RESEARCH ARTICLE

Impact of room lighting and image display device in the radiographic appearances of the endodontic treatments

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Objectives: To assess the radiographic appearances of the endodontic treatment in different room lighting conditions and image display devices.

Methods: After approval by Research Ethical Board, 20 images were obtained from blocks with one endodontically treated tooth. Of the 20 endodontic treatments conducted in the laboratory, of those the randomly selected 10 teeth (50% of sample) received some quality defect in three parameters—apical limit, adaptation to root canal and homogeneity of the root canal filling material. Digital radiographs (DIGORA® Optime, Soredex, Milwaukee, WI) were obtained, which were evaluated (8 times) by 10 observers in two different conditions of room lighting, with bright (1000 to 1200 lux) and dim light (25 to 50 lux), using two different image display devices, smartphones and laptop computers. The observers assessed the radiographic appearances of the endodontic treatment with respect to quality of each one of three parameters individually. The data of observers' responses in terms of the quality of each parameter were statistically compared using Cronbach's α coefficient, diagnostic tests, π coefficient and ANOVA with Tukey tests, at a significant level setting of 5% ($\alpha = 0.05$).

Results: The mean of reliability of observer responses ranged from 0.89 (intra-evaluator) to 0.66 (inter-evaluator). The mean values of the receiver operating characteristic (ROC) area were 0.661 (PD = 0.098), with laptop in bright lighting appraising homogeneity of the root canal filling material on the worst performance (ROC area = 0.57), which was statistically significant ($p < 0.05$), and 0.81 with laptop in dim lighting appraising apical limit on the best performance. Differences ($p < 0.05$) occurred mainly among parameters used for assessment.

Conclusions: Room lighting and image display devices have very little influence in the radiographic appearances of the endodontic treatment. Thus, we suggest the use of smartphones as an acceptable image display device in daily clinical practice in routine bright lighting conditions. *Dentomaxillofacial Radiology* (2018) 47, 20170372. doi: [10.1259/dmfr.20170372](https://doi.org/10.1259/dmfr.20170372)

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Introduction

Techniques for endodontic treatment has undergone many improvements over the years. In spite of the effectiveness of the endodontic treatment is not only dependent on technique quality, radiographic appearances of the endodontic treatment is also often very significant in

relation to the prognosis of long-term periapical tissue health. However, the definition of the quality of the endodontic treatment through its radiographic appearance is not a simple task. Mainly in case of dentist is required for determining an endodontic retreatment to meet patient needs.^{1–3}

The definition of quality suffers great interpersonal disparity caused by different subjective values related to

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professional experience and previous knowledge of the patient's history,³ besides to the limitations of the image examinations and individual visual perception.⁴ The radiation dose also can be a limitation factor to improvement of diagnosis, because examinations of high-resolution images, as tomographic, cannot be prescribed for a standard endodontic treatment. Thus, radiographic diagnosis, a "visual specialty", using two-dimensional images generated from three-dimensional structures, continues to depend on the ability of the observer for interpretation.⁵

A radiographic diagnosis in endodontic specialty is very challenging for daily dental practice, because the dentist must be able to distinguish images of different radio-opacities, from typical anatomic tissues to many others as root canal filling material or resorptions caused by inflammatory processes. Oftentimes the radiographs are assessed using individual image display devices without any calibration, in a clinical setting with bright lighting conditions.^{6–8}

In dentistry area, there is limited knowledge and controversy over how observer performance to specific diagnosis is influenced by the type of image display devices, considering different technologies, and condition of room lighting. Thus, the aim of this study is to assess the radiographic appearances of the endodontic treatment in different room lighting conditions and image display devices.

Methods and materials

This study began after the approval by the Research Ethical Board, which complies with the Helsinki Declaration.

The sample size of human teeth for this study was calculated based on this formula: $Sw^2 = N^2 2n(m - 1)$, where "Sw" is within-subject standard deviation (value = 1.96), "N" is the extrapolation of sample that had inadequate quality of the endodontic treatment (value = 30%), "m" is the number of measurements per sample (considering the minimum, one assessment per image), and "n" is the number of sample. In this calculation, a sample size of 21.3422 teeth was needed to obtain 95% confidence interval for a repeatability test. Nevertheless, a sample of 20 teeth was used due to number of assessment that was greater than the minimum (increase in "m", from 1 to 2). After extractions, that were independent of carrying out this research, all teeth were cleaned by removing debris and were stored in distilled water at 48 °C for not more than six months post extraction. For standardization, all teeth that were used as samples had only one root canal, which were verified through radiographic confirmation.

