EUROPEAN ENDODONTIC JOURNAL

ORIGINAL ARTICLE

Usage of Image-Enhancement Tools When Reading Radiographs Taken During Root-Canals Treatments' Procedures

Ahmad A MADARATI

ABSTRACT

Objective: This study aimed at exploring the usage of radiographic image-enhancement tools in Saudi dental practice when interpreting radiographs taken for root-canal-treatments' (RCTs) procedures and the influencing factors.

Methods: An online survey including questions related mainly to the usage of images enhancement tools and the reasons for no or low frequently usage was constructed. The survey was sent to 550 general dentists (GDs), randomly selected from the Saudi Dental Register, and all endodontists (185) in Saudi Arabia using the Google-Drive tool. A reminder email was sent two months later to encourage none-respondents to complete the survey. Data were analyzed using the Chi-square and Linear-by-Linear Association tests at p=0.05.

Results: While the highest percentage of GDs (48.3%) never used the colour-coded tool, the highest percentage of endodontists (46.1%) used it sometimes (P<0.001). The majority (84.2%) used the contrast tool either generally (67.8%) or sometimes (16.4%) (P<0.001); with more endodontists (77.55%) than GDs (63.1%) (P=0.011). As participants experience decreased and the weekly performed cases increased, the trend of using this tool increased (P<0.05). While most GDs (67.6%) either never (46%) or few-times (21.6%) used the highlight tool, most endodontists (56.9%) either used it generally (34.4%) or sometimes (22.5%) (P<0.001). The majority (82.3%) were using the magnification tool either generally (55.1%) or sometimes (27.2%). The highest percentage (36.1%) was generally using the negative-view tool (P=0.045); with more endodontists (63.7%) than GDs (20.8%) (P<0.001). While "I don't know how to use it" was the dominant reason reported by GDs for not using most of the tools, lack of time was the dominant reason reported by endodontists (P≤0.001).

Conclusion: The contrast and magnification were the most common used image-enhancement tools in Saudi dental practice. Endodontists reported greater preferences on using all images-enhancement tools than GDs. Unawareness and lack of time were the dominant reasons for not using the tools reported by GDs and endodontists, respectively. Further studies are required to determine the exact application for each tool and to investigate the impact of all image-enhancement tools on their diagnostic accuracy.

Keywords: Digital, endodontics, image-enhancement, questionnaire, radiography, survey, tools

HIGHLIGHTS

- The contrast, magnification (Zoom-in) and the ruler (Linear measurement) were the most common used tools to interprete radiographic images taken during RCTs.
- GDs were not using frequently other images-enhancement tools.
- The greater the number of weekly performed RCTs cases, the greater the trend among participants (GDs and endodontists) to use images-enhancement tools.
- GDs and endodontists reported overall different preferences on using specific tools.
- GDs and endodontists reported different reasons for not using specific images-enhancement tools.

INTRODUCTION

The field of medical and dental radiography has witnessed remarkable developments since it was discovered in 1895 up to this date, such as shorter acquisition and exposure time (1, 2) and the use of filters collimation as well as lead covers for better protection of patients and clinicians (3, 4). Also, the X-ray tubes and machines underwent significant improvement (2). In addition, dental x-ray films changed from the glass photographic plates, to hand-wrapped dental X-ray packets, to the prewrapped intraoral films, to high-speed films,

Please cite this article as: Madarati AA. Usage of Image-Enhancement' Tools When Reading Radiographs Taken During Root-Canals Treatments' Procedures. Eur Endod J 2020; 2: 94-104

From the Department of Restorative Dental Sciences (A.A.M. ✉ ahmad.madarati@hotmail.co.uk) Taibah University, Madina, Saudi Arabia

Received 03 November 2019, Accepted 26 December 2019

Published online: 13 February 2020
DOI 10.14744/eej.2019.62634

and eventually to digital sensors; which were introduced in 1980s (2, 5, 6). Digital radiography offers many advantages over conventional radiography, such as: low-radiation-dose, elimination of hazardous chemicals associated with processing of conventional films and better archiving and documentations, hence facilitating usage of all-electronic patients' records (7, 8). Moreover, many of the disadvantages of earlier digital radiography equipment were solved, including better image resolution, advanced computer technology and the decreased sizes of the bulky images' receptors (1). These advantages may explain the increased popularity of digital radiology in dental practice in the last two decades (9-13).

