THESIS SUMMARY.

The Pseudocolor in digital radiographic image. Diagnosis of demineralization in dental calcified tissues.

UNIVERSIDAD NACIONAL DE ROSARIO
Facultad de Odontología | Radiology Department

PhD: Od. María Rosa Moyano
Th. Director: Prof. Dr. Martha Siragusa

YEAR 2012

Received: May 2012 | Aceptado: Sep. 2012

INTRODUCTION

In dentistry, health alterations include developmental disorders, functional disabilities and general diseases of the masticatory system; they require a treatment where the essential first step is the diagnosis (Pasler, 1992).

The use of the Diagnostic Images in general and of the X-ray in particular, are part of a creative explorer strategy to make a diagnosis as perfect as possible and a comprehensive oral treatment planning, as well as an evaluation of the presence and extent of pathological processes, their evolution during treatment and the therapeutic effects achieved (Pasler, 1992, p9)

The image definition varies according to the different points of view from which the concept is structured. From physics, an image is the reproduction of an object figure, formed by the reflection or refraction of the light that spring from it, which could be a real image when it is formed at the point where the reflected or refracted or virtual rays converged, the one that is seen from behind a mirror or lens, at the point where the divergent rays extensions that reach the eyes of the observer meet. (Siragusa and McDonnell, 1999)

The term image also refers to a two-dimensional function of light intensity expressed as f (x, y), where x and y represent the spatial coordinates and the f at any point (x, y) is proportional to the brightness of the image at that point. (Gonzalez and Wood, 1996)
From the observer point of view, the image is the condensation or summary of information of the object that it represents. In this case the interpretation of the information of the image content becomes a cognitive act not implicit in the image itself, but totally dependent on the observer, his capabilities and goals (Siragusa and Mc Donnell, 1999, p 4)

The radiographic image responds to its specific diagnostic objectives, they are not artistic images, they must faithfully reproduce the observed object, therefore, its mode of representation or support must have the minimum necessary standards or conditions of the object representation so that the interpretation could be only dependent on the abilities of the observer.

The characteristics of the diagnostic image mainly reveal differences in the X ray transmission (radiographs, fluoroscopy, CT), in ultrasound reflectance (ecography), radioisotopes concentration (nuclear medicine) or radio frequency signals emission (MRI). These features require a learning to acquire a database suitable for their interpretation (Hendee, 1993)

To make the interpretation of the images the human observer applies a process of visual perception, which although it is extraordinarily complex it has become implicit and subconscious. (Mol, 2000)

The perception can be defined as the act of acquiring knowledge, of interacting and having experiences with the environment by stimulating our senses. The senses collect information from the outside world and from our body. This information reaches the brain where it is transformed, resulting in our immediate experience of the world. In the encephalon, this processing will be influenced by our past experiences and the context in which it is perceived. (Roger Verges, 2002)

Current theories of visual perception suggest that detection and recognition of objects comprise a continuous exchange of perception and comprehension of the outside world. Therefore there would be a constant interaction between perception and cognition rather than a simple step in which neural signals are integrated into the visual image somewhere in the visual cortex.

That is why it is no longer possible to separate the detection, recognition and interpretation of visual images mechanisms; this process can be considered, instead, as a unique interaction in which the acquisition of visual information is integrated with recognition and interpretation and even with knowledge (Hendee, 1993, P199)
The visual experience begins when we open our eyes and we have the experience of perceiving how the light reflects on the objective physical environment objects. A light emitter and a detector of that light are needed to produce the vision. The detector is the eye and the emitter or environment optical transmitter is any direct, punctual or secondary light emitter of any point in the space by reflection of a primary focus. (Roger Verges, 2002, p)
Light is all we can see; it is an electromagnetic phenomenon and is only a tiny part of a wide range of electromagnetic waves called the electromagnetic spectrum. (Hewitt, 2007)
The human visual system perceives only a very small segment of the continuum of electromagnetic energy, the visible light. (Bushong, 1993)
The light enters in the eye through the transparent covering called the cornea, where it refracts (necessary 70% deviation of the light) before passing through the pupil, iris aperture that expands and contracts regulating its size, admitting more or less light as its intensity change. Then the light passes through a lens, the crystalline lens, where it suffers the additional diversion so that images are stay focused on the retina. (Hewitt, 2007, P506)

The vision of the object is due to a distribution of the photoreceptor on the surface of the retina. There are two kinds of light receptors: 6 or 7 million cones, sensitive to color, located in the central region of the retina called the fovea, and 75 to 150 million rods, sensitive to light level but not to color, scattered throughout the retina. (Siragusa and Mc Donnell, 1999, p5)

The rods are extremely sensitive to very low light intensities, contributing to the vision in semi-darkness called night vision or scotopic, but they do not participated in normal lighting conditions. The cones are three types of cells involved in normal day vision or photopic vision. (Millan, 2007)

The ability of the rods to apreciate small details (visual acuity) is much smaller than that of the cones. The cones also have greater capacity than the rods to detect differences in brightness (contrast perception); furthermore cones are sensitive to a much greater range of wavelengths and perceive colors, while rods are virtually blind to them. (Bushong, 1993, p64)

Beside the photoreceptors, the retina has four groups of cells within which are ganglion cells, which axons form the optic nerve. The function of these intermediate cells is to pre-process the convergence of signals information from the 120 million rods to about 1 million specific ganglion cells. The large proportion of rods (photoreceptors) with respect to the ganglion cells facilitates the vision in low light conditions. In contrast, each cone in the fovea is associated with a single ganglion cell, which explains the high spatial resolution of the visual system under bright lighting conditions. The intermediate cells are also used to refine the signal from specific ganglion cells to add information about movement, direction and configuration. (Hendee, 1993, p200)

From the point of view of an observer who is interpreting radiographic images, it is essential the comprehension of some aspects of the human visual system performance:

- **Contrast sensitivity:** related to spatial frequency, it can be said, in general, that the visual system is more sensitive to spatial frequencies contrast of about 2 cycles / degree. Contrast sensitivity declines sharply in both high and low spatial frequencies. We must also say that when the luminance of adaptation from scotopic to photopic conditions increases, also increases the contrast sensitivity for all spatial frequencies, increasing, as well, the spatial frequency at which the minimum peak contrast sensitivity showed and the higher spatial frequency to which it can be detected (Colombo and O'Donnell, 2006, p29; Hendee, 1993, P203)
- **to enlightenment:** the visual system can operate over a range of lighting levels close to 12 log units, from the scotopic threshold to the glare limit (only in photopic vision there is 5 to 6 orders of magnitude) (Jain, 1989).

The full range of light levels that it can discriminate simultaneously is rather small (2 to 3 log units of luminance) compared with the full range of adjustment. The range of subjective illumination that the eye can perceive when it is adapted to a level is called enlightenment level of adaptation. (Gonzalez and Wood, 1996, p 27)

For each specific level of adaptation the human eye is capable of discriminating changes in illumination. The discrimination is poor at low light levels and it improves as the backlight grows. (Gonzalez and Wood, 1996, p 29)

There are two phenomena that clearly demonstrate that the perceived light is not a simple function of intensity. The first is based on the fact that the visual system tends to overestimate or underestimate the intensity near the boundaries of two regions with different intensities. This phenomenon known as Mach band effect shows that, although the intensity of the stripes is constant, a strongly graded illumination pattern, particularly near the borders between stripes, is actually perceived. (Gonzalez and Wood, 1996, p30)

The second phenomenon, known as simultaneous contrast, is related to the fact that a perceived lighting area depends not only on its intensity but also on the intensity of its border areas

- **Texture discrimination:** The visual system is able, almost instantaneously, to detect internal inconsistencies or improper settings in a scene. The visual system's ability to recognize almost instantly an image characteristic is called "early warning", which is a global phase of pre-attention of the visual response mechanism.
  Within the pre-attention phase there is a local phase of "aware vision" that requires slower and more careful analysis of the visual scene. During the aware vision the information is processed by an area beyond the fovea, called functional field of view. Radiologists use these two phases of the process to detect abnormalities in images based diagnosis and then identify and interpret them by direct visual attention (Hendee, 1993, p 205)
- **Color Discrimination:** It is possible due to the sensitivity of the human visual system, to the frequencies comprised in the visible light spectrum.

> "It is known today, that vision of the colors has to do with three types of color sensitive cone-shaped cells found in the retina. Such cells, whereby they contain red, green or blue pigments respond differently to the light reflected by a colored object. Pigments, proteins that absorb light, are particularly sensitive to the regions of long wave length (red), medium (green) and short (blue) within the visible light spectrum. The relative amounts of light absorbed by each type of cone are transformed by retinal nerves into electrical signals, and then they are transmitted to the brain where the stimuli conjoint causes the sensation of a specific color (Nathans, 2005, p20)

The human eye can distinguish thousands of colors, but is more sensitive to green/yellow light than to the red/ blue one. Blue has a small contribution to the sensation of brightness while yellow has a high one. But the human eye is more able to distinguish nuances in the border colors of the spectrum (red, blue and purple) than in yellow ones. (Millan, 2007, p3)

The color values can be quantified according to different color models, known as additive and subtractive system. In the additive system colors are mixed as lights, making able to obtain a variety of colors by mixing the appropriate amounts of Red, Green and Blue lights. In the subtractive system colors are obtained by combining Cyan, Yellow and Magenta pigments. (Siragusa and Mc Donnell, 1999, p25-26)

The Land's theory of color vision, "Retinex" is the mathematical model of a comparison process that aims to color constancy.

To see a color involves making comparisons. This process begins in the retina, which has three layers of cells. The signals of red and green cones of the first layer are compared by the red and green "antagonist" cells present in the second layer, which computed the balance between the red and green light that comes from a specific part of the visual field . Other antagonist cells compared blue cones signals with the combined signals of red and green cones. (Howard Hughes Medical Institute, 2008)

For the psychological theory of color, the signal transmitted by the optic nerve would not depend on the number of photons of different frequencies that reach the retina cones but rather on the relationship between these quantities. In this way the eye would not encode the luminance but the contrast, so the feeling of reality of an image will be more influenced by a proper gradation of tones or color shades. (Millan, 2007, p 4)

The diagnosis of demineralization caused by tooth caries at the different stages of the evolution process, has been a constant concern of the Dental Clinic and Radiology. Radiographic images allow detecting tooth caries because the decay process causes a demineralization of the tooth. The demineralized area of tooth, which allows a larger X rays penetration, is seen darker (radiolucent) that the healthy area and could be detected on radiographs because of differences in optical density (contrast). (Goaz and White, 1995, P311)

The image display of the early decay process will depend on the production of a sufficient difference of optical density (contrast) between the demineralised area and the preserved one so the observer can detect differences in shades of gray, which represent the different degrees of calcification.

