THE INFLUENCE OF DISPLAY MODALITIES ON PROXIMAL CARIES DETECTION AND TREATMENT DECISION

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ABSTRACT

The aim of this study was to investigate the influence of digital radiographic display on caries detection and choice of treatment among undergraduate students. Forty images of extracted human teeth were acquired using a PSP digital system. The proximal surfaces were evaluated for the presence of proximal caries and choice of treatment by 36 undergraduate students, divided into three groups according to the semester they were taking. The images were evaluated in two forms of image display: laptop, and printed on acetate viewed on a lightbox. The accuracy of the different forms of image display on caries detection was evaluated by means of ROC curve analysis and its effect by mixed linear regression. Residue analysis was used to verify the adequacy of the treatment of choice for the chosen diagnosis. There was no significant effect either for the display modalities (p=0.058) or for the different undergraduate student groups (p=0.991). The Az was 0.539 for printed images and 0.516 for laptop. The decisions based on treatment of choice were consistent with the scores achieved for caries detection. Accuracy of caries detection using a laptop was comparable to accuracy using printed images. Treatment decision was not affected by image display modality. The semester of the dentistry course that undergraduate students were taking did not significantly increase the accuracy of their proximal caries detection.

Key words: *Dental Caries, Radiography, Dental-Diagnosis, Oral.*

INFLUÊNCIA DOS MEIOS DE APRESENTAÇÃO RADIOGRÁFICA NO DIAGNÓSTICO E TRATAMENTO DA CÁRIE

RESUMO

O objetivo deste estudo foi investigar a influência do meio de apresentação da imagem radiográfica digital no diagnóstico da carie e na decisão de tratamento realizado por alunos de graduação. Foram obtidas 40 imagens digitais de dentes humanos extraídos através do sistema digital PSP. As superfícies proximais dos dentes foram avaliadas quanto à presença de cárie proximal por 36 estudantes de odontologia, distribuídos em três grupos de acordo com o nível de formação. As avaliações foram efetuadas em um laptop e em imagens impressas com o auxílio do negatoscópio. A acurácia dos meios de apresentação quanto à detecção de cárie incipiente foi avaliada pela média das áreas sob as curvas ROC e seu efeito por uma análise de regressão linear mista. Para a tomada de decisão terapêutica foi realizada uma análise de resíduos para verificar sua adequação ao diagnóstico. Não houve efeito significativo nem para a modalidade de visualização (p=0.058) e nem para os grupos de alunos (p=0.991). A média das áreas sob as curvas Roc para o filme foi de 0.539 e de 0.516 para negatoscópio. A decisão de tratamento foi condizente com o diagnóstico efetuado. A acurácia do diagnóstico da cárie proximal realizado em tela de laptop é comparável ao realizado em negatoscópio. A tomada de decisão terapêutica não foi afetada pelo meio de apresentação da imagem radiográfica digital. A progressão do aluno no curso não melhora a precisão diagnóstica da cárie proximal.

Palavras chave: *Cárie Dentária, Radiografia Dentária, Diagnóstico Bucal.*

INTRODUCTION

Proximal caries still pose a challenge to dental care providers mainly because due to their location, they can only be detected clinically when a great extension of the proximal surface is compromised[1]. Bitewing radiography is used for detecting caries, but does not usually detect lesions in early stages, before cavitation. New, more accurate and more reproducible diagnostic methods are therefore needed to supplement early diagnosis and plan appropriate treatment for caries based on their low prevalence and extension and slow progression[2].

The use of dental radiographic films has largely been replaced by intraoral digital radiographic systems, most of which have been tested for efficiency in detecting caries[3-7].

Because digital images enable the acquired image to be viewed on a computer monitor, the evaluation of the different forms of image displays is of interest for dental health care providers and researchers. Haak et al.[8] evaluated the influence of digital image size on different types of monitors and found that the type of monitor has no effect on caries detection. Another form of image display still used by some professionals is a printed image, usually on acetate, which is similar to a conventional image[8].

Hellen-Halme et al.[9] suggest that in order to view proximal caries in digital images, ambient light conditions should be dimmed and brightness and contrast of the monitor adjusted to provide excellent image quality. Carmona et al.[10] claim that observer experience improves radiographic caries detection, reducing false negative results and increasing accuracy.