Nevertheless, one of the main advantages of digital radiology is images enhancement by software (14). The primary aim of radiographic images enhancement is to adjust them to fit to a specific task, hence more accurate interpretation may be obtained by a specific observer. Like most dental fields, radiographic imaging is an essential tool in endodontics. They are mainly used for: 1) diagnosis of pulpal and periapical diseases and estimation of case difficulty by identification root-canals systems' morphologies; 2) therapeutic procedures (like determination of radiographic root canals lengths); and 3) evaluation the outcome of endodontic treatment (15, 16). Apparently, the quality of radiographic images is fundamental in endodontics, as it allows more accurate interpretation of the radiographic images. Consequently, many studies investigated the impact of images enhancement on observers' ability to more accurately interpret radiographic images in different endodontic scenarios (17-28).

However, to this date, there is no report on the extent to which image enhancement tools are being used. Therefore, the aim of this study was to investigate usage of the different image enhancement tools by general dentists (GDs) and endodontists in Saudi dental practice when interpreting radiographs taken for root canal treatments' (RCTs) procedures. In addition, it aimed to explore factors affecting their preferences on using each tool.

MATERIALS AND METHODS

Ethical Aspects: The ethical approval was obtained from the Research Ethics Committee (REC) at Taibah Univesity College of Dentistry (No: TUCD- REC.15.12.2016). The study was executed, between June and December 2018. It was accompolished according to the World Medical Association's Helsinki Declaration, because, it was an online questionnaire, in which participants' identities were not requested.

Pilot Study, Survey's Construction and Execution: A pilot survey was distributed electronically to a group of staff members at Taibah University College of Dentistry and 50 dentists, working in private clinics, to ensure that the questions were relevant and easily answered. The final online survey constituted questions related to the following four main aspects:

a. Participants' demographic information: category of participants (GDs, endodontists, others), their experience, types of practice (government and private), number of weekly performed RCTs.

b. Types of radiographic systems used during RCTs; whether participants were using film-based radiography (FBR), semi-digital radiography (SDR) or fully digital radiography (FDR) during RCTs.

c. Using of images-enhancement tools: whether participants were using/not using some images-enhancement tools and the reasons for not using or the low frequently usage.

The questionnaire was accompanied with an original radiographic image (Fig. 1a) and its copies after enhancement to illustrate the function of each specific enhancement tool (Fig. 1b, c, d, and e), (Fig. 2a and b) and (Fig. 3a-c). The sample size of the study was determined taking into consideration the number of GDs in Saudi Arabia and the minimum accepted response rate of 50%. A sample size of 375 GDs would have given a 99.9% confidence level. However, to enable more reliable statistical comparison among subgroups, by reducing the number of expected cells that count less than five in crosstabs tables, it was determined to send the ques-