The contrast of the area under study will be mainly determined by:

- Amount of lost mineral substance (density)
- Thickness of the preserved tissues adjacent to the lesion and interposed in the direction of X-ray beam

Early diagnosis of dental caries is of high importance because incipient lesions may require only preventive and / or remineralizing treatment. (Goaz yWhite, 1995, P329)
The paradigm shift in clinical dentistry over the treatment of incipient, non cavitated, enamel caries has resulted in minimal interventions for prevention proposing the conservation of the tooth structure.

This paradigm shift increases the demand on accuracy in diagnosis to differentiate healthy teeth of incipient or detained caries, as well as to predict the progression and prognosis of the lesion. (Aoba, 2004, P255)

Digital radiographic image: digital format has allowed a change in the acquisition, processing, monitoring, storage and transmission of the image, completely altering the traditional analog image method. (Plus et al, 1998)
To evaluate a diagnostic test, the obtained results should be compared to a reference method gold rule or "gold standard". (Wenzel and Verdonschat, 1994)

In laboratory experiments (in vitro), in order to check the accuracy of a diagnostic method of natural caries, the teeth histological sections are used as a “gold standard”. Once it is established the presence or absence of actual disease, through a microscope, it can determined if with a radiographic study, for example, the correct diagnosis has been made. (Woodward and Leake, 1996)

The validation method mentioned above is impracticable in clinical research for caries diagnosis. "At present time there are no methods for caries diagnosis accurate enough to be used as standard in the clinical evaluation of new evidence. Clinical studies should investigate parameters different to precision like accuracy of diagnosis also called reproducibility, repeatability and reproducibility, or variation inter or intra-observer, as well as what is more important, the implications that the exclusion or establishing of the diagnosis has on the patient. The impact on therapeutic decisions and the prognosis represents the final evaluation of any new diagnostic method". (Wenzel, 2000)

The direct digital image in dentistry was introduced in 1987 with the RVG system or by RadioVisioGraphy by Mouyen for intraoral techniques. This was possible because of the development of sensors with suitable dimensions for intraoral use after the progress obtain in the miniaturization of electronic circuits. (van der Stelt, 2000)

In the digital image, instead of silver halide grains it is used a high number of light sensitive elements. These devices record the image data from the shadow that the X-ray induces. The electrical signal produced by the sensor is an analogue signal that can take on any value between a minimum voltage and a maximum voltage, showing variations depending on time. An analog / digital converter connected to the sensor make a sample of the signal at short intervals to convert the analog signal into a digital one. The product of the measurement is stored in the computer in a numerical form of whole values, which are then presented as different shades of gray on a monitor screen. (van der Stelt, 2000, P256)

So the Digital Image is a form of numerical representation that uses whole numbers within a defined scale. Therefore there are limitations on the representation of the smooth variations of the parameter to represent as there are a limited number of different values. The minimum distance between points within the observable surface of the digital image (resolution) is also limited. (Siragusa and Mc Donnell, 1999, p8)

Thus, the advantage of digital image is, the possibility of being processed.
The processing does not add information to the image itself, but makes the information contained in its data more accessible to the human eye. In diagnostic image terms, the processing objective is to make clear the relevant information, by creating more suitable images for human visual perception or by grouping data from the analysis of the image content. (Mol, 2000, P323)

The processing may referred to three basic types of operations (Digital Imaging in Dentistry, 1995)

- **Analysis:** operations based on numerical information that occurs in the image used to describe some aspect of it which is not actually obtained visually. The most common is the histogram.
- **Highlight:** operations that subjectively or objectively modify the appearance of an image. The most common used operations are contrast manipulation, spatial filtering and pseudocolor (see p 25).
- **Codification:** operations that codify an image in a new form which can serve to reduce the amount of information necessary to describe an image, eg compression with or without loss of information.

Digital images are represented in the form of maps of bits or bitmaps. This format represents the image as a grid or mosaic of image elements called pixels, each one with a particular value of color and intensity. (Siragusa and Mc Donnell, 1999, p11)

The grayscale images can be converted to false color or pseudocolor by assigning a different color to a specific range of gray values. This creates a colored image that can use the feature of human vision to discern thousands of color shades in comparison to only a limited number of gray levels. (Siragusa and Mc Donnell, 1999, p27)

The amount of different colors obtained will depend on the number of bits assigned in the process. A full range of colors can be represented using 24 bit per pixel, assigning 256 values for each component of red, green and blue, allowing de production of over 16 million colors. This is enough to ensure a full photo-quality image and is referred as true color. To save images of these features is very expensive from the point of view of storage. To reduce these requirements palettes may be used. (Siragusa and McDonnell, 1999. P28)

In the palette or color look up table (CLUT), each color is specified with the same degree of accuracy than in 24-bit color space but fewer different colors are available.
The size of the palette limits the maximum number of the different colors available for the image. When 8 bits per pixel are used 256 of color discreet values can be achieved for each of them. To save a bitmap of only 256 colors it is required the third part of the space required by a true color image. (Siragusa and Mc Donnell, 1999, p28)

At present, most digital systems allow conversion to color of greyscale images, in what is call pseudocolor.

Within the image processing software the UTHSCSA Image Tool (IT) was developed in the Scientific Dental Diagnostic Department at The University of Texas Health Science Center, San Francisco, Texas, by C.Donald Wilcox, S. Brent Dove, W.Doos Mc David and David B.Greer.

Image Tool can acquire visualized, edit, analyse, process, compress and print images. Among the functions of image enhancement it allows the conversion of gray scale to pseudocolor in the RGB system

OBJECTIVES

To investigate whether the assignment of a pseudocolor palette to a digital radiographic image in gray scale, allows an early detection demineralization in the dental enamel

MATERIALS AND METHODS

Fifthteen 1º upper and lower premolars and molars and fifthteen 3º upper and lower molars were used.
The technical conditions for obtaining images were standardized as follows:

1. Positioning of dental package and teeth
2. X-ray film Kodak Insight brand.
3. DSJ dental radiographic equipment, with capacity of 60 kV and 10 mA.
4. Exposure time: 0.65 seconds.
5. Manual and simultaneous film processing.

Once the images without treatment were obtained, the demineralization process was done, with 37% phosphoric acid gel of the mesial and distal faces of all teeth, in an area of approximately two millimeters in their point of the contact zone, isolating the area with clear lacquer.

Acid application times were done with six hours duration each one, in a progression of: 6, 12, 18 and 24 hours, with subsequent neutralization with irrigation.
After each application the respective images of all the treated parts were obtain and they were manually processed.

All obtained radiographs were scanned according to the conditions listed below:

1. AGFA Scanner SNAPCAN 600, 9/2/04 Lux Photo program, set to original: transparent, and mode: grayscale, with input resolution of 300 ppi, 100% scale, nothing in the tone curve, sharpness, Despeckle and flavour were not used.
2. Of the automatic range the histogram was sought according to the needs of the images, adjusting to 10-184.
3. The digitization resulted in a Tiff file of the images.

The saved images were processed with the 300 UTHSCSA University of Texas Image Tool program. In such program the Tiff original images were opened and they were cut in order to reduce its size and to reduce vision dispersion. Then the images were saved in JPG format, without compression, so later the pseudocolor palette could be applied. Once the image was selected it was doubled and the 1.PAL pseudocolor tool was applied.

Once the colored image was obtained, it was filed with a name for its later identification. For data collection and observations record of demineralization in gray and pseudocolor values of premolars and molars proximal surfaces, the corresponding tables were prepared and attached in the Results section.
The categorization of the demineralization to study included four possibilities: 1 = no differences, 2 = slight differences, 3 = marked differences, 4 = very marked differences.

IMAGES OBSERVATION

The visualization was performed on a 14 inches, PC monitor, with a screen resolution of 800 x 600 pixels and color quality of 32 bits. Environmental conditions were determined (lighting level) for the study of the images according to the comfort of the observer, reiterating them throughout the whole process.

The digitized radiographic images in gray and then processed in pseudocolor that were obtained from the 30 teeth were examined in every moment of the demineralization process. In every treatment time two observations per tooth were done, one for each of the proximal surfaces, named for their identification as right (R) and left (I) for organizational reasons in data collection, constituting the 60 observations for shades of gray and the 60 for pseudocolor in every time of acid application (0, 6, 12, 18 and 24 hs).

The observations were made by comparing the original images, without decalcification, with those obtained at different treatment times in both, gray scale and pseudocolor. They were made by a single dental radiology expert observer, who made a previous training to become familiar with the pseudocolor tool as all his previous experience was made with black and white images.

The scores obtained in the above observations due to the categories mentioned before were recorded in the tables made for that effect to its subsequent statistical processing.

RESULTS

Digital radiographic images in shades of gray and pseudocolor were compared to detect incipient enamel demineralization in dental enamel. The main objective was to investigate if the false color would allow the earlier observation of the demineralization than the original black-white of the images.

An experimental in vitro model was chosen, with an artificial induction of the decalcified process, to observe it from its most incipient faces. 30 healthy teeth (15 premolars and 15 molars) were chosen as study subject. Each tooth was conventional radiographed before the application of the decalcifier acid and after each treatment time, so that five radiographic images were obtained for each premolar and molar, with standardized technique for capture geometry.

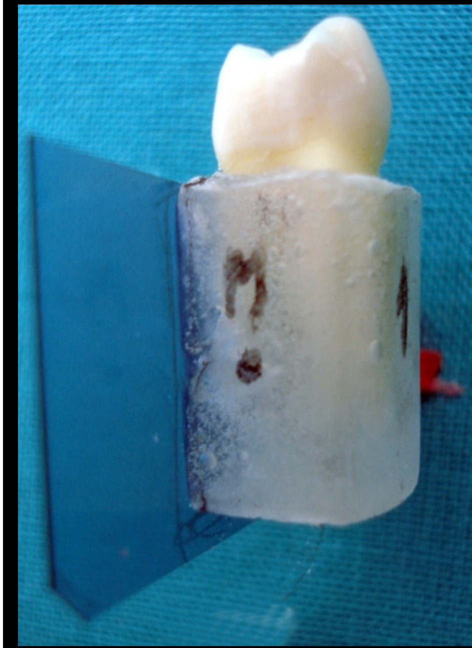


Figure 1:
Preparation of the tooth

Figure 1 shows the tooth equipped with a flap of radiolucent material which facilitated its immobility in the positioning and in Figure 2 the positioning system with the radiographic image and the tooth positioned to obtain the image.

The standardization of the exposure values as well as manual processing of radiographs, guaranteed the fact of the achieving similar optical densities in all the images obtained
The demineralization performed in the proximal surfaces (mesial and distal) in the area adjacent to the contact point using phosphoric acid gel with prior limitation of the treated area with colorless lacquer was of high practicality although a slight overflow that increased the punctate initial treated surface was inevitable.