Based on the above, the aim of this study is to evaluate the influence of different image displays and the level of experience of undergraduate students on the diagnosis of proximal caries and treatment decisions by observing dental students from a Brazilian institution.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of the Department of Dentistry at the State University of Paraíba (Protocol number CAAE 0384.0.133.000-11). Fifty extracted human teeth (10 canines, 20 premolars and 20 molars) were mounted on 10 silicone blocks, each of which held five teeth, simulating a normal condition. The canine was used to ensure proximal contact with the first premolar. The premolars and molars were either intact or had a small area of demineralization on their proximal surfaces.

Digital images were acquired using a GE 1000 (General Electric Company, Milwaukee, WI, USA) unit operating at 65 kVp and 10 mA. An acrylic plate 1.2 cm thick was placed adjacent to the models as a material equivalent to soft tissue. To ensure reproducible imaging geometry, the silicone blocks were stabilized on a customized acrylic device to provide a distance of 34 cm between the target and the image receptor, a centrally oriented X-ray beam and a distance of 2 cm between the teeth and the receptor.

The image receptor used in this study was size 2 intraoral PSP digital imaging (DenOptix, Gendex Dental Systems, Milan, Italy). Before exposure, each plate of the digital system was exposed to a lightbox for 130 s, as recommended by the manufacturer. The exposed phosphor plates were scanned using 300 dpi resolution and the files were exported and saved in tagged image file format (TIFF).

The acquired TIFF images were mounted in a PDF and printed using AGFA acetate film (Agfa Healthcare, Gevaert Group, Belgium) on a laser printer Drystar 5300 (Agfa Healthcare, Gevaert Group, Belgium). Each film contained eight images, and there were a total of five films.

Gold Standard

Histological sections (700 μm) served as a validating criterion for the presence and depth of the caries lesions. Before selection, the teeth were individually embedded in acrylic (Vipi, São Paulo, Brazil) and then sectioned in mesiodistal direction using a 200 mm diamond band. The sections were cleaned and glued to microscope slides using transparent varnish. Independent histological validation was performed by two previously trained observers under incident light (12.5 – 20X magnification) using a binocular microscope. If the observers' ratings varied, they were asked to perform a joint assessment to establish agreement.

Caries were defined as present when an opaque-white demineralization or brown discolored area was observed on the surface. For the histological surface, the following scale was applied: 0 = no enamel demineralization or narrow surface zone of opacity; 1 = demineralization limited to the enamel; 2 = demineralization involving the dentine.

Viewing Sessions

Prior to the examination sessions, the observers received explanations and practical instructions, and underwent calibration tests so that they would be familiar with the specific characteristics of the digital images used in the study. Viewers need to be trained with regard to the specific characteristics of images in each digital system so that diagnosis would not be compromised by the difference between systems. The professors were not required to undergo calibration because they are already familiar with the digital images used in this institution. The researchers who were not familiar with them underwent calibration but did not participate in the student training.

During calibration, the evaluation method was explained, and training and knowledge were verified. The researcher responsible for training the observers remained in the same room to answer any questions that might arise during the evaluation sessions. The digital images were displayed on a 17" color laptop monitor, size 1:1, and the printed images were displayed on a lightbox placed in a quiet room with dimmed lighting. The digital images could not be enhanced. All images were evaluated in a quiet and darkened room.

Each observer evaluated individually forty teeth, resulting in the evaluation of eighty proximal surfaces. The number of images evaluated at each session was determined by the observer and could not exceed 20 at a time.

Thirty-six independent observers, all undergraduate dentistry students at the State University of Paraíba (14 from the 7th semester, 12 from the 8th semester, and 10 from the 9th semester) were selected to evaluate the images. They were chosen according to their grades and success in radiology classes, and were considered able to diagnose dental caries. They were divided into groups based on the semester they were taking and coded as: Group A – 7th semester, Group B – 8th semester, and Group C – 9th semester.

The presence of proximal caries lesions was scored using a 5-point confidence scale: 1 = definitely not present, 2 = probably not present, 3 = unsure, 4 = probably present, and 5 = definitely present. After scoring the images individually for the presence of caries lesion, the observer scored the same image to indicate adequate clinical follow-up as: N – no treatment needed, P – Preservation, R – Restorative treatment.

Data Analysis

To measure the accuracy of the images displayed in different modalities and evaluated by different groups, the area under the Receiver Operating Characteristic (ROC) curves (Az) were calculated. Az was calculated for each observer in each modality evaluated. The possible effect of the observer group and image display modality on the ROC curves was evaluated using a mixed linear regression model, taking into consideration the possible structure of score correlation because each observer evaluated the dental surface in two forms of image visualization: printed on acetate viewed on a lightbox, and on a laptop monitor.

