the sensor plays the biggest role with regards to image quality.

The sensor is the modernized version of the old camera film.

It is a highly sophisticated part of the camera body. The light coming through the lens is captured by the sensor and turned into a digital signal.

It is filled up with small squares called pixels, through which the light is captured before it's turned into an image.

A million pixels are equal to a megapixel (MP).

The image quality is mainly affected by the sensor and the pixels inside it.

Smartphones have led many people into believing that the more pixels we have, the better is the image quality. As a matter of fact, the size of the sensor is the most important factor that influences this quality and not only the pixels inside it.

With respect to the size of the sensor that the camera contains, the amount of light used to create the image will vary. For example, a camera with a large sensor has more surface area that is exposed to light, and will therefore result in an image with a better image quality [5].

When comparing the size of a DSLR to the size of a smartphone, the difference is huge. DSLR sensors are measured in width and height in millimeters while the measurement of a smartphone's sensor is usually in inches. (eg. 1/2.3", 1/3.06").

A 35mm area of a full frame DSLR camera is about 50 times bigger than the standard 1/3" area of a smartphone sensor.

As a consequence, the pixels in a larger sensor in DSLR are much larger, resulting in a much better low light performance and lower noise at high ISOs.

For example, a DSLR sensor with 18mp resolution will have bigger pixels than a mobile camera sensor with an 18mp resolution, because filling a 35mm sensor with 18 million pixels will require bigger pixels than filling

a much smaller sensor like the 1/16" with the same number of pixels. Bigger pixels results in much more light information and thus less noise in low light. This is why a DSLR with an 18mp resolution gives a much better image than a 21mp mobile phone sensor.

Lens

Some aspects of the final image – such as its clarity, sharpness, and the general quality – are greatly influenced by the quality of the lens [14].

When we refer to the lens, we talk about the aperture (the opening through which the light travels) and the focal length.

As mentioned above, the aperture is the deciding factor for 'depth of field'.

The focal length is the distance (measured in millimeters) from the optical center of the lens to the digital camera sensor.

It's a measure of how strongly the system is able to focus the light. It also determines the distance to the objective that is photographed.

The longer the focal length, the higher the magnification but the narrower is the field of view.

For dental photography, a dual-purpose lens is necessary for two reasons. First is for close-up photography and second is for portrait [15].

The characteristics of the lens must combine a high optical quality to minimize the barrel distortion, and a high contrast that results to a higher resolution.

The DSLR biggest advantage is its versatility that comes through interchangeable lenses. This factor allows the photographer to use different lenses with different focal lengths to suit his needs.

A DSLR's standard lens has a focal length of 50mm; a shorter focal length like 28mm is useful for capturing wide-angled shots such as landscapes. A longer focal length like 200mm is used to take shots of events like wildlife or sports (telephoto lens) [9].

For dental purposes, macro lenses with a fixed focal lengths designation

between the 85mm to 105mm provide the ideal combination between a convenient working distance and a good magnification [15].

A real macro lens has a magnification ratio of at least 1:1.

The magnification ratio is the ratio of the size of the image projected on the sensor compared to the actual size of the object.

The ideal magnification for dental photography is 1:1, which means that the size of the image on the sensor is equal to the real life size of the object photographed.

The focal lengths of a macro lens vary from 15 mm to 200 mm [16]; however, the lower the focal length, the closer you need to be to the subject you're photographing.

As for the mobile phone lenses, they are designed to be used for everyday photography and selfies. Due to their indications and their small size, all the mobile phones' lenses cannot be but wide angled lenses (short focal lengths ranging between 24-32mm).

Theoretically, this kind of wide-angle lenses, leads to a geometrical distortion which is the barrel distortion; the face and nose appear enlarged.

Flash unit

In DSLR cameras, in order to have a sharp, noiseless image and an appropriate depth of field, we should decrease the shutter speed, the ISO and the aperture diameter respectively.

By decreasing all these factors, very little light will be able to strike the sensor and the image will be underexposed.

The only practical solution is increasing the intensity of the illumination by using flashes.

For DSLR three types of flashes are commonly used as illuminations for dental photography:

1-Ring-flash: The Ring flash was invented by Lester A. Dine in 1952 especially for use in dental photography, but now is commonly used in applications such as macro, portrait and fashion photography.

It surrounds the lens and provides light from all around it. This eliminates shadows. It creates a uniform burst of light, useful for taking pictures of posterior teeth or areas of difficult access. The major drawback with ring flashes is the uniform light output, which creates a flat, bland and lackluster image. While excellent for illuminating posterior regions of the mouth, for anterior teeth or for restorations where aesthetics are of paramount concern, ring flashes are not recommended since the uniform burst of light obliterates fine detail, translucency and color transitions within individual teeth [16].

2-Twin flash mounted on brackets: This set-up is the ideal choice when photographing anterior teeth for capturing nuances of characterization and color, texture and translucency, which are critical for aesthetic anterior prostheses [16].

It's not recommended for the posterior teeth and the occlusal shots.

It is more expensive and requires more experience than the ring flash.

3-Studio flashes: Studio flashes are the ideal, predictable and widely used for high quality photos.

It gives soft and uniform illumination, reveals surface details, color transitions, translucency variations and crack lines [16].

They require more experience, more space, higher budget and some specific accessories like soft boxes.

For smartphones, due to all the limitations already mentioned in this study (sensor size, wide-angle lens, short focal length, fixed aperture and shutter speed), the smartphones cameras were "theoretically" unable to take high quality images in dentistry.

A new device designed by Prof. Louis Hardan, developed by Smile Line (Switzerland) and powered by the international group "Styleitaliano" was introduced to the market and has drastically improved the quality of dental photos. It's the smile lite MDP.

The device is equipped with three groups of LEDs (light emitting diodes). Each group can be lit up individually with the possibility to set the power

of illumination (four different steps of power).

The three groups of LEDs are the equivalent of a ring flash and twin flashes. It has also diffusers and a polarizer as additional accessories.

The back of Smile Lite MDP is equipped with a universal adaptor that is adjustable for any model of smartphone with a width varying between 55-85mm.

Smile lite MDP is less expensive than all flash units of DSLR, and it doesn't require any specific experience.

Conclusion

Digital photography has become a must in everyday dental practice, from patient communication, to legal protection and to all the other indications stated earlier. Smartphones are on the fast track trying to replace expensive set ups like DSLRs, which are considered as the best cameras until this day. However this comparative review remains a theoretical comparison and must be powered by other practical studies, to find out how practical have become the smartphone cameras when used in dental photography.

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