Figure 2:
Set of the film and tooth

It can be seen in Figure 3 a premolar after acid application after 12 hours of treatment.

Figure 3:
Example of demineralising process at 12 hours

The digitization of conventional radiographic images was performed according to the established minimum necessary conditions for the observation of images in endodontic (Plüss, et al, 1989), in 300 dpi and 8 bits for the spatial and gray resolution respectively, with automatic adjusted of the histogram that optimized the image presentation.
For the application of pseudocolor 1 PAL palette of the program UTHSCSA Image Tool program was selected (The University of Texas Health Science Center, San Francisco) The observer's choice of the palette was entirely subjective.
Figures 4 and 5 show two examples of images in shades of gray and pseudocolor obtained from two premolars and two molar during demineralising process.

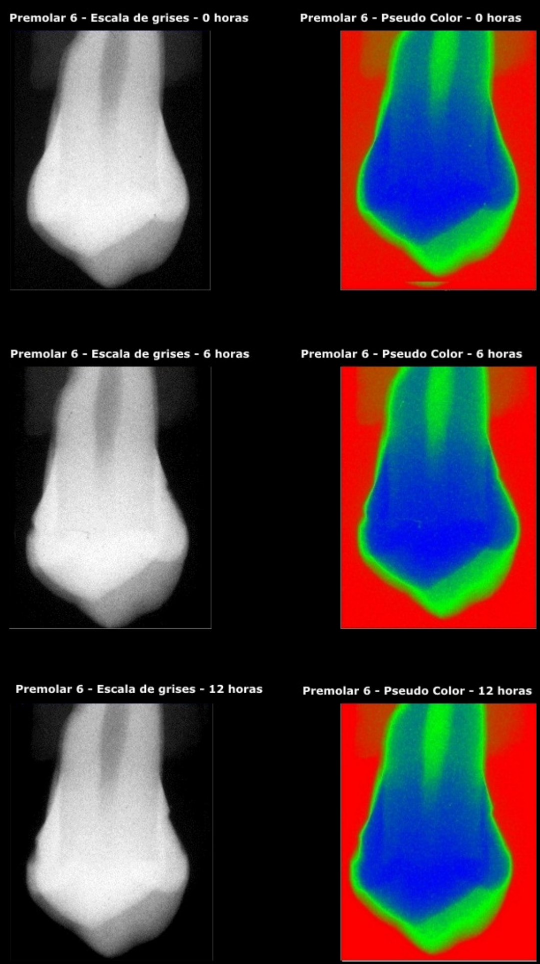


Figure 4:
Images in gray and pseudocolor of a premolar obtained during decalcification process

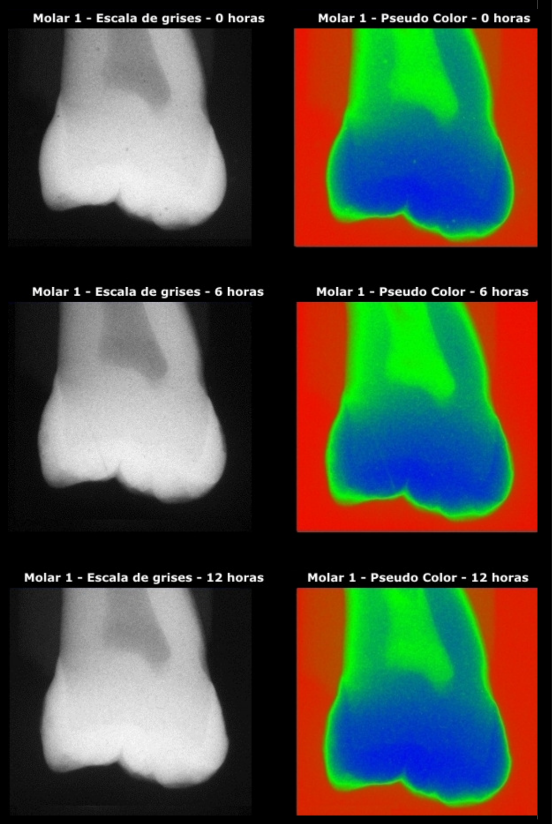


Figure 5:
Images in gray and pseudocolor of a molar obtained during decalcification process.

The observations were made by only one expert in dental radiology Odontologist due to minimize the inherent subjectivity of diagnostic methods in both conventional and digital images.

The information obtained in the observations was gathered in two tables made for such purpose and the data processing was done in Excel format.

In Tables 1 and 2 the scores collected during the observations of the images of the premolars and molars respectively were shown.

The total number of observations for each tooth was 20, corresponding 4 to each stage of demineralization (0, 6, 12, 18 and 24 hours).

In the 0 hours variable, clinically validated without caries, scores 1 (no difference) were registered for all parts. Once it was radiographically confirmed the absence of caries, the image was used for comparison with those obtained in other times of demineralization.
The following pages include 1 and 2 Tables and then, the interpretation of the values collected on the tables before the statistical analysis.

DEMINERALIZATIONS IN GRAY (G) AND PSEUDOCOLOR (P) VALUES

Time	**0 HOURS**				**6 HOURS**				**12 HOURS**				**18 HOURS**				**24 HOURS**			
PREMOLAR	**I**		**D**		**I**		**D**		**I**		**D**		**I**		**D**		**I**		**D**	
	G	**P**	**G**	**P**	**G**	**P**	**G**	**P**	**G**	**P**	**G**	**P**	**G**	**P**	**G**	**P**	**G**	**P**	**G**	**P**
1º	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	4	4	3	4
2º	1	1	1	1	2	2	3	4	2	2	3	4	2	3	4	4	3	3	4	4
3º	1	1	1	1	3	3	1	2	3	3	1	3	3	3	3	3	4	4	4	4
4º	1	1	1	1	1	2	2	2	2	2	3	2	3	3	3	3	3	3	3	3
5º	1	1	1	1	3	3	3	3	3	3	4	4	3	4	4	4	4	4	4	4
6º	1	1	1	1	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4
7º	1	1	1	1	3	3	2	2	4	3	2	2	4	4	3	3	4	4	3	3
8º	1	1	1	1	3	3	3	3	3	3	4	3	4	3	4	3	4	4	4	4
9º	1	1	1	1	2	3	2	2	2	3	2	2	3	4	2	2	4	4	2	2
10º	1	1	1	1	3	3	2	2	3	3	3	3	4	4	3	3	4	4	3	3
11º	1	1	1	1	3	3	2	2	3	3	3	3	3	3	4	4	4	4	4	4
12º	1	1	1	1	2	2	1	3	3	2	2	2	3	3	3	3	3	3	3	3
13º	1	1	1	1	3	3	1	1	3	3	1	2	3	3	2	3	3	3	4	4
14º	1	1	1	1	3	3	2	2	3	3	3	3	4	3	4	4	4	3	4	4
15º	1	1	1	1	3	3	2	0	4	4	2	2	4	4	3	3	4	4	3	4

Table 1: scores obtained in premolars

SCORE
1: NO DIFFERENCE
2: SLIGHT DIFFERENCE
3: MARKED DIFFERENCE
4: VERY MARKED DIFFERENCE

Although the scores analysis obtained in all treatment stages were taken into account, it was of particular interest those collected in the earliest stages (6 and 12 hours.) according to the research objectives.

After 6 hours of decalcification for all the premolars the scores were the same for both methods (gray and pseudocolor) in 25 records, the remaining 5 showed differences with higher values for pseudocolor in all cases.

The range value of scores obtained from all the observations in the first two stages was very wide. The possible causes could have been the premolars differences in size (with consequent more or less proximal enamel thickness) and also the different densities of calcified tissue, both with an impact on the X-ray attenuation. Nevertheless subjective factors inherent to observation must not be ignored.

Within the same tooth, the proximal surfaces (D and I) showed differences in scores, in the majority of the premolars, some very pronounced as in the case of N° 2, N° 3 and N° 13 premolars; this would be explained by anatomical differences in the proximal surfaces of those teeth which, by influencing the enamel coating thickness traversed by the X-ray, determined different degrees of radiation absorption.

In general the scores were higher than expected for the 6 hours of treatment, according to the tests prior to final model. Probably there must have been implemented one more interval between the 0 and 6 hours of the acid application that could allow more amount of observations with slight differences.

DEMINERALIZATIONS IN GRAY (G) AND PSEUDOCOLOR (P) VALUES

Time	0 HOURS				6 HOURS				12 HOURS				18 HOURS				24 HOURS			
MOLAR	I		D		I		D		I		D		I		D		I		D	
	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G	P	G	P
1º	1	1	1	1	3	3	3	2	3	3	3	2	3	3	4	3	3	4	4	4
2º	1	1	1	1	2	2	3	3	2	2	3	3	3	3	3	3	4	4	4	4
3º	1	1	1	1	2	2	3	3	2	2	3	3	3	3	3	3	3	3	3	4
4º	1	1	1	1	2	2	2	2	3	3	3	3	3	3	3	3	3	4	3	4
5º	1	1	1	1	4	4	3	3	4	4	3	3	4	4	3	3	4	4	4	4
6º	1	1	1	1	2	2	2	2	3	3	2	3	3	3	3	3	3	3	4	4
7º	1	1	1	1	2	2	2	2	3	3	2	2	3	3	2	2	3	4	2	3
8º	1	1	1	1	3	3	1	2	3	3	2	2	3	3	3	3	4	4	3	3
9º	1	1	1	1	3	3	2	2	3	3	2	2	3	4	3	3	4	4	3	3
10º	1	1	1	1	2	2	1	1	2	2	2	2	2	2	2	2	3	3	2	3
11º	1	1	1	1	2	2	2	3	2	2	3	3	2	4	4	4	4	4	4	4
12º	1	1	1	1	1	2	1	1	3	2	1	2	3	3	1	2	4	3	2	2
13º	1	1	1	1	2	2	2	2	2	2	3	2	3	3	4	4	3	3	4	4
14º	1	1	1	1	2	2	2	2	3	3	2	3	3	3	3	4	3	3	4	4
15º	1	1	1	1	3	3	3	3	3	3	3	3	3	3	4	4	3	3	4	4

Table 2: Scores obtained in molars

SCORE
1: NO DIFFERENCE
2: SLIGHT DIFFERENCE
3: MARKED DIFFERENCE
4: VERY MARKED DIFFERENCE

Within 12 hours of the application of demineralizating it was found that matching scores decreased for gray and color methods, registering 21 equal and 9 different; between these last 5 scores of greater value for the pseudocolor and 4 for gray. This trend, with a slight increase for matching values (23) was repeated for 18 hours, reversing in the last stage of 24 hours, where there was recorded the highest number of matches of the two methods (27), with 3 discrepancies where 2 of which were of greater score for pseudocolor. The increase is explained by the accumulated hours of decalcification which determines, easy detectable, high score values.