All 20 teeth were endodontically treated in the laboratory, using the lateral condensation technique. Of the 10 teeth that were randomly selected from these samples (50%), the endodontic treatments received some

quality defect in one of the three parameters—apical limit, adaptation to root canal and homogeneity of the root canal filling material. A quality defect template was used as a gold standard to objective analysis of the observers' performance using diagnostic test.

The endodontic treatment protocol consisted of progressive chemo-mechanical manual preparation. Access to root canals was performed by using high-speed spherical carbide bur and Endo-Z (Dentsply-Maillefer, Ballaigues, Switzerland), whereas the measurements and the root canal length were established with an apex locator Root ZX (J Morita Manufacturing Co., Kyoto, Japan) and confirmed radiographically. The canal was prepared with stainless steel FlexoFile (Dentsply-Maillefer, Ballaigues, Switzerland) using irrigation of 2.5% sodium hypochlorite and 17% trisodium EDTA. After drying with absorbent paper points (Tanari Industrial Ltda., MA, Brazil), the root fillings were performed with gutta-percha points (Tanari Industrial Ltda., MA, Brazil) and AH Plus sealer (Dentsply DeTrey GmbH, Konstanz, Germany).

20 blocks, using a blend of rice and gypsum (proportion of 1:2 in volume) into ice cube mold to simulate trabecular bone, were confectioned to support one teeth each. Digital radiographs (DIGORA® Optime, Soredex, Milwaukee, WI) were obtained by parallel technique in a standardized projection geometry of the set blocks, image receptor and X-ray tube extension (Figure 1). A 12-mm thick white utility wax (Lysanda Produtos Odontológicos LTDA, SP, Brazil), a soft tissue-equivalent material, was placed between the X-ray tube extension and the blocks to simulate radiation scatter. The exposures were made using an X-ray machine (Heliodent 60B, Siemens, Erlangen, Germany) operating at 60 kVp, 10 mA, 0.12 s, 40 cm target-to-receptor distance, with total filtration at 2 mm of Al.

The 20 digital radiographic images were randomly ordered in a PowerPoint presentation on a dark background. 10 observers, general dentists who routinely use digital images for the diagnosis of the quality of endodontic treatment, independently recorded the images. Each observer assessed the same presentation 8 times [first time—one presentation in each condition ($N = 4$); second time—repetition of 100% ($N = 4$)] in two different conditions of room lighting, with bright (1000 to 1200 lux) and dim light (25 to 50 lux), using two different image display device, smartphones and laptop computers. The luminous intensity from the procedure room was measured by a Photometer 07–621 (Fluke Biomedical, Cleveland, OH). All rooms and devices were of personal use of general dentists, reproducing the habitual place and working conditions of observers. All assessments were made by following the same protocol and awaiting at least 2 days of interval time between each one of these. The observers assessed radiographic appearances of the endodontic treatment using the Likert scale with 5-point rating, as follows: 5 = perfect quality; 4 = good quality; 3 = medium quality,

Figure 1 Representative images of quality of endodontic treatment used in this study. (Images representing (a) better treatment, (b) good treatment that were considered with adequate quality (70% of sample), and (c) poor treatment that was considered with inadequate quality (30% of sample).

2 = bad quality, 1 = without quality, in relation to quality parameters: (a) apical limit of the root canal filling material, considering with adequate quality apex distances from 0 to 2 mm; (b) adaptation of the filling material to root canal; (c) homogeneity of the radiographic contrast of the filling material along the entire root canal.

The data of the Likert scale from the analysis of the radiographic appearances of the endodontic treatment in relation to the quality were tabulated, and then the Cronbach's α coefficient was used to evaluate the intra and interobserver reliability response pattern. To assess the observers' overall performance, the data were binarized considering 4 and 5 scores as "0" (adequate quality) and 1, 2 and 3 scores as "1" (inadequate quality). The three parameters in each condition of room lighting and image display devices were individually analyzed using diagnostic tests, π coefficient and ANOVA with Tukey tests. All statistical analyzes were conducted with a significance level of 5% ($\alpha = 0.05$).

Results

Reliability of the response pattern for Likert scale of observers was adequate for statistical analysis. The Cronbach's α coefficient values showed a mean of 0.89 (0.87 of minimum and 0.92 of maximum) for intraobserver analysis, and a mean of 0.66 (0.54 of minimum and 0.80 of maximum) for interobserver analysis.

Table 1 shows the results of observers' overall performance using diagnostic tests. The mean values of the receiver operating characteristic (ROC) area were 0.661 (PD = 0.098), with laptop in bright lighting appraising homogeneity of the root canal filling material on the

worst performance (ROC area = 0.57), and 0.81 with laptop in dim lighting appraising apical limit on the best performance.