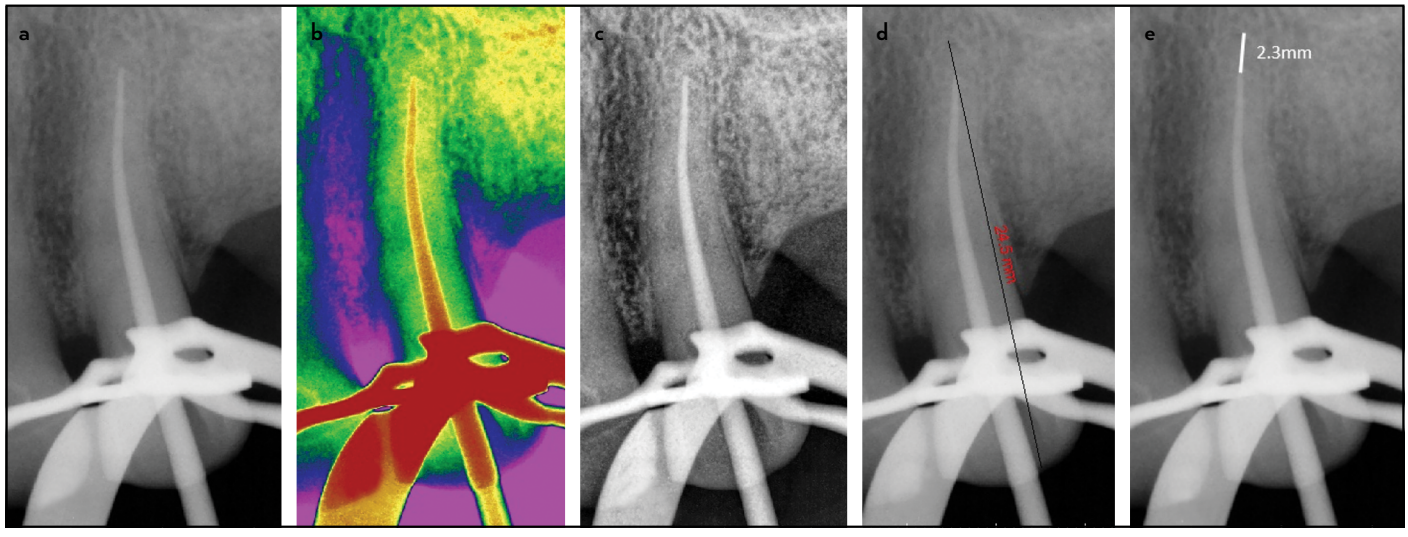

Figure 1. (a) Original digital radiographic image, (b) and (c) image A after application of the colour-coded and contrast image-enhancement tools, respectively. (d and e) are after application of the ruler (linear measurement) tool

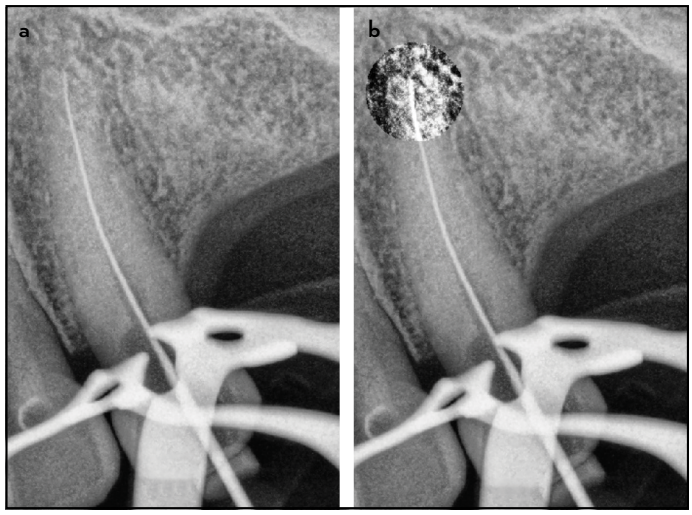

Figure 2. (a) Original radiographic digital image and (b) the image A after application of the highlight tool

tionnaire to 550 GDs. These were selected, from the Saudi Dental Register, randomly using the systematic sampling method. The final survey was emailed to the 550 selected GDs and all endodontists (185) working in Saudi Arabia using the Google-Drive tool (https://www.google.com). The email listed the studies aims and assured that participants' responses would remain anonymous. A reminder email was sent two months after the first sent-out to encourage none-respondents to complete the survey.

Statistical analysis

Following converting the responses excel sheet into SPSS data sheet using the SPSS 20 for Windows software (SPSS Inc, Chicago, USA), data were analyzed using the Chi-square and Linear-by-Linear Association tests at P=0.05.

RESULTS

Response rates and participants' gender & classification

Four hundred and one out of the 735 recipients responded to the survey. Respondents were: 99 endodontists (24.7%), 276 GDs (68.8%), 6 students or residents in endodontic postgraduate programmes (1.5%), and 20 other specialists (5%). The overall final response rate was 54.6% (401/735) (non-endodontists response: 302/550=54.9% and endodontists response rate: 99/185=53.5%). Overall, significantly most participants (64.9%) were using FDR for RCTs followed by 24.2% using FBR, and 11.2% who were using SDR (P<0.001) (Table 1). There was no significant difference between early respondents who were using FDR (63.1%) and late respondents (66.9%) (P=0.493).

Usage of the colour-coded tool

While the highest percentages of participants (44.9 and 24.8%) never and sometimes used the colour-coded tool (Fig. 1a and 1b), respectively, the lowest percentage (8.8%) did so generally (P<0.001) (Table 2). Moreover, the percentage who never or few-times used it (66.3%) was significantly greater than those who used it sometimes or generally (33.7%) (P<0.001). While the highest percentage of GDs (48.3%) never used the colour-coded tool, the highest percentage of endodontists (46.1%) used it sometimes (P<0.001).