Observations showed values with similar trend to those obtained in premolars. After 6hs the concordance for both methods, gray and pseudocolor, was very high, 26 cases, and in non-concordant (4), there were 3 higher scores for pseudocolor.

Differences in size, anatomical shape, variations in the thickness and density of the interproximal enamel of molars under observation determined extremely dissimilar values between N° 12 and N° 5 molars.

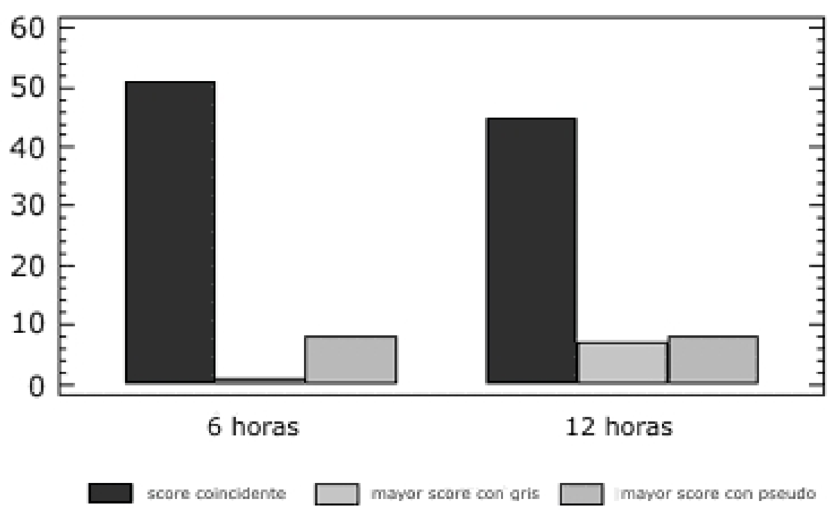
After 12 h of treatment the only case of parity in higher values of scores for both methods was found, registering for the 6 cases of mismatch, 3 scores higher for gray and 3 for pseudocolor. In the remaining variables scores were always higher for pseudocolor.

The most significant difference between premolars and molars at 6 hours of decalcification was found in the number of score values 1 (no difference) and 2 (slight difference), being of 31 in premolars and 40 in molars, justified by the difference of the buccolingual thickness of the proximal enamel between both dental groups

STATISTICAL ANALYSIS

Observations made at each time of demineralization of the entire study population, categorized according to the named above scores, were statistically described in graphs of frequency and percentage and the degree of agreement between the methods (gray and pseudocolor) analyzed using Cohen's kappa coefficient (K).

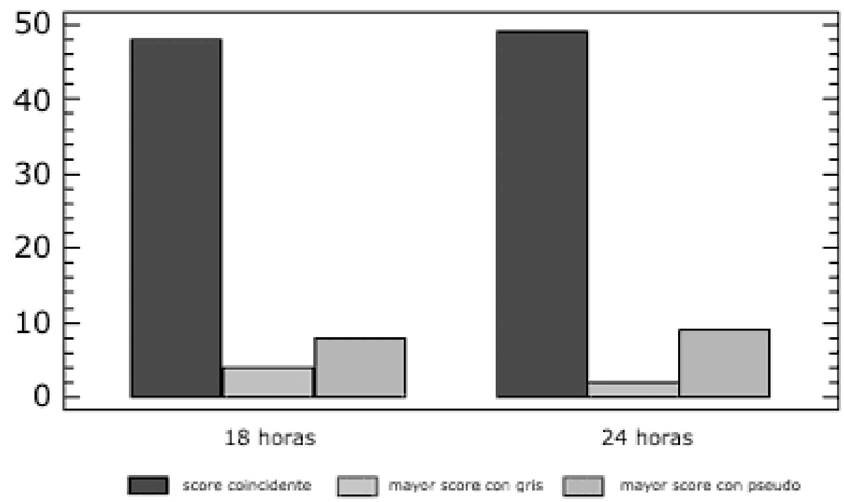
Firstly, all the observations made at each treatment stage were related depending on the coincidence or non-coincidence of the scores. Figure 1 show the number of observations made at 6 and 12 hours of treatment, classified since scores have more coincident with the gray method or with the pseudocolor.



Graphic 1:
Classification of observations made at 6 and 12 hours of treatment in both methods.

Classification of observations made at 6 and 12 hours of treatment in both methods.

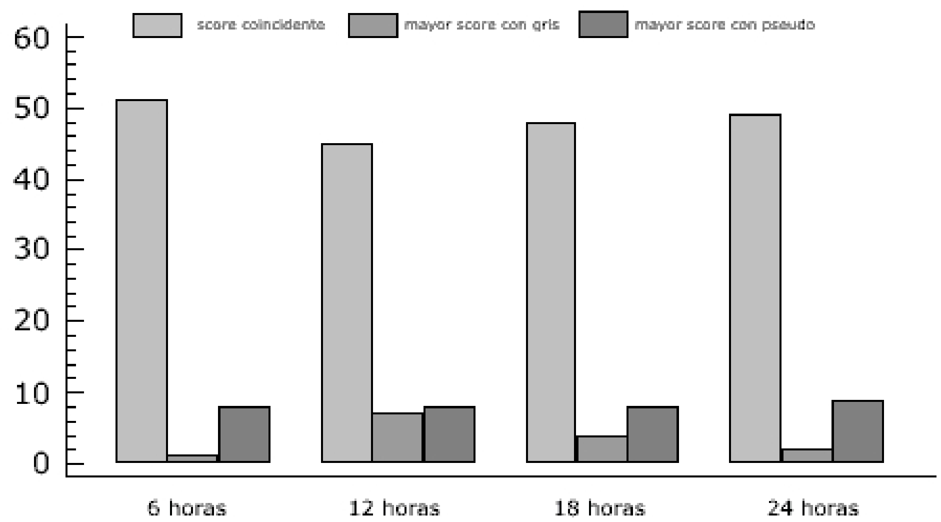
It can be seen a clear predominance of scores coincident with both methods. Within the less frequent cases of mismatch, at 6 hours, the supremacy of the pseudocolor over the gray was stated, while at 12 hours both methods tend to equalize.



Graphic 2:
Classification of observations using both methods at 18 and 24 hours of treatment

The match frequency between gray and pseudocolor methods is very high in both times. The pseudocolor dominance in both demineralization stages keeps recurring.

The total number of observations in all variables under study can be seen in Figure 3

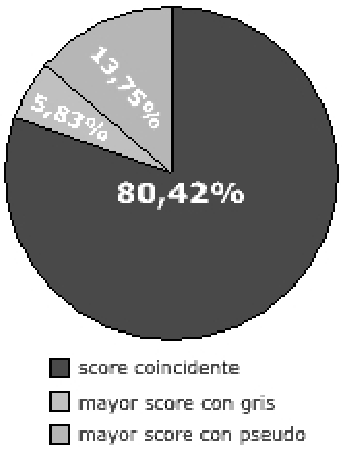


Graphic 3*:*
Classification of observations made with both methods at each stage according the relations between scores.

In Figure 3 it can be seen that, at all times, there is a clear predominance of scores coincident with both methods. Among the rarer cases of mismatch, there were detected some where the pseudocolor score observed is higher than the gray method and others where the opposite happened, although the latter are less common than the previous in all times.

The circular sector graph (Figure 4) shows the distribution for the categories of the variable depending on the agreement percentage between the observation methods.

The percent of agreement between the scores obtained with both methods (80%) is highly significant. The remaining 20% gives a bigger score proportion of more value to pseudocolor than to grey in all observations. (13,75% and 5,83% respectively).



Graphic 4:
Distribution of observations according the concordance between the scores

To analyze the degree of agreement between both methods at each time the K coefficient was estimated. The closer it value is to +1, the greater the degree of agreement, besides a value of K = 0 indicates that the observed agreement is the expected one due only to chance.

In the first instance, the coefficients of both sides at each time were compared. These coefficients did not differ significantly in any case, that is why, scores in both sides jointly for each time were observed.

Time	*Averaged K*	Confidence Interval
6 horas	0.79	[0.66 ; 0.90]
12 horas	0.63	[0.47 ; 0.79]
18 horas	0.65	[0.48 ; 0.73]
24 horas	0.69	[0.52 ; 0.83]

Table 3:
K Coefficients sharply estimated and by 95% confidence interval.

The values obtained while estimating the coefficient at each time both, sharply on time as well as by 95% confidence intervals can be seen in Table 3.
The K coefficient does not significantly vary over time.

Its general valuation is:

Averaged K	Confidence Interval
0.79	[0.66 ; 0.90]

The estimated value of K coefficient indicates that the observations that measure the demineralization by gray and pseudocolor has a substantial agreement, using for the classification the qualitative scale of Landis and Koch (1977):

→ 0.00 = poor
→ 0.01 / 0.20 = slight
→ 0.21 / 0.40 = acceptable
→ 0.41 / 0.60 = moderate
→ 0.61 / 0.80 = substantial
→ 0.81 / 1.00 = almost perfect

DISCUSSION

The advantage of assigning pseudocolor to gray intensity values of the pixels on a digital radiographic image is based on the fact that the human visual system perceives more easily color variations than gray, which is a relevant aspect in low contrast images [(Siragusa and McDonnell, 2009)]. This theoretically implies that diagnostic information could be seen better, theoretically, in a colored image than in a black and white one and, therefore, the replacement of a gray scale by a pseudocolor one would be favorable [(Shi and Li, 2009)].

However the results obtained in this study indicate that there are no statistically significant differences between the radiographic images in shades of gray and in false color treated as regard the detection of incipient demineralization in calcified dental tissues. These results are consistent with previous studies made by Shi and Li [(2009), (Li, et al, 2007) (Kositbowornchai S, et al, 2004)] that analyzed the color performance in relation to conventional black-white images, in different diagnostic tasks.

In the above investigations there were used experimental models that differed in more than one aspect with the one developed in the present work. One of the most important issues is related with the algorithm or color scale assigned to gray values.

The possibility of creating color scales to replace the gray shades of a digital radiographic image in what is called pseudo-colored; it was investigated by Clarke and Leonard [(1989)], who proposed an algorithm according to the colors of the rainbow.