The mean of the degree of association between observers' responses and gold standard, also all results of statistical analysis comparing different image assessment conditions, image display devices and room lighting, and different parameters to assess quality of the radiographic appearance of endodontic treatments, are shown in Table 2. The observers' performance differed ($p < 0.05$) for the worst only during the use of laptop in bright lighting to assess homogeneity of the root canal filling material. The statistical differences ($p < 0.05$) occurred mainly among parameters used for assessment, with the worst results related to the adaptation to the root canal and the homogeneity of the root canal filling material, leading to the overestimation of the perception of quality of endodontic treatment (quality defect practically imperceptible).

Discussion

In this current short-term laboratory study, the radiographic appearances of the endodontic treatment were evaluated under the different conditions of room lighting using different image display devices. This methodology for evaluation of a specific oral diagnostic differed from other previous studies^{6,9-12} commonly found in the literature because all environments and devices were of personal use of general dentists, who were the observers of the current study. Thus, there was no rigorous laboratorial standardization of these variables, room lighting and image display devices. This freedom was essentially directed towards the target of the current study,

Table 1 Results of the observers' overall performance using diagnostic tests for quality parameters of the endodontic treatment in accordance to evaluated variables

Variables (environments and devices)	Quality parameters ^a	Sens.	Spec.	ROC area	LR+	LR−	O. R.	PPV	NPV
Laptop in bright illumination ^b	A	60%	94%	0.77	10.00	0.43	23.50	90.9%	70.1%
	B	25%	95%	0.60	5.00	0.79	6.33	83.3%	55.9%
	C	31%	83%	0.57	1.82	0.83	2.19	64.6%	54.6%
Laptop in dim illumination ^b	A	72%	90%	0.81	7.20	0.31	23.10	87.8%	76.3%
	B	28%	95%	0.62	5.60	0.76	7.39	84.8%	56.9%
	C	33%	85%	0.59	2.20	0.79	2.79	68.8%	55.9%
Smartphone in bright illumination ^b	A	66%	92%	0.79	8.25	0.37	22.30	89.2%	73%
	B	22%	98%	0.60	11.00	0.80	13.80	91.7%	55.7%
	C	26%	92%	0.59	3.25	0.80	4.04	76.5%	55.4%
Smartphone in dim illumination ^b	A	68%	92%	0.80	8.50	0.35	24.40	89.5%	74.2%
	B	20%	95%	0.58	4.00	0.84	4.75	80%	54.3%
	C	30%	91%	0.61	3.33	0.77	4.33	76.9%	56.5%

LR+, likelihood ratio positive; LR−, likelihood ratio negative; NPV, negative predictive value; O.R., odds ratio; PPV, positive predictive value; Sens, + Spec./2; Sens, sensitivity; Spec, specificity.

^aQuality parameters: (A) apical limit of the root canal filling material, considering with adequate quality apex distances from 0 to 2 mm; (B) adaptation of the filling material to root canal; (C) homogeneity of the radiographic contrast of the filling material along the entire root canal.

^bLighting-bright lighting (1000 to 1200 lux) and dim lighting (25 to 50 lux).

for evaluating a clinical condition approach that is feasible or practical for observers, considering habitual place and working conditions of observers, in spite of a procedure room using lighting with dim light (25 to 50 lux) is not habitual for most of general dentists. All observers of the current study reported that they worked clinically only in dental offices with bright lighting (1000 to 1200 lux) at all time. Furthermore, a standardization in measuring room lighting and display performance is very difficult in practice. Some items that are very similar, e.g. two monitors of same configuration, will not probably have a similar performance, mainly due to calibration parameters.^{6–8}

Advancements made in digital technologies have considerably increased the types of image display devices that can be used in daily dental clinical practice^{13–15} in different conditions of room lighting for radiographic diagnosis.^{6,9–12} However, absence of rigorous standardization of these variables did not mean complete absence of control; to be part of the sample only general dentists who has image display device that secured the a minimum quality were selected. Thus, the minimal specifications were standardized with regard to ensuring

adequate quality pattern. For smartphones, the configurations needed to have a minimum of display resolution 640 × 960 pixels, density of 330 PPI (pixels per inch) and physical size of the monitor (3.5-inch touch screen). For laptop computers, the configurations of LED screen needed to have a minimum of display resolution 1920 × 1080 pixels, density of 176.23 PPI (pixels per inch) and physical size of the monitor (12 inch). These are minimum configurations that were used in previous studies^{9–11,13–15} independently of the aim. Accordingly, as there was wide range of image display devices, any individual specifications were disregarded in statistical evaluation. The current velocity of launch of new products and technologies makes any strict comparison of equipment could quickly become outdated.^{13–15} Besides, the result of Kallio-Pulkkinen et al,¹² which concluded that for diagnosis of anatomical structures and pathological lesions, the experience of dentist is more important than medical display or viewing condition high quality to support the current methodology.