The possible association between caries detection and treatment decision was verified using the chi-square test. Adjusted residue analysis was used to identify the most significant sources of association presented in each contingency table for each group. All statistical tests adopted a 0.05 level of significance.

RESULTS

Of the 80 microscopically evaluated surfaces, 29 (36.25%) presented proximal caries lesions, of which 26 were restricted to the enamel, and only 3 reached the outermost dentin.

Table 1 shows the mean values for the area under the ROC curve, standard deviations, and confidence intervals (CI) for each group of observers for each image display modality. There was no statistical difference between display modalities ($p = 0.058$) or among the three observers groups (A, B, C) ($p = 0.991$).

Tables 2a and 2b show the adequacy of treatment choice to the caries detection scores chosen by group A for printed and laptop monitor image modality, respectively. The restorative treatment

Table 1: Means and Standard deviations of the areas under the ROC curves for the undergraduate student groups and image modalities.

		Modality			
		Printed		Laptop	
Group	N	Mean	Standard Deviation	Mean	Standard Deviation
A	14	0.538	0.070	0.515	0.091
B	12	0.542	0.068	0.516	0.079
C	10	0.536	0.052	0.515	0.068
Mean	36	0.539	0.063	0.516	0.079

Table 2a: Caries detection and treatment decision scores for the 14 observers in Group A for display modalities.

Display modality	Caries Detection	Treatment of choice			
		N*	P**	R***	Total
		n (%)	n (%)	n (%)	n (%)
Printed	Definitely not present	219 (92.8)	7 (3.0)	10 (4.2)	236 (100.0)
	Probably not present	68 (25.8)	188 (71.2)	8 (3.0)	264 (100.0)
	Unsure	18 (9.1)	155 (78.7)	24 (12.2)	197 (100.0)
	Probably present	1 (0.3)	176 (61.1)	111 (38.5)	288 (100.0)
	Definitely present	0 (0.0)	2 (1.5)	133 (98.5)	135 (100.0)
	Total	306 (27.3)	528 (47.2)	286 (25.5)	1120 (100.0)
Laptop	Definitely not present	251 (98.0)	4 (1.6)	1 (0.4)	256 (100.0)
	Probably not present	87 (33.3)	173 (66.3)	1 (0.4)	261 (100.0)
	Unsure	16 (14.4)	95 (85.6)	0 (0.0)	111 (100.0)
	Probably present	2 (0.6)	242 (71.4)	95 (28.0)	399(100.0)
	Definitely present	0 (0.0)	2 (1.3)	151 (98.7)	153 (100.0)
	Total	356 (31.8)	516 (46.1)	248 (22.1)	1120 (100.0)

*N = No treatment needed; **P= Preservation; ***R = Restorative treatment. Q-Square Test: $p < 0.001$.

Table 2b: Adjusted residues for Group A on display modalities.

Display modality	Caries Detection	Treatment of Choice		
		N	P	R
Printed	Definitely not present	25.407	-15.303	-8.446
	Probably not present	-0.652	8.961	-9.592
	Unsure	-6.309	9.768	-4.734
	Probably present	-11.919	5.510	5.873
	Definitely present	-7.596	-11.333	20.736
Laptop	Definitely not present	25.923	-16.266	-9.544
	Probably not present	0.613	7.480	-9.668
	Unsure	-4.141	8.799	-5.920
	Probably present	-14.772	11.198	3.123
	Definitely present	-9.087	-11.955	24.543

decision for surfaces scored for caries definitely present was practically unanimous (98.5% and 98.7%), whereas surfaces considered sound did not receive indication for treatment (92.8% and 98%) for either image display modality.

Tables 3a and 3b represent the correspondence between caries detection and treatment of observer group B on both image display modalities. In this group there is greater consistency between caries detection and restorative treatment decision when evaluating image modality (100%). None of the faces scored as sound or probably sound were scored for restorative treatment.

Tables 4a and 4b show the results for therapy chosen based on the diagnosis made by group C. Surfaces that the observers considered questionable were indicated for follow-up when evaluated in printed image modality by all observers, whereas for the laptop monitor modality, the result was 96.4%.

Table 3a: Caries detection and treatment decision scores for the 14 observers in Group B for display modalities.