These scales were subsequently modified by Lehmann, et al [(1997)], taking into account the preservation of the brightness order of greyscales. These improvements were based on the physical properties of color and human visual response to them, especially on its sensitivity to the different wavelengths of the spectrum and the intensity or brightness of the stimuli. According to Shi et al [(2002)], the scales derived from nuances or shades of the rainbow for gray scales replacement can affect visual perception. This is based on the fact that the human visual system is more sensitive to the spectral region corresponding to the green, and perceive more intensely the yellows than the reds because of its brightness, when trying to replace an original grayscale radiography in one based on the rainbow hues, a sense of discontinuity is created as the perception increases from green to yellow and decreases from the yellow to red. This does not correspond with the perception of the gray scale where the brightness continuously increases from black to white. To try to overcome these differences Shi, et al [(2002)], designed a new color scale that combines the natural response of the human eye to color with its physical properties. The design began with a subjective assessment of a range of 16 colors from a dark to a clear area to replace the conventional black-white, using dark blue, going thru magenta, red, orange to yellow. A chromaticity diagram (CIELUV) was used to verify the scale subjectively generated, so as to ensure similarity in the tones or shades differences between the 16 colors. The brightness of each step was also adjusted to match the human visual system's response to luminance. This scale was used in a computer-generated image test to evaluate whether contrast sensitivity was improved in relation to the same image of gray range. The 8-bit image has a series of columns with successive increase in gray values, forming a background for 11 circular points that one by one staggered, exhibit an increased contrast from the uppermost to the lowermost in each column. The contrast perception was subjectively assessed by the investigators, who determined, definitely, better perception with the color than with white-black.

Later this scale was used again by Shi, et al (2004) to assess the perception of low contrast in digital radiographic images in shades of gray and pseudocolor. In this case a test object was used, with defects in the form of staggered holes of different depths (0.03 to 0.30 mm). The object was irradiated with different exposure times. The ten observers had to localize the observable defects with lower contrast. The results showed that the information on radiographs with pseudocolor was as good as the information on the conventional white-black. Moreover, at lower exposure ranges pseudo-colored images exhibited a better perception than traditional gray.

The application of the color scale created by Shi and colleagues was tested in a vitro research for natural proximal caries detection, using a digital system with sensor (Dixi) and another one with stimulable phosphor plate (Digora Optime), (Shi and Li, 2009). The study compared the diagnostic accuracy for the radiographs in black and white and in pseudocolor. The observation was made by seven dentists at the Institute of Dentistry, Karolinsca, Sweden, who received a brief introduction to pseudocolor in radiographic images, and seven at the Stomatology School, Peking University, Beijing, China, who did not receive instructions before the observation. The remaining conditions for the interpretation of the images were exactly the same in both places. The evaluation was done according to a five-point scale ranging from healthy tooth to caries of different depth in enamel and dentin. The results did not show statistically, significant differences for any cavities between black-white images and pseudocolor. Similarly there was no difference between the two digital systems used, or between observers which indicate that the familiarity with the color in the image did not influence in the outcome of this investigation.

The conclusions arrived in this study did not attributed to the color algorithm used more accuracy in the detection of interproximal caries than to the gray scale and, because there was not loss of information and it was more comfortable for the observer, it could be used as an alternative to grayscale digital radiographs.

Matching results were found for Kositbowornchai S, et al (2004) in the detection of occlusal caries, in an investigation where there were used three digital image enhancement tools: sharpness, zoom and pseudocolor scale in monochromatic shades of brown, which were compared with the black-white originals. The results in this study did not show statistically significant differences for any of the techniques used, however the pseudocolor showed the lowest accuracy.

Similar conclusions were obtained in an in vivo study on accurate measurements of alveolar bone levels in patients with chronic periodontitis from the evaluation of gray scale and pseudocolor radiograph (Li, et al, 2007) In this study, vertical distances measures between the enamel-cement and the most apical alveolar bone margin were compared and those measures clinically obtained during the surgery performed after the radiography were used as standard reference. The result of the statistical analysis determined that there were no significant differences in the vertical distances obtained in the radiographic images, with and without enhancement, nor with the corresponding standard references. Also, there was no significant inter-and intra-observer variability. The authors concluded that the pseudocolor did not improve the performance of the gray scale in the accuracy of the evaluation of alveolar bone levels.

However when pseudocolor was applied on images obtained with digital subtraction technique (SRD) to evaluate small changes in the alveolar bone, it proved to be a more effective tool for the diagnosis compared with the same technique without color (Reddy, et al, 1991). In the mentioned research two different enhancement techniques in blue ranges were used. In one the color was applied subjectively to the entire image, on the other shades of blue were assigned only to the gray values in the image histogram below 119, since the 99% of the points in the image in an unchanged bone area were between 120 to 136 gray values. This latter enhancement, which acted only on the area of interest, was significantly more sensitive for the visualization of bone loss across all the range of depths evaluated. This finding agrees with Mol findings (2000, P223) who states that it is possible to assign specific values of gray to image aspects that are relevant in the diagnostic process, the color conversion can take advantage of the color sensitivity of the human visual system.

In relation to another diagnostic task Scarfe et al (1999) investigated the ability of a color scale in the estimation of linear measurements of periapical bone injury. To achieve this, conventional images and digital images were compared (with and without color enhancement, and equalized with and without color) with in vivo impressions of the injury during surgery. The results concluded in an underestimation of the size of the images in all forms in relation to the impressions obtained in vivo. The pseudocolor was significantly less accurate than all the other systems used, so the authors estimated that the processing of digital images in pseudocolor has a limited value in the periradicular lesions size estimation.

In the present investigation the 1 PAL palette of UTHSCSA Image Tool program was selected, that uses the mixture of the primary colors (red, green and blue) keeping the rainbow model, assigning values from 0 (black) for red to 256 (white) for blue.

In the performance of this scale it could be observed, in some cases, that the image contrast was satisfactory to detect incipient changes in the surface of dental enamel, due to demineralization. Also in intermediate gray zones with little difference in optical density, the color by contrast strongly emphasized the variations of the aforementioned densities, allowing in some teeth to better distinguish the anatomical limits of the different structures as compared to the gray intensity values.

Taking into account that in the most of the investigations several examiners were involved, the decision to use a single observer in the images evaluation meant another important distinction. The justification is based on the fact that, besides knowledge and experience, there is a strong subjective component in the task of interpretation. In this regard, Tewary, et al (2011) evaluated inter and intra observers concordance in the interpretation of digital radiographic images with different processing types for the diagnosis of periodontal disorders. The observations were made by two endodontists residents, two practising endodontists and an oral and maxillofacial radiologist, with different degrees of knowledge, experience and training in digital systems (one year minimum). The results show a large degree of scatter in the values obtained for the inter-and intra-observer agreement, lacking the precision, accuracy and consistency expected for a group of highly trained and with practical experience examiners. The authors conclude that the interpretation of dental radiographs is subjective, whether it is done for conventional or digital systems. They also consider that the most important factor in the match is the years of experience and the observer familiarity with the digital system operability.

Those statements are not consistent with the findings that Shi and Li (2009) and Li, et al (2007) obtained in each investigation (see p 48/49) in which pseudocolor was employed as a digital image enhancement. In the first case there was no difference between observers trained in the use of the tool and those who did not receive prior instruction. In the second case, there were no significant inter-and intra-observer variability.

Moreover, in their investigations, in which changes in the density of marginal alveolar bone were estimated, Bragger and Pasquali (1989) and Shi et al (1999) found that the intra and inter concordance in the examiners evaluation of the results in digital subtraction radiographic images with pseudocolor enhanced significantly increased in relation to the no enhanced ones.

Similarly, Ready and colleagues (1991) in their research already mentioned, emphasized that the benefit of the pseudocolor enhancement increased when the observer had little or no previous experience of subtraction images, and not for the radiology experienced observers that could not interpret the same accuracy in white-black.

The training and personal skills influences are two important aspects in the interpretation of diagnostic images. Syriopoulos, et al (2000), attributed to the greater ability of radiologists' observers the significant difference with general dentists' observers to assess the accuracy of the depth of caries lesions in a study that compares the capacity of conventional versus digital radiographs. Erten, et al (2005), found significant differences between observers in the evaluation of proximal caries for conventional and digital radiographic systems. In that case there were three observers: a radiologist and two endodontists clinical dentists. The radiologist showed the highest performance, because of his greater experience in the radiographic diagnosis of caries. The influence of the level of experience of the examiner in the interpretation of artificial bone lesions by conventional radiography and digital subtraction radiography (SRD) was investigated by Tocarewicz, et al (2007), who concluded that the experience of the observer is strongest in the conventional technique; the SRD was able to increase the sensitivity regardless of the level of experience of the examiner.

As regard the performance of radiographic images in the detection of demineralization in the early stages of caries, low sensitivity and high specificity have been assigned to the radiographic method (Pitts-Kidd, 1992) (Woodward-Leake, 1996), which means that false negative diagnoses are proportionally able to occur in the presence of disease than false positive diagnoses in the absence thereof (Dove 2001).

Although it is widely documented the value of bitewing radiography in the dentine caries diagnosis, especially for interproximal surfaces (Sturdevant, 1999; Wenzel, 1995, White and Yoon, 1997 and Kang, et al, 1996), the radiography limitations are accentuated when enamel early lesions are been diagnosed, in most cases without cavitation, so that the sensitivity values considerably decrease (Hintze et al, 1994; White and Yoon, 1997, Castro et al, 2007).

Moreira da Silva Neto, et al (2008), in an ex-vivo study compared the clinical and radiographic examination in the diagnostic of incipient proximal enamel caries; found that clinical examination was more sensitive than the radiographic one, agreeing with Pitts and Rimmer (1992). In contrast, in the same study, the radiography had higher specificity than the clinic, similar to the results obtained by De Vries et al (1990). The authors concluded that bitewing radiography is not a reliable method for detecting incipient proximal caries, coinciding with Hintze, et al (1994), whose in a comparative study of different diagnostic methods for conventional and digital techniques to assess in vitro proximal enamel caries diagnostic capability, concluded that the radiographs were almost no valid in their detection. In another study (Ekstrand, et al, 1997) similar results were obtained in the evaluation of in vitro demineralization in enamel and dentin occlusal area. Radiographs did not detect enamel demineralization, but they had high diagnostic accuracy in the dentin ones.

In the search for new tools, it have been developed technologies that include standardized disciplined observations according to established techniques (ICDAS), technologically improved visual observations, new image processing technologies and combinations of these methods (Pitts and Stamm, 2004).

Digital radiographic images within the new technologies are an attempt to improve the ability to detect caries and assess their activity. Valid evidence available suggests that the use of a digital method provides small sensitivity profits without loss of specificity and that image analysis techniques can offer substantial profits (Dove, 2001).

Early researches on caries diagnosis with digital systems were made using the indirect method, ie digitizing radiographic images with scanner or video camera. Wensel, et al (1991) as a result of an investigation that compared visual methods, conventional radiographs, xeroradiography and digitized radiographs for occlusal caries detection, concluded that the sensitivity increased using digitized images in comparison to conventional plates, but this grater sensitivity was accompanied by an increase in the percentage of false positive results. In another study (Wenzel, et al, 1993), for occlusal caries without cavitation, evaluated with visual inspection, FOTI and several digitized radiographic imaging modalities with different algorithms processing, did not find better performance of the images in relation to clinic inspection.