Other important methodological differences from previous studies^{11,16–18} were the blocks used as object to produce radiographic image to simulate trabecular bone.

Table 2 Mean values (standard deviation) of the κ coefficient of responses of each observer compared with gold standard in accordance to evaluated variables for quality parameters of the endodontic treatment

Quality parameters ^a	Laptop in bright illumination ^b	Laptop in dim illumination ^b	Smartphone in bright illumination ^b	Smartphone in dim illumination ^b
A	0.576 (0.095) aA	0.632 (0.133) aA	0.603 (0.048) aA	0.630 (0.050) aA
B	0.337 (0.125) bA	0.330 (0.148) bA	0.339 (0.204) bA	0.193 (0.061) bA
C	0.173 (0.095) bB	0.297 (0.193) bAB	0.360 (0.146) bA	0.287 (0.115) bAB

Same letters (lower case in columns and upper case in rows) represent groups that did not differ significantly (using ANOVA with Tukey test, $p > 0.05$).

^aQuality parameters: (A) apical limit of the root canal filling material, considering with adequate quality apex distances from 0 to 2 mm; (B) adaptation of the filling material to root canal; (C) homogeneity of the radiographic contrast of the filling material along the entire root canal.

^bLighting-bright lighting (1000 to 1200 lux) and dim lighting (25 to 50 lux).

This object made diagnostic of endodontic treatment even more difficult for observers that a simple image of teeth in a resin block.¹⁶ As *in vitro* studies the object that generate the radiographic image is very simple any extrapolations to context clinical becomes delicate. On the other hand, images *in vivo* are also not adequate when a control of variables as quality of endodontic treatment defining a gold standard is needed.⁶ In this case, only a cadaver would be the most adequate option, which is not an easy one to resolve,¹⁸ but not an option possible with the current study. The radiographic diagnosis in dentistry is very challenging in clinical practice due to different factors as anatomic variations of each of following case: geometry of exposure, overlaid images, optical illusions of Mach Bands, beside others.⁵ The current study used a more complex object than others,¹⁶ but which nevertheless are not sufficient to be compared to the complexity of human trabecular bone or of the intraoral radiographic anatomy.

In relation to the outcome of the observers' performance in different image assessment conditions, considering three parameters to assess the quality of the radiographic appearance of endodontic treatments, there were differences in performance caused by variations of room lighting and image display devices, with the worst performance caused during the use of laptop in bright lighting to assess homogeneity of the root canal filling material, and there were also differences between parameters when compared with each other. The diagnosis of the apical limit of the root canal filling material is relatively easy to carry out,² principally in cases that the apical space of the periodontal ligament is more visible.^{2,19} Conversely, diagnosis of the adaptation to root canal and homogeneity of the root canal filling material are the most difficult challenges due to two-dimensional representation of the image and radiopacity of the root canal filling material.²

²⁰ In practice, the contextual situation can cause influence in perception of the technical details of the root filling, considering as to be "good enough"²⁰ a

image that, out of the context, could be regarded as an adequate quality or with a need for retreatment. The experience of the observer can also be a factor of the discrepancy,^{1,3} tending more or less towards conservative choices. The gold standard used in statistical analysis of the current study was defined during confection of endodontic treatment, designing quality defect in one of the three parameters—apical limit, adaptation to root canal and homogeneity of the root canal filling material, in a conscious way. However, not all quality defect, which are visible even in two-dimensional images, would be classified as inadequate quality that results in retreatment. In current study, in a subjective classification, only 30% of sample had defects that characterize the endodontic treatment with inadequate quality.

Thus, the definition of the quality for an endodontic treatment in asymptomatic teeth with base only in radiographic appearances can be very controversial.³ Further studies should be done to increase scientific knowledge about how observer's performance to specific diagnosis is influenced by these variables.

Conclusion

Within the limitations of this laboratorial study, under the settings of clinical condition approach of the current study, room lighting and image display devices have very little influence in the radiographic appearances of the endodontic treatment. Thus, we suggest the use of smartphones as an acceptable image display device in daily clinical practice in routine bright lighting conditions.

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