Display modality	Caries Detection	Treatment of choice			
		N*	P**	R***	Total
		n (%)	n (%)	n (%)	n (%)
Printed	Definitely not present	403 (99.5)	2 (0.5)	0 (0.0)	405 (100.0)
	Probably not present	43 (26.2)	121 (73.8)	0 (0.0)	164 (100.0)
	Unsure	1 (0.8)	104 (84.6)	18 (14.6)	123 (100.0)
	Probably present	0 (0.0)	105 (67.3)	51 (32.7)	156 (100.0)
	Definitely present	0 (0.0)	0 (0.0)	112 (100.0)	112 (100.0)
	Total	447 (46.6)	332 (34.6)	181 (18.8)	960 (100.0)
Laptop	Definitely not present	361 (99.4)	2 (0.6)	0 (0.0)	363 (100.0)
	Probably not present	51 (37.0)	87 (63.0)	0 (0.0)	138 (100.0)
	Unsure	1 (0.9)	110 (97.3)	2 (1.8)	113 (100.0)
	Probably present	0 (0.0)	149 (73.0)	55 (27.0)	204 (100.0)
	Definitely	0 (0.0)	10 (7.0)	132 (93.0)	142 (100.0)
	Total	413 (43.0)	358 (37.3)	189 (19.7)	960 (100.0)

*N = No treatment needed; **P= Preservation; ***R = Restorative treatment. Q-Square Test: $p < 0.001$.

Table 3b: Adjusted residues for Group B on display modalities.

Display modality	Caries Detection	Treatment of Choice		
		N	P	R
Printed	Definitely not present	28.092	-18.970	-12.758
	Probably not present	-5.736	11.590	-6.779
	Unsure	-10.894	12.478	-1.281
	Probably present	-12.740	9.390	4.828
	Definitely present	-10.511	-8.187	23.360
Laptop	Definitely not present	27.536	-18.356	-11.962
	Probably not present	-1.555	6.760	-6.286
	Unsure	-9.631	14.054	-5.099
	Probably present	-13.985	11.898	2.944
	Definitely present	-11.217	-8.075	23.787

DISCUSSION

This study evaluated the influence of two different image display modalities on caries detection and treatment choice. Two methods for displaying the radiographic digital image were compared: printed on acetate viewed on a lightbox, and displayed on a laptop monitor. This study also aimed to evaluate whether students' undergraduate dental experience in radiology classes and clinical practice improved their capacity to detect incipient proximal caries lesions.

Most of the studies which have evaluated the influence of image quality on caries detection used a relatively small number of observers, typically oral radiologists or dental professionals with significant experience in caries detection[4,11,12]. In Rockemback et al. [13], one observer conducted the evaluation, while in other studies the number of observers varied from three[11,14,15] to 14[3] or 20[16]. Few studies used dental students as observers[16–18]. In our study, the evaluations were performed by 36 dental

Table 4a: Caries detection and treatment decision scores for the 14 observers in Group C for display modalities.

Display modality	Caries Detection	Treatment of choice			
		N*	P**	R***	Total
		n (%)	n (%)	n (%)	n (%)
Printed	Definitely not present	310 (98.4)	2 (0.6)	3 (1.0)	315 (100.0)
	Probably not present	64 (55.2)	52 (44.8)	0 (0.0)	116 (100.0)
	Unsure	0 (0.0)	67 (100.0)	0 (0.0)	67 (100.0)
	Probably present	1 (0.7)	91 (66.9)	44 (32.4)	136 (100.0)
	Definitely present	1 (0.6)	1 (0.6)	164 (98.8)	166 (100.0)
	Total	376 (47.0)	213 (26.6)	211 (26.4)	800 (100.0)
Laptop	Definitely not present	349 (98.0)	6 (1.7)	1 (0.3)	356 (100.0)
	Probably not present	23 (31.9)	49 (68.1)	0 (0.0)	72 (100.0)
	Unsure	2 (2.4)	81 (96.4)	1 (1.2)	84 (100.0)
	Probably present	0 (0.0)	108 (70.1)	46 (29.9)	154 (100.0)
	Definitely present	1 (0.7)	5 (3.7)	128 (95.5)	134 (100.0)
	Total	375 (46.9)	249 (31.1)	176 (22.0)	800 (100.0)

*N = No treatment needed; **P= Preservation; ***R = Restorative treatment. Q-Square Test: $p < 0.001$.

Table 4b: Adjusted residues for Group C on display modalities.

Display modality	Caries Detection	Treatment of Choice		
		N	P	R
Printed	Definitely not present	23.481	-13.403	-13.150
	Probably not present	1.907	4.797	-6.972
	Unsure	-8.053	14.196	-5.118
	Probably present	-11.866	11.667	1.736
	Definitely present	-13.454	-8.521	23.785
Laptop	Definitely not present	25.964	-16.104	-13.279
	Probably not present	-2.661	7.095	-4.724
	Unsure	-8.638	13.664	-4.867
	Probably present	-12.972	11.634	2.624
	Definitely present	-11.728	-7.506	22.518

students in order to investigate the influence of academic training and level of experience on radiographic proximal caries detection.