With the advent of Radiovisiography the first digital sensors researches did not produced significant differences when they were compared with the digitized plates (Wenzel, et al, 1991). With the current sensors, better results in areas of low contrast have been achieved, especially in dark areas, which may be clinically relevant (Grassi-Schulze, 2007).

Collating the direct digital images with the conventional X-Rays obtained with current films, the results showed similarity in the diagnosis accuracy for proximal caries in the majority of the works. (White-Yoon, 1997) (Nair-Nair, 2001) (Hintze-Wenzel, 2002) (Erten, et al, 2005) (Khan et al, 2005) (Araujo et al, 2005) (Alkurt, et al, 2007) (Rockenbach, et al, 2008). Accordingly, Pontual, et al (2010) compared the accuracy of three photostimulable phosphor digital systems with INSIGHT radiographic film for proximal enamel caries detection resulting in the fact that no significant differences between the methods used. Meanwhile, Senel et al (2010) evaluated the accuracy of several methods: visual inspection, radiographic film, digital sensors and Cone Beam Computerized Tomography for proximal caries detection, to conclude that all systems showed similarity in behaviour, being the cone beam tomography the one that had the highest accuracy values.

Ferreira et al (2006) evaluated diagnostic accuracy of artificially induced enamel demineralization using conventional X-Rays, digitalization and a stimulable phosphor digital system. The result obtained was a similar behavior of the conventional plate and the digital system.

In a few studies it was observed that some digital systems had less accuracy than the conventional plate for proximal caries detection. (Price-Ergul, 1998) (Uprichard, et al, 2000) (Hintze, et al, 2002)

One of the main advantages of digital image is the possibility of processing to improve or highlight certain aspects of it and therefore make the contents of the information more accessible to the human visual system. Digital processing can produce diagnostic information more effectively than images based on films. (van der Stelt, 2005) The brightness and contrast optimization is one of the tools with more advantages in the digital system because an image with excellent density and contrast is a prerequisite for increasing diagnostic accuracy. (Wenzel, 1988) In this regard, in a study in which the contrast was enhanced, departing from original X-Rays of low density, an increase of sensitivity of about 20% without increase of false positives was demonstrated. (Wensel-Fejerskov, 1992) Similarly Moystad, et al (1996) compared diagnostic accuracy for proximal enamel and dentin caries on an in vitro study from images obtained with radiographic film and a stimulable phosphor digital system with and without enhanced, he reported that the enhanced digital were significantly more accurate for the detection of both types of caries.These results were confirmed by Yoshiura K, et al (1999), in an investigation to compare image quality in digital and conventional X- rays detection that showed that brightness and contrast manipulation gave to the digital technic the possibility of obtaining maximum of information with reduction of radiation exposition time. In this study an artificial model was used as image quality test; it emphasized the importance of exposure parameters in order to obtain the maximum of information specially in minor injuries. The visualization of the defects (holes) in the model allowed quantification over the image quality with optimum exposition parameters (optical density of 1 in enamel and dentin) and with optimal minimum exposition parameters so as the radiographic films and the digital systems could be compared with and without contrast enhancement. The results obtained in this investigation strongly suggested that digital systems, with appropriate use of contrast adjustment, could be more effective than the radiographic film to detect changes in low contrast small interest zones. Likewise, Svanaes et al (2000), compared the depth of proximal caries evaluation between a conventional film and a phosphor stimuly digital system with contrast enhancement, to find that the last mentioned method significantly improved the accuracy in the evaluation of enamel surface caries depth in comparison with the conventional film, but in this case increases of false positives were recorded.

However, in other studies, at proximal caries evaluation, there were not found significant differences between enhanced and not enhanced images. (Dove, McDavid, 1992) (Peretz, et al, 2009) Moreover, when Tyndall et al (1998) compared conventional film with the digital system, with or without brightness and contrast enhancement for proximal caries detection, they concluded that the enhanced images had significantly lower accuracy than no enhanced conventional and digital ones. This unusual finding, the authors explained, could be because the digital system used, Sidexis brand, uses a filtering process that optimizes the image histogram before it is displayed on the monitor, so any enhancement alteration applied was in detriment of the diagnosis process if the screen image was actually in optimal brightness and contrast. Besides, it is possible that the observers were not sufficiently trained on enhancement software control handling, therefore, they did not use the program to its full potential.

The experimental model of this thesis project was not designed to quantify the sensitivity or specificity the pseudocolor method for caries detection, however, without making an statistical analysis and under the conditions in which the investigation was conducted, it could be observed a high percentage of incipient interproximal enamel demineralization, both in gray shades and in pseudocolor digital images.

The development of digital technology has enabled applications to diagnosis support and images processing tools that imply a new order of complexity in the interpretation. (Siragusa-Mc Donnell , 2009)

Color can add a variability dimension that could exceed observers' ability to assimilate and interpret information (Hendee, 1993, P208) and that is why its use is not very popular in the dental practice, that is very well adapted to black and white X-ray images. However, it has been checked in this investigation that, in some cases, it could be useful as a visual response mechanism trigger, and thereby cause a thorough revision of the original images.

The new offerings in acquisition techniques of digital images for diagnosis represent a challenge for dentistry professionals and for the teachers in charge of their formation because they included new codes that have to be interpreted correctly. (Siragusa and Mc Donnell, 2009)

As it was expressed by the authors mentioned above “The university must ensure to insert in dental profession the human resources that are receptive to the progress of technology but with critic participation to support or modify the technology. It is necessary to assume quality control to evaluate what improves the dentist work quality and, therefore, the quality of life of the population”.

REFERENCES

(1) Alkurt MT, et al (2007): "In vitro comparison of four different dental x-ray films an direct digital radiography for proximal caries detection". Oper Dent; 32(5): 504-9.
(2) Aoba T (2004): "Solubility properties of human tooth mineral patogenesis of dental caries". Oral Diseases; 10:249-257.
(3) Araujo EA, et al (2005): "Comparison of direct digital and conventional imaging with Ekta Speed Plus and INSIGHT films for detection of approximal caries". Am J Dent; 18(4): 241-4.
(4) Barbieri Petrelli G, et al (2006): "Actualización en radiología dental. Radiología convencional Vs digital". Av. Odontoestomatología; 22-2: 131-139.
(5) Barrancos Money J (2002): Operatoria Dental. Buenos Aires, Argentina, Editorial Panamericana, 1176 p.
(6) Basrani E, Blank A, Cañete M. (2003): Análisis Radiográfico de la Patología
(7) Dentaria Adquirida en Relación con la Endodoncia. En Basrani E, et. al (2003) Radiología en Endodoncia. Caracas, Venezuela, Actualidades Médico Odontológi-cas Latinoamérica, 291p.
(8) Brägger U, Pasquali L (1989): "Color conversion of alveolar bone density changes in digital sustraction images". J Clin Periodontol; 16:209-214.
(9) Bushong SC (1993): Manual de radiología para técnicos. Madrid, España, Mosby, 5ªedición, 710p.
(10) Castro VM, et al (2007): "In vitro comparison of conventional film and direct digi-tal imaging in the detection of approximal caries". Dentomaxillofac Radiol; 36:138-142.
(11) Clarke FJJ, Leonard JK (1989): Proposal for a standardized continuous pseu-docolor spectrum with optimal visual contrast and resolution.Third International conference on image processing and its applications; Warwick, UK; 1989; p 687-91. En Shi XQ, Li G (2009): "Detection accuracy of approximal caries by black-and-white and color-coded digital radiographs". Oral Surg Oral Med Oral Pathol Oral Radiol Endod; 107: 433-436.
(12) Colombo E, O´Donnell B. (2006): Luz, color, visión. En Manual de Iluminación eficiente (en línea). Bs. As, 2006. Editorial de la Universidad Tecnológica Nacio-nal, Argentina. (Fecha de consulta: 14/ 04/09)Capítulo 2. Disponible en <www. edutecne.utn.edu.ar> ISBN (Publicación electrónica) 978-950-42-0077-2.
(13) De Vries, et al (1990): "Radiographic versus clinical diagnosis of approximal car-ies lesions". Caries Res; 40:97-103.
(14) Digital Imaging in Dentistry (1995): "Dental Diagnostic Science". UT Health Sci-ence Center. San Antonio. Texas.
(15) Dove SB (2001): "Radiographic Diagnosis of Dental Caries". Journal of Dental Education; 65:985-990
(16) Dove SB, McDavid WD (1992): "A comparison of conventional intra-oral radiog-raphy and computer imaging techniques for the detection of proximal surface den-tal caries". Dentomaxillofac Radiol; 21: 127-134.
(17) Ekstrand KR, Ricketts DNJ, Kidd EAM (1997): "Reproducibility and Accuracy of Three Methods for Assessament of Desmineralization Depth on the Occlusal Sur-face: An in Vitro Examination". Caries Res; 31: 224-231.
(18) Erten H, Akarslan ZZ, Topuz O (2005): "The efficiency of three different films and radiovisiography in detecting approximal carious lesions". Quintessence Int; 36:65-70.
(19) Farman AG, Farman TT (2005): "A comparison of 18 different X-ray detectors currently used in dentistry". Oral Surg Oral Med Oral Pathol Oral Radiol Endod; 99: 485-9. En Barbieri Petrelli G, et al (2006): "Actualización en radiología dental. Radiología convencional Vs digital". Av. Odontoestomatología; 22-2: 131-139.
(20) Ferreira RI, et al (2006): "Assessment of enamel desmineralization using conven-tional, digital and digitized radiography". Braz Oral Res; 20(2): 114-9.
(21) Giménez C (2002): Manual de Diagnóstico por Imágenes y Terapia Radiante, To-mo1. Rosario, Santa Fe, Establecimiento Gráfico Cervantes, 239p.
(22) Goaz PW, White SC (1995): Radiología Oral. Principios e Interpretación. 3ª edi-ción, España, Mosby-Doima Libros, S.A, 736p.
(23) González RC, Wood RE. (1996): Tratamiento digital de imágenes. Wilmington, EUA, Addison- Wesley Iberoamericana, SA, 800p.
(24) Grassi U, Schulze RK (2007): "In vitro comparison of low-contrast feature in digi-tal, film, and digitized dental radiograpraphs: a receiver operating characteristic analisis". Oral Surg Oral Med Oral Pathol Radiol Endod; 103(5): 694-701.
(25) Guyton AC, Hall JE (2002): Tratado de Fisiología Médica. 10ª edición, México McGraw Hill Interamericana, 1280p.
(26) Haring J, Jansen L (2002): Radiología Dental. Principios y Técnica. 2ª edición Méjico, McGraw Hill Interamericana, 613p.

