Periapical radiographic technique errors made with film and phosphor plates

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Abstract

Objective: The aim of this research was to analyse the errors that are related to the periapical radiographic technique when using radiographic film (conventional radiography) and when using photo-stimulated-phosphor (PSP) imaging plates (IP) (digital imaging), together with X-ray machines utilising cylindrical and rectangular collimators.

Materials and Method: A total of 672 periapical radiographs of all of the maxillary and mandibular regions were performed with a mannequin model by dental students in their last year at the Dentistry School of the Pontifical Catholic University of Rio Grande do Sul (PUCRS), Brazil. Each student performed 32 radiographs. 16 radiographs were performed when using conventional film and 16 radiographs were performed when using photo-stimulated-phosphor plates, with eight (8) exposures utilising a cylindrical collimator and eight (8) exposures with a rectangular collimator.

Results: Horizontal angular errors were the most frequent mistakes (39.4%), followed by a poor centring of the film (25.9%). Cone cutting (22.8%), identifying marks with an incorrect positioning (11.0%), non-parallel or insufficient safety margins (8.6%), were also observed.

Conclusions: There were no significant differences between the technique errors when using radiographic film or when using the phosphor plates. There were more errors with the use of the rectangular collimator.

Keywords: Diagnostic errors, Dental radiography, Diagnostic imaging, Learning

Introduction

Periapical radiographs, regardless of the technique used, whether it is the bisecting angle or paralleling, are frequently requested for in a dental clinic.(1) A correct execution of the technique is fundamental in order to obtain an adequate radiographic imaging to complement the diagnosis, the planning and the follow-up of the treatments performed.(2)

Certain errors in the technique or in the radiographic processing, besides being difficult to interpret, lead to a repetition of the radiography. This not only exposes the patient to X-rays more times than necessary,(2) but it also increases the clinical time and the treatment costs.(3)

The learning of intraoral radiographic techniques is initiated during the undergraduate course in dentistry. During this period, it is important that the students are able to make a critical analysis of the radiographs that they have performed. This learning can be improved when the students practise their practical activities,(3) by improving the true radiographic technique and by identifying the types of errors and their causes. The creation and the development of new teaching methods can help to correct these observed deficiencies, as well as to contribute to an improvement and a consolidation of the contents addressed.(4)

Therefore, the objectives of this study were to identify and to quantify errors of the radiographic technique in periapical incidences, when performed by undergraduate students of dentistry. This was achieved by using radiographic film (conventional radiography) and photo stimulable storage phosphor (PSP) plates for the dental imaging (digital imaging) and to compare the errors by relating them to two types of collimators (cylindrical and rectangular).

Materials and Method

A total of 672 periapical radiographs of all of the maxillary and mandibular regions were performed in a mannequin model by twenty-one (21) dental students, randomly selected, in their last year at the Dentistry School of the Pontifical Catholic University of Rio Grande do Sul (PUCRS), Brazil.

The periapical radiographs were obtained by using Kodak DF-58 Ultra-Speed Film (Eastman Kodak Company, Rochester, NY, USA), with an exposure time that was determined for each region according to the manufacturer's guidelines. The radiographs were performed by using the bisecting angle technique and then they were processed by the automatic film processor method (A / T 2000® XR, Air Techniques Co. Hicksville, NY, USA) with a dry-to-dry processing time of 4.5 minutes and at 28° C.

For the acquisition of the digital periapical images, photostimulable storage phosphor (PSP) plates (size 2) of the DenOptix Digital System (Gendex, Des Plaines, IL, USA) were used as receptors. The exposure time that was used took into consideration the electrical factors of the X-ray machines, the X-ray area and the receptor used. The processing of the digital radiographic images was performed by using the VixWin 2000 program (Gendex, Des Plaines, IL, USA) that is found in the DenOptix Digital System (Gendex, Des Plaines, IL, USA).

The X-ray device that was used in order to obtain the periapical radiographs was a Sommo (Gnatus, Ribeirão Preto, SP, Brazil) with an electrical regime of 70kVp, 7mA and with a 2.5mm aluminium filter.

In order to perform the radiographic technique, positioners for the image (film and phosphor plate) (Indusbello, Londrina, Paraná, Brazil) and collimators of the cylindrical and rectangular type were used in the X-ray machines (Gnatus, Ribeirão Preto, SP, Brazil).

Each student performed 16 conventional radiographs (with radiographic film), eight (8) exposures when using a cylindrical collimator and eight (8) exposures when using a rectangular collimator. The exposures included the regions of the molars, the premolars, the canines and the incisors, both in the upper and lower jaws. The same procedures were performed in order to obtain the digital radiographs when using phosphor plates as receptors. Each student, therefore, performed 16 conventional periapical radiographs and 16 digital periapical radiographs, totalling 672 radiographs that were performed by all of the students.