The teeth sample used in this study consisted of premolars and molars with carious lesion in the initial stages, which previous studies found to be more difficult to detect[3,9,11,12,19,20]. According to Shintaku, Scarbeczm and Venturim, the Az values are significantly higher when results are validated based only on radiographic and clinical evaluation[21,22].

To assess how the scores reflected on the diagnostic decision, Az values were calculated for each observer for each modality of image display. As in our study, Ferreira et al. evaluated enamel demineralization using radiographic film and digital and digitized images[23]. They evaluated the diagnostic performance of each observer and measured the efficiency of the methods by using the areas under the ROC curves. Otis & Sherman[22] evaluated caries diagnosis using printed photographic paper interproximal images and in the statistical analysis, calculated Az for each

observer and image format. Other similar studies evaluated observer performance by using ROC curve analysis[4-6,11,16,22,24].

Ludlow & Abreu[25] found that the accuracy values for caries lesions evaluated on laptop monitors were comparable to the accuracy values for printed images evaluated using the lightbox, in agreement with our study. All viewing sessions in our study were done in a quiet room with dimmed light for both image display methods; a setup which substantially increases diagnostic precision[9,12,26].

The Az projects total diagnostic accuracy and consequently represents the performance of the observer. In this type of analysis, perfect performance is represented by an Az value close to 1; nevertheless, values from 0.75 to 0.80 are considered acceptable for the detection of proximal caries involving dentin tissue. However, incipient caries are more difficult to diagnose because enamel decalcification needs to be higher than 30% for them to be detected in radiographic images, leading to lower Az levels than when evaluating dentin lesions[10]. In this study, the Az values ranged from 0.515 to 0.542, revealing lower diagnostic accuracy than is usually found in studies of this nature. Similar Az values were found in a study by Diniz et al.[16], in which the Az value for Brazilian undergraduate dental students was 0.53 for enamel caries detection. Hellen-Halme, Nilsson and Petersson[4] reported similar Az values, ranging from 0.542 to 0.557, even though the observers were one oral radiologist and six dental professionals, including dentists with more professional experience than the observers in our study, who were undergraduate dentistry students.

Adjusted residual analyses based on caries detection and therapeutic treatment decision for both forms of image display reflected alignment of academic teaching at the university with the new caries treatment philosophy. The strong tendency to prefer preservation over restorative treatment was clearly evident. The score showed that restoration was only selected for surfaces scored as caries definitely present. The theory of minimum intervention is based on preventive dentistry, which postpones filling or its substitution until strong evidence exists of caries lesion[27] and recommends maximum preservation of sound tooth structure, executing conservative preparation and providing higher resistance to the remaining dental structure. New developments in long-lasting restorative adhesive materials enable the use of conservative preparation limited to the size of the lesion and do not require additional time wearing of mechanical retention[28].

Rocha et al. found that, when in doubt, the undergraduate student prefers to classify the surfaces as intact during radiographic evaluation, increasing the number of false negatives, which immediately reflects on the therapeutic choice in the form of non-treatment or preservation[17]. On the other hand, the results found by Bervian et al.[18] revealed that a significant proportion of students chose restorative treatment for caries lesions restricted to the enamel surface, and this proportion was more evident among students attending private schools. As previously seen in other professional courses, the quality of dentistry education is related to the university and the course having an adequate pedagogical model . Despite the occurrence of major changes in higher education, the educational model for dentistry in Brazil still focuses mainly on technical training.

Our study found that when the diagnosis was either caries definitely present or definitely sound, the treatment decision was consistent with the diagnosis, which implies greater confidence of the observer during evaluation of the images. Definitely sound surfaces were not treated, while restorative treatment was indicated when caries were definitely present. The uncertain options, considered probably present or probably sound, or without any condition to diagnose -score 3-, led to follow-up, which is a safe, conservative therapy. These students should be trained to detect incipient proximal caries more effectively because the definitive diagnosis should not be jeopardized in favor of follow-up, as a neglected caries lesion can evolve. In conclusion, this study demonstrated that the different forms of digital image displays resulted in similar performance by observers and did not affect the precision of proximal caries detection or treatment decision. Student level in a dentistry course does not significantly increase precision with regard to proximal caries detection.

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