(27) Hendee WR (1993): Characteristics of the Human Visual System. En Digital Imag-ing. Medical Physics Monograph nº 22. Summer School on Digital Imagin of the American Association of Physicists in Medicine. Virginia, USA, 1993. ISBN: 0-944838-42-1, 648 p.
(28) Hewitt PG (2007): Física conceptual. 10ª edición. México, Pearson Educación, 496p.
(29) Hintze H, et al (1998): "Reliability of visual examination, fibre-optic transillumina-tion, and bitewing radiography, and reproducibility of direct visual examination following tooth separation for the identification of cavitated carious lesions in con-tacting approximal surfaces". Caries Res; 32:204-209.
(30) Hintze H, Wenzel A (1994): "Clinically undetected dental caries assessed by bite-wing screening in children with little caries experience". Dentomaxillofac Radiol; 23: 19-23.
(31) Hintze H, Wenzel A (2002): "Influence of validation method on diagnostic accu-racy for caries. A comparison of six digital and two conventional radiographyc systems". Dentomaxillofac Radiol; 31(1): 44-9.
(32) Hintze H, Wenzel A, Frydenberg M (2002): "Accuracy of caries detection with four storage phosphor system and E-speed film". Dentomaxillofac Radiol; 31:170-175.
(33) Hintze H., Wenzel A, Larsen MJ (1995): "Stereomicroscopy, filmradiography, mi-croradiography, and naked-eye inspection of tooth sections as validation for occlusal caries diagnosis". Caries Res; 29:359-363.
(34) Hintze H, Wenzel A, Jones C (1994): "In vitro comparison of D and E speed film radiography, RVG and Visualix digital radiography for detection of enamel ap-proximal and dentinal occlusal caries lesions". Caries Res; 28:363-367.
(35) Howard Hughes Medical Institute (2008): Descifrando el código de los colores: Juz-gando un color. Viendo, Oyendo y Oliendo el Mundo (en línea) (fecha de consulta: 21/07/09). Disponible en < htpp www.hhmi.org/senses-esp/b140.html>
(36) Jain, AK (1989): Fundamentals of Digital Image Processing. New Jersey, USA, Prentice Hall, Englewood Cliffs.
(37) Kang BC, et al (1996): "Mechanical defects in enamel vs natural dental caries: Ob-server differentiation using Ektaspeed Plus film". Caries Res; 30: 156-162.
(38) Khan EA, et al (2005): "Proximal caries detection: Sirona Sidexis versus Kodak Extaspeed Plus". Gen Dent; 53(1): 43-8.
(39) Kositbowornchai S, et al (2004): "Accuracy of diagnosing occlusal caries using enhanced digital images". Dentomaxillofac Radiol; 33:236-240.
(40) Küppers H. (1992): Fundamentos de la teoría de los colores. 4ª edición, México, Ediciones G. Gil.
(41) Landis J, Koch G (1977): "The measurement of observer agreement for categorical data". Biometrics; 133: 159-74.
(42) Larsen MJ, Fejerskov O (1989): "Chemical and structural challenges in reminerali-zation of dental enamel lesions". Scand J Dent Res. 97: 285-296. En Aoba T (2004): "Solubility properties of human tooth mineral patogenesis of dental caries". Oral Diseases; 10:249-257.
(43) Lehmann TNM, Kaser A, Repges R (1997): "A simple parametric equation for pseudocoloring gray scale images keeping their original brightness progression". Im-age Vis Com; 15: 251-7.
(44) Li G, Engstrom PE, Welander U (2007): "Measurement accuracy of marginal bone level in digital radiographs with and whithout color coding". Acta Odontol Scand; 65: 254-8.
(45) Lozano RD (1978): El color y su medición. Bs. As, Argentina, Editorial Ameri-calce,
(46) Millán AJ. (2007): Física del color. Tecnología del PC. Versión 0.63.04 (en línea) (fecha de consulta: 19/04/2006). Disponible en <http:www.zator.com>.
(47) Mol A. (2000): Instrumentos de procesamiento de imagen para aplicaciones denta-les. En Miles Dale A: Clínicas Odontológicas Norteamericanas. Vol.2: Aplicacio-nes de las distintas modalidades de la imagen digital en odontología. Méjico, Mc Graw-Hill-Interamericana, 482p
(48) Moreira da Silva Neto J, et al (2008): "Radiographic diagnosis of incipient proxi-mal caries: an ex-vivo study". Brazilian Dental Journal; 19(2): 97-102.
(49) Moystad A, et al (1996): "Detection of approximal caries with a storage phosphor system: a comparison of enhanced digital images with dental X-ray film."Dentomaxillofacial Radiology; 25:202-206
(50) Nair MK, Nair UP (2001): "An in vitro evaluation of Kodak Insight and Ektaspeed Plus film with CMOS detector for natural proximal caries: ROC analysis" Caries Res; 35: 354-358.
(51) Nathans J. (2005): "Genes para ver los colores". Investigación y ciencia. Barcelo-na, España. Prensa Científica S.A.
(52) Nikiforuk G (1985): Understanding dental caries. Etiology and mechanisms. Basic and clinical aspects. Karger: Basel. En Aoba T (2004): "Solubility properties of human tooth mineral patogenesis of dental caries". Oral Diseases, 10:249-257.
(53) Pasler FA. (1992): Atlas de Radiología Odontológica. Barcelona, Ediciones Científicas y Técnicas, S.A. 266p.
(54) Pereira JL. (2002): "Terapia Radiante". En Giménez, C: Manual de Diagnóstico porImágenes y Terapia Radiante, Tomo1. Rosario, Santa Fe, Establecimiento Grá-fico Cervantes, 239p.

(55) Peretz B, Kaffe I y Amir E (2009): "Digital images obtained whit a digital camera are not associated with a loss of critical information- a priliminary study".Britihs Dental Journal 206, E9.
(56) Pitts NB, Kidd EAM (1992): "Some of the factors to be considered in the prescrip-tion and timing of bitewing radiography in the diagnosis and management of dental caries".J Dent; 20:74-84.
(57) Pitts NB, Rimmer PA (1992): "An in vivo comparison of radiographic and directly assessed clinical caries status of posterior approximal surfaces in primary and per-manent teeth". Caries Res; 26:146-52.
(58) Pitts NB, Stamm JW (2004): International Consensus Workshop on Caries Clinical Trials (ICW-CCT): final consensus statements-agreeing where the evidence leads. J Dent Res; 83(special issue C):C125-8.
(59) Plüss J, Siragusa M, Mc Donnell DJ (1998): "Hacia la TELEODONTOLOGIA.Educación y Salud" Electronic Journal of Dental Re-search Nº3.
(60) Pontual AA, et al (2010): "Comparison of digital systems and conventional dental film for detection of approximal enamel caries". Dentomaxillofac Radiol; 39(7): 431-6.
(61) Pretty IA (2006): "Caries detection and diagnosis: novel technologies". J Dent; 34(10): 727-39.
(62) Price C, Ergül N (1998): "A comparison of a film-based and a direct digital dental radiographic system using a proximal caries model". Oral Surg Oral Med Oral Pathol Oral Radiol Endod; 85:113-118.
(63) Reddy MS, et al (1991): "Contrast enhancement as an aid to interpretation in digi-tal subtraction radiography". Oral Surg Oral Med Oral Pathol; 71:763-9.
(64) Rockenbach MI, Veek EB, da Costa NP (2008): "Detection of proximal caries in conventional and digital radiographs: an in vitro study". Stomatologia; 10(4):115-20.
(65) Rubio Martínez E, et al (2006): "Técnicas de diagnóstico de la caries dental. Des-cripción, indicaciones y valoración de su rendimiento". Bol Pediatr, Sociedad de Pediatría de Asturias, Cantabria, Castilla y León, 2006; 46: 23-31.
(66) Saap, JP, et al. (2003): Patología Oral y Maxilofacial Contemporánea. Madrid, España, Elsevier España S.A., 433p.
(67) Scarfe WC, et al (1999): "In vivo accuracy and realibility of color-coded image enhancements for the assessment of periapical lesion dimensions". O Surg OMed O Pathol Oral Radiol Endod; 88(5): 603-611.
(68) Schneiderman A, et al: "Assessment of dental caries with Digital Imaging Fiber Optic Transillumination (DIFOTI): in vitro study". Caries Res; 31: 103-10.
(69) Seif R, et.al. (1997): Cariología. Prevención, Diagnóstico y Tratamiento contempo-ráneo de la caries dental. Caracas, Venezuela, Actualidades Médico Odontológicas Latinoamericanas, 350p.
(70) Senel B, et al (2010): "Diagnostic accuracy of different imaging modalities in detec-tion of proximal caries". Dentomaxillofac Radiol; 39(8):501-11.
(71) Shi, XQ, et al (1999): "Comparison of observer reliability in assessing alveolar bone changes from color-coded with subtraction radiographs". Dentomaxillofac Radiol; 28:31-36.
(72) Shi XQ, Sallstrom P, Welander U (2002): "A color coding method for radiographic images" Image Vis Comp; 20:761-7.
(73) Shi XQ, Li G, Welander U (2004): "Perceptibility curve test for conventional and color-coded radiographs". Dentomaxillofac Radiol; 33:318-322.
(74) Shi X-Q y Li G (2009): "Detection accuracy of approximal caries by black-and-white and color-coded digital radiographas. Oral Surg Oral Med Oral Pathol Oral Radiol Endod;107: 433-436.
(75) Siragusa M, Mc Donnell DJ. (1999): "Imágenes Odontológicas Digitales". Rosario, Santa Fe, U.N.R, F.O.R, 1999, 50p.
(76) Siragusa M, Mc Donnell DJ (2009): Visión Crítica de la Aplicación de las Herra-mientas Informáticas para las Imágenes en el Diagnóstico Odontológico. En Lima Machado ME (2009): Endodoncia- de la Biología a la Técnica. Cap 5. Actualida-des Médico Odontológicas Latinoamerica AMOLCA. Caracas, Venezuela.
(77) Sturdevant CM (1999): Operatoria Dental: Arte y Ciencia. 4ta edición. Harcourt Brace. España, S.A, Madrid.
(78) Svanaes DB, Moystad A, Larheim TA (2000): "Approximal caries depth assess-ment with storage phosphor versus film radiography. Evaluacion of the caries –especific Oslo enhacement procedure". Caries Res; 34(6): 448-53.
(79) Syriopoulos K, et al (2000): "Radiographic detection of approximal caries: a com-parison of dental films and digital imaging systems". Dentomaxillofac Radiol; 29: 312-318.
(80) Tewary S, Luzzo J, Hartwell G (2011): "Endodontic Radiography: Who Is Reading the Digital Radiograph?" J Endod; 37(7): 919-21.
(81) Tocarewics D, et al (2007): "Influência do nível de experiência do examinador na interpretaçao de radiografias obtidas a través de técnica convencional e da subtra-çao radiográfica digital (SRD)". R Periodontia; 17:73-79.