The conventional radiographs were evaluated by a calibrated observer in a dimly lit environment using a negatoscope and a four-magnification magnifying glass (when necessary). For the analyses, the radiographs were placed in plastic assemblies. They were all observed individually and separately. The digital radiographs were also analysed individually in an environment with controlled lighting by a monitor properly calibrated and with physical characteristics according to the visualisation needs. Finally, all of the radiographs were analysed again in order to evaluate the intra-rater reliability.

The radiographs were classified according to the errors that were presented when related to the radiographic technique, these being: a) shortened image or elongated image (incorrect vertical angulation); b) beam of the X-ray not parallel to the proximal surfaces of the teeth (incorrect horizontal angulation); c) cone cutting image (incorrect incidence point); d) incorrect positioning of the receptor (film or phosphor plate) which included the following errors: an incorrect exposure surface, a poor receptor centring, non-parallel or insufficient safety margins, an identifying mark with an incorrect positioning, and an incorrect long axis of the receptor (film or phosphor plate); e) double exposure; f) non-exposure.

The results were evaluated when considering the way that the radiography was obtained. That is, the technique was performed when using different receptors (radiographic film versus photostimulable storage phosphor plates), together with which the X-ray equipment was performed with different collimators (cylindrical versus rectangular).

The data that was obtained was tabulated, the percentages were calculated and the corresponding tables were created, all when considering the frequencies of the occurrences of the radiographic technique errors.

The statistical analyses of this study were performed by using descriptive statistics and comparisons between the groups. Pearson's Chi-squared test was used and was complemented by Fisher's exact test. The *P* value was considered statistically significant at 0.05.

Results

In order to evaluate the intra-rater reliability, the Kappa test was used, which showed an excellent agreement (with a variation of 1.000 - 0.971). Thus, only the first analyses were used in the presentation of the results. A total of 336 conventional radiographs (with radiographic film) were used and these were separated into 168 with a cylindrical collimator and 168 with a rectangular collimator. Table 1 shows the radiographic technical errors that were observed in the conventional radiographs when obtained with the cylindrical and rectangular collimators.

In the conventional radiographs that were obtained with the cylindrical collimator, the most frequent error was with the horizontal angulation (X-ray beam not parallel to the proximal surfaces of the teeth) (42.3%), followed by a poor film centring (26.8%), an identifying mark with an incorrect positioning (17.3%), together with non-parallel or insufficient safety margins (7.1%). In the conventional images that were performed with a cylindrical collimator, errors of an incorrect exposure surface and non-exposure were not observed.

With the use of the rectangular collimator, the most frequent error was the central ray of the X-ray beam not being parallel to the proximal surfaces of the teeth (42.3%), followed by the cone cutting image (41.7%) and a poor film centring (20.8%). No elongated image errors occurred that were due to an incorrect exposure, a double exposure, non-exposure or an incorrect positioning of the film in relation to the long axis. (Table 1)

Table 1: Comparisons, according to the types of error, between the conventional radiographs that were performed when using the cylindrical or rectangular collimators

Errors	Collimator		p*
	Cylindrical	Rectangular	
	n (%)	n (%)	
Elongated Image	1 (0.6)	0 (0.0)	1.0
Shortened Image	4 (2.4)	4 (2.4)	1.0
X-Ray Not Parallel to the Proximal Faces of the Teeth	71 (42.3)	71 (42.3)	1.0
Cone Cutting	8 (4.8)	70 (41.7)	<0.001
Incorrect Exposure Surface	0 (0.0)	0 (0.0)	1.0
Poor Film Centring	45 (26.8)	35 (20.8)	0.249
Non-Parallel or Insufficient Safety Margins	12 (7.1)	11 (6.5)	1.0
Identifying Mark with an Incorrect Positioning	29 (17.3)	19 (11.3)	0.160
Incorrect Long Axis of the Receptor	2 (1.2)	0 (0.0)	0.499
Double Exposure	1 (0.6)	0 (0.0)	1.0

* Minimum Level of Significance of 0.05.

336 digital radiographs were performed when using phosphor plates. 168 were performed with a cylindrical collimator and 168 were performed with a rectangular collimator. Table 2 shows the radiographic technique errors

that occurred when obtaining the digital radiographs that were performed with phosphor plates as image receptors and when using either cylindrical or rectangular collimators. (Table 2)

Table 2: Comparisons, according to the types of error, between the digital radiographs that were performed with phosphor plates when using cylindrical or rectangular collimators

Errors	Collimator		p*
	Cylindrical	Rectangular	
	n (%)	n (%)	
Elongated Image	1 (0.6)	0 (0.0)	1.0
Shortened Image	2 (1.2)	2 (1.2)	1.0
X-Ray Not Parallel to the Proximal Faces of the Teeth	62 (36.9)	61 (36.3)	1.0
Cone Cutting	4 (2.4)	71 (42.3)	<0.001
Incorrect Exposure Surface	3 (1.8)	0 (0.0)	0.248
Poor Film Centring	43 (25.6)	51 (30.4)	0.395
Non-Parallel or Insufficient Safety Margins	23 (13.7)	12 (7.1)	0.073
Identifying Mark with an Incorrect Positioning	13 (7.7)	13 (7.7)	1.0
Incorrect Long Axis of the Receptor	0 (0.0)	0 (0.0)	1.0
Non-Exposure Errors	0 (0.0)	2 (1.2)	1.0
Double Exposure	1 (0.6)	1 (0.6)	1.0
* Minimum Level of Significance of 0.05.			

The following errors occurred in the digital radiographs when performed with the cylindrical collimator: a) central ray of the X-ray beam not parallel to the proximal teeth (36.9%), b) a poor centralisation of the phosphor plate (25.6%), c) safety margins not parallel or insufficient (13.7%), d) identifying mark with an incorrect positioning (7.7%). No incorrect positioning errors were observed in relation to the long axis of the phosphor plate or non-exposure of the plate to the radiation.

The radiographs that were obtained with the phosphor plates when using a rectangular collimator had a cone cutting image (42.3%) as the most frequent error. There were also errors with the horizontal angulation (36.3%) and a poor centralisation of the plaque (30.4%). Only one case was observed for a double exposure error (0.6%) and a non-exposure error (1.2%). No errors were found regarding an elongated image, an incorrect exposure, or an incorrect positioning of the phosphor plate in relation to the long axis. (Table 3)

Table 3: Total distribution of the periapical radiographic technique errors when using film and phosphor plates with the cylindrical and rectangular collimators

Error Type	n	%	CI 95%	
X-Ray Not Parallel to the Proximal Surfaces of the Teeth	265	39.4	35.7	43.1
Poor Receptor Centring	174	25.9	22.6	29.2
Cone Cutting	153	22.8	19.6	25.9
Identifying Mark with an Incorrect Positioning	74	11.0	8.6	13.4
Non-Parallel or Insufficient Safety Margins	58	8.6	6.5	10.8
Shortened Image	12	1.8	0.8	2.8
Double Exposure	3	0.4	0.0	1.0
Incorrect Exposure Surface	3	0.4	0.0	1.0
Incorrect Long Axis of the Receptor	2	0.3	0.1	0.7
Elongated Image	2	0.3	0.0	0.7

Table 3 presents the errors related to the periapical radiographic technique of the 672 radiographs that were analysed in this study. The total distribution of the radiographic technique errors that were observed when using film or phosphor plates with the cylindrical collimator or the rectangular collimator were as follows: the horizontal angulation error when the central ray of the X-ray beam was not parallel to the proximal faces was the most frequent error (39.4%), followed by a poor centralisation of the image receptor (25.9%). Cone cutting image errors (22.8%), identifying mark with an incorrect positioning (11.0%), as well as non-parallel or insufficient safety margins (8.6%), were also observed. There were only two errors for an elongated image (0.3%) and an incorrect long axis of the receptor (0.3%). In addition, errors regarding the non-exposure of the image receptor to the X-ray beam were not found.

Discussion

The most frequent error, in all of the radiographs that were analysed in this study, was that the central ray of the X-ray beam was not parallel to the proximal faces of the teeth (Table 3), in other words, a non-centric horizontal angulation. As a consequence, the images overlapped the proximal surfaces of the teeth. The second most frequent error was that of a poor receptor centring (i.e. an incorrect positioning of the image receptor, the film or the phosphor plate). Similar works in the literature have also shown a high number of radiographs with errors when they were performed and obtained. Zhang et al.[5] identified positioning and central ray targeting errors as being the most frequent technique errors for both receptors types (film and phosphor plates). Peker and Alkurt[2] found that most of the errors occurred due to an incorrect angulation (34.92%), followed by an incorrect positioning of the film (34.48%), as well as cone cutting radiographs (21.18%). For this study, the processing of the films was performed by an automatic method, so the processing errors did not practically occur. In a recent study, 13,104 periapical radiographs were also performed by undergraduate students on a dentistry course. Of these, 3,538 (27%) were considered by the examiners as not being suitable for use in a complementary diagnostic examination, due to the technical errors that occurred in their attainment.[3]

The percentages of errors that have been observed vary greatly among studies. According to Patel,[6] this variability in the results may occur due to the intraoral technique performed, the positioner type, the collimator used, as well as the method that was used to evaluate the radiographs. In the present study, the examiners observed that there were more errors of non-parallel or insufficient safety margins in the images that were obtained with the phosphor plates than in those that were obtained with the radiographic film. One justification for this result may be the fact that in order to be used, the plates needed to be placed in disposable protective barriers to protect their faces from light exposure. These barriers are usually dark and they are larger than the phosphor plates. This could make it difficult to visualise and position them, creating an image with insufficient safety margins that were not parallel to the teeth. In a study performed by Zhang et al.,[5] there were significantly more positioning and overlapping errors in the phosphor plate images than in those that were obtained with film. For these authors, this data could be related, in part, to the protection wrap of the phosphor plate. The size and the dark protection in the wraps, as well as the low intraoral illumination, can affect a student's ability to visualise and align the parallel plates along the long axes of the teeth. In addition, the students may also become confused when aligning the tooth with the edge of the protective cover, rather than with the true edge of the plaque.