(82) Tyndall DA, et al (1998): "A comparison of Kodak Extaspeed Plus film and the Siemens Sidexis digital imaging system caries detection using receiver operating characteristic analysis". Oral Surg Oral Med Oral Pathol Oral Radiol Endod; 85(1): 113-8.
(83) Uprichard KK, et al (2000): "Comparison of direct digital and conventional radiog-raphy for detection of proximal surface caries in the mixed dentition". Pediatr Dent; 22(1): 9-15.
(84) van der Stelt PF (2000): Principios de la Imagen Digital. En Miles Dale A: Clínicas Odontológicas de Norteamérica. Vol 2: Aplicaciones de las distintas modalidades de Imagen Digital en Odontología. Méjico, McGraw-Hill Interamericana, 482p
(85) van der Stelt PF (2005): "The uses of digital radiography in dental practice". J Am Dent Assoc; 136(10): 1379-1387.
(86) Verdonschot EH, et al (1992): "Performance of some diagnostic systems in exami-nations for small occlusal carious lesions". Caries Res; 26: 59-64.
(87) Vergés Roger C (2002): "La percepción visual. Qué vemos y cómo vemos". Mi-crocirugía ocular" Nº 4, Diciembre 2002 (en línea) (fecha de consulta 21/07/09). Disponible en <www. Oftalmo.com/secoir2002/rev02-04/02d-02.htm>
(88) Wenzel A (1988): "Effect of image enhancement for the detectability of bone le-sions in digitized intraoral radiographs". Scand J Dent Res; 96: 149-160.
(89) Wenzel A (1995): "Current treds in radiographic caries imaging". Oral surg Oral Med Oral Pathol Oral Radiol Endod; 80:527-539
(90) Wenzel A (2000): Imagen digital en la caries dental. En Clínicas Odontológicas de Norteamérica, vol. 2/2000, Mc Graw-Hill Interamericana, p. 349.
(91) Wenzel A (2004): "Bitewing and Digital Bitewing Radiography for Detection of Caries Lesions". J Dent Res; 83(Spec Iss C): C72-C75.
(92) Wenzel A, et al (1993): "Developments in radiographic caries diagnosis". J Dent; 21:131-140.
(93) Wensel A, Fejerskov O (1992): "Validity of diagnosis of questionable caries le-sions in occusal surfaces of extracted third molars".Caries Res; 26:188-194.
(94) Wensel A, Larsen MJ, Fejerskov O (1991): "Detection of occlusal caries without cavitation by visual inspection, film radiographs, xeroradiographs, and digitized ra-diographs. Caries Res; 25: 365-371.tihs Dental Journal 206, E9.
(95) Pitts NB, Kidd EAM (1992): "Some of the factors to be considered in the prescrip-tion and timing of bitewing radiography in the diagnosis and management of dental caries". J Dent; 20:74-84.
(96) Pitts NB, Rimmer PA (1992): "An in vivo comparison of radiographic and directly assessed clinical caries status of posterior approximal surfaces in primary and per-manent teeth". Caries Res; 26:146-52.
(97) Pitts NB, Stamm JW (2004): International Consensus Workshop on Caries Clinical Trials (ICW-CCT): final consensus statements-agreeing where the evidence leads. J Dent Res; 83(special issue C):C125-8.
(98) Plüss J, Siragusa M, Mc Donnell DJ (1998): "Hacia la TELEODONTOLOGIA.Educación y Salud" Electronic Journal of Dental Re-search Nº3.
(99) Pontual AA, et al (2010): "Comparison of digital systems and conventional dental film for detection of approximal enamel caries". Dentomaxillofac Radiol; 39(7): 431-6.
(100) Pretty IA (2006): "Caries detection and diagnosis: novel technologies". J Dent; 34(10): 727-39.
(101) Price C, Ergül N (1998): "A comparison of a film-based and a direct digital dental radiographic system using a proximal caries model". Oral Surg Oral Med Oral Pathol Oral Radiol Endod; 85:113-118.
(102) Reddy MS, et al (1991): "Contrast enhancement as an aid to interpretation in digi-tal subtraction radiography". Oral Surg Oral Med Oral Pathol; 71:763-9.
(103) Rockenbach MI, Veek EB, da Costa NP (2008): "Detection of proximal caries in conventional and digital radiographs: an in vitro study". Stomatologia; 10(4):115-20.
(104) Rubio Martínez E, et al (2006): "Técnicas de diagnóstico de la caries dental. Descripción, indicaciones y valoración de su rendimiento". Bol Pediatr, Sociedad de Pediatría de Asturias, Cantabria, Castilla y León, 2006; 46: 23-31.
(105) Saap, JP, et al. (2003): Patología Oral y Maxilofacial Contemporánea. Madrid, España, Elsevier España S.A., 433p.
(106) Scarfe WC, et al (1999): "In vivo accuracy and realibility of color-coded image enhancements for the assessment of periapical lesion dimensions". O Surg OMed O Pathol Oral Radiol Endod; 88(5): 603-611.
(107) Schneiderman A, et al: "Assessment of dental caries with Digital Imaging Fiber Optic Transillumination (DIFOTI): in vitro study". Caries Res; 31: 103-10.
(108) Seif R, et.al. (1997): Cariología. Prevención, Diagnóstico y Tratamiento contempo-ráneo de la caries dental. Caracas, Venezuela, Actualidades Médico Odontológicas Latinoamericanas, 350p.
(109) Senel B, et al (2010): "Diagnostic accuracy of different imaging modalities in detec-tion of proximal caries". Dentomaxillofac Radiol; 39(8):501-11.

(110) Shi, XQ, et al (1999): "Comparison of observer reliability in assessing alveolar bone changes from color-coded with subtraction radiographs". Dentomaxillofac Radiol; 28:31-36.
(111) Shi XQ, Sallstrom P, Welander U (2002): "A color coding method for radiographic images" Image Vis Comp; 20:761-7.
(112) Shi XQ, Li G, Welander U (2004): "Perceptibility curve test for conventional and color-coded radiographs". Dentomaxillofac Radiol; 33:318-322.
(113) Shi X-Q y Li G (2009): "Detection accuracy of approximal caries by black-and-white and color-coded digital radiographas. Oral Surg Oral Med Oral Pathol Oral Radiol Endod;107: 433-436.
(114) Siragusa M, Mc Donnell DJ. (1999): "Imágenes Odontológicas Digitales". Rosario, Santa Fe, U.N.R, F.O.R, 1999, 50p.
(115) Siragusa M, Mc Donnell DJ (2009): Visión Crítica de la Aplicación de las Herra-mientas Informáticas para las Imágenes en el Diagnóstico Odontológico. En Lima Machado ME (2009): Endodoncia- de la Biología a la Técnica. Cap 5. Actualida-des Médico Odontológicas Latinoamerica AMOLCA. Caracas, Venezuela.
(116) Sturdevant CM (1999): Operatoria Dental: Arte y Ciencia. 4ta edición. Harcourt Brace. España, S.A, Madrid.
(117) Svanaes DB, Moystad A, Larheim TA (2000): "Approximal caries depth assess-ment with storage phosphor versus film radiography. Evaluacion of the caries –especific Oslo enhacement procedure". Caries Res; 34(6): 448-53.
(118) Syriopoulos K, et al (2000): "Radiographic detection of approximal caries: a com-parison of dental films and digital imaging systems". Dentomaxillofac Radiol; 29: 312-318.
(119) Tewary S, Luzzo J, Hartwell G (2011): "Endodontic Radiography: Who Is Reading the Digital Radiograph?" J Endod; 37(7): 919-21.
(120) Tocarewics D, et al (2007): "Influência do nível de experiência do examinador na interpretaçao de radiografias obtidas a través de técnica convencional e da subtra-çao radiográfica digital (SRD)". R Periodontia; 17:73-79.
(121) Tyndall DA, et al (1998): "A comparison of Kodak Extaspeed Plus film and the Siemens Sidexis digital imaging system caries detection using receiver operating characteristic analysis". Oral Surg Oral Med Oral Pathol Oral Radiol Endod; 85(1): 113-8.
(122) Uprichard KK, et al (2000): "Comparison of direct digital and conventional radiog-raphy for detection of proximal surface caries in the mixed dentition". Pediatr Dent; 22(1): 9-15.
(123) van der Stelt PF (2000): Principios de la Imagen Digital. En Miles Dale A: Clínicas Odontológicas de Norteamérica. Vol 2: Aplicaciones de las distintas modalidades de Imagen Digital en Odontología. Méjico, McGraw-Hill Interamericana, 482p
(124) van der Stelt PF (2005): "The uses of digital radiography in dental practice". J Am Dent Assoc; 136(10): 1379-1387.
(125) Verdonschot EH, et al (1992): "Performance of some diagnostic systems in exami-nations for small occlusal carious lesions". Caries Res; 26: 59-64.
(126) Vergés Roger C (2002): "La percepción visual. Qué vemos y cómo vemos". Mi-crocirugía ocular" Nº 4, Diciembre 2002 (en línea) (fecha de consulta 21/07/09). Disponible en <www. Oftalmo.com/secoir2002/rev02-04/02d-02.htm>
(127) Wenzel A (1988): "Effect of image enhancement for the detectability of bone le-sions in digitized intraoral radiographs". Scand J Dent Res; 96: 149-160.
(128) Wenzel A (1995): "Current treds in radiographic caries imaging". Oral surg Oral Med Oral Pathol Oral Radiol Endod; 80:527-539
(129) Wenzel A (2000): Imagen digital en la caries dental. En Clínicas Odontológicas de Norteamérica, vol. 2/2000, Mc Graw-Hill Interamericana, p. 349.
(130) Wenzel A (2004): "Bitewing and Digital Bitewing Radiography for Detection of Caries Lesions". J Dent Res; 83(Spec Iss C): C72-C75.
(131) Wenzel A, et al (1993): "Developments in radiographic caries diagnosis". J Dent; 21:131-140.
(132) Wensel A, Fejerskov O (1992): "Validity of diagnosis of questionable caries le-sions in occusal surfaces of extracted third molars".Caries Res; 26:188-194.
(133) Wensel A, Larsen MJ, Fejerskov O (1991): "Detection of occlusal caries without cavitation by visual inspection, film radiographs, xeroradiographs, and digitized radiographs. Caries Res; 25: 365-371.