In this study, the examiners observed that the cone cutting image error was significantly higher on the radiographs that were performed with the rectangular collimator (41.7%) than they were with the cylindrical collimator (4.8%) (Table 1). The same was observed in the radiographs that were made with the phosphor plates, where the percentage of the cone cutting error was 42.3% in those radiographs that were performed with the rectangular collimator, while it was 2.4% in those that were performed with the cylindrical collimator. Other studies have also reported the occurrence of a smaller number of cone cutting imaging errors in those radiographs that were generated with the cylindrical collimators, than in those that were obtained with the rectangular collimators. These results were probably due to a higher area of incidence of the X-ray beam when using the cylindrical collimators.[7,8] According to Horton et al.,[9] more cone cutting image errors may occur with the use of rectangular collimators than with the use of cylindrical collimators which have a larger exposure area. If cone cutting images prevented important details from being displayed in the image, new X-rays may be required. These new X-rays will result in an increment of the dose of radiation to the patient, thus cancelling the purpose for the use of rectangular collimators.

Therefore, those images that were obtained with cone cutting, besides making it difficult to diagnose by the image itself, can also determine a greater number of repetitions, with more of an exposure of the patient to the ionising radiation. The use of a rectangular collimator is more effective in reducing the amount of radiation that the patient is exposed to when compared with cylindrical collimators. However, for this scenario to occur, a further training of operators is deemed to be necessary, so that the radiographs can be obtained correctly, with a minimum occurrence of errors.[5,7,9]

In the present study, the radiographic imaging was obtained with the use of positioners, which certainly explains the small number of vertical misalignment errors (shortened image and elongated image). However, even with the use of positioners, it was observed that the radiographs with unsatisfactory images were related to the technical errors that had occurred. The positioners aided in determining the correct vertical angulation, but care must be taken with regard to the horizontal angulation, so that the central ray of the X-ray beam is positioned parallel to the proximal surfaces of the teeth that are to be radiographed, avoiding an overlapping of the image with the interproximal surfaces. Contrary to what was observed in the present study, Tax et al.[10] also used positioners in order to obtain the periapical radiographs and they did not identify any vertical angulation errors when using the same imaging receptors.

The main limitations of intraoral radiographs are that they are a two-dimensional image of structures that are three-dimensional, resulting in an overlapping of the anatomical structures. This, for the most part, prevents a distinction among those structures that are located by vestibular, palatal, or lingual means, making diagnoses and treatment planning difficult. The periapical technique is susceptible to projection errors. This may result in an overlapping of the proximal crown surfaces, and thus, prevent a proper diagnosis of the carious lesions. However, from a craniocaudal perspective, the projection errors may also lead to a misinterpretation, such as the true height of the alveolar bone, the length of the roots, as well as the root canals.[11]

It is hoped and believed that this study can contribute to and encourage the accomplishment of more research that is related to this subject. Even if conventional radiographic imaging that is obtained with radiographic film is gradually being replaced by digital image detectors, the principles of the radiographic technique to be used are the same for all image receptors, i.e., radiographic film, phosphor plates, or solid-state sensors. By performing a correct radiographic technique results in good quality imaging, together with a lower dose of radiation exposure to the patient. The use of rectangular collimators is associated with a dose reduction of radiation to the patient. However, it is imperative that the technique is performed correctly. For this, it is necessary to train the operators with the use of these collimators.

It is also recommended that dentists always have attention and care in the execution and the obtainment of periapical radiographs. Radiographs that display a good quality will provide essential information in order to obtain a correct diagnosis and be complementary to the clinical examinations in different dental specialties. It is also important to emphasise the importance of rigorousness on the part of the teachers, requiring them to be demanding of their students, in order to obtain radiographic examinations of an excellent quality.

Conclusions

There were no significant differences between the periapical radiographic technique errors when using radiographic film or phosphor plates. This result is probably related to the fact that phosphor plates and radiographic film resemble each other both in size and in thickness.

A higher number of errors were observed with the use of the rectangular collimator when this was compared to the cylindrical collimator. These consequences could be associated to a greater training of the students with the cylindrical collimator, together with the higher areas of exposure that can be obtained with this particular collimator.

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