The trend of using this tool significantly increased as the number of weekly performed RCTs increased (P=0.014); with the highest percentage of those who sometimes or generally used it, was within those who performed more than 12 RCTs per week (50.7%). There were no significant correlations of this tool usage neither with participants' experience after graduation nor with the place they were working for (private clinics, private academic, governmental academic or governmental clinics) (P≥0.05).

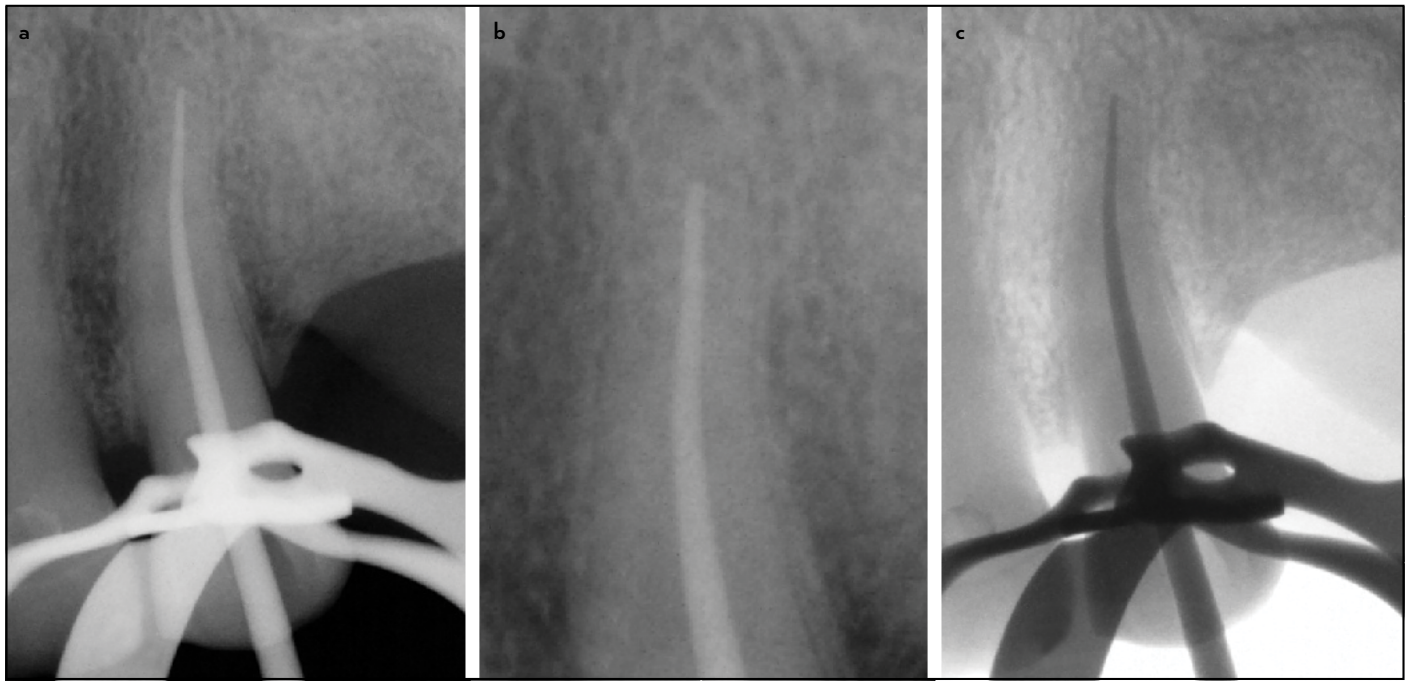

Figure 3. (a) Original radiographic digital image, (b) and (c) the image A after application of the magnification (zoom-in) and the negative image-enhancement tools, respectively

TABLE 1. Types of radiographic systems used according to participants' gender and classifications

Early & late responses	Type of radiographic system used: No (%)			
	FBR	SDR	FDR	Total
Early responses (69.8)	70 (25.5)	31 (11.3)	173 (63.1)	274 (100)
Late response (30.2)	26 (22)	13 (11)	79 (66.9)	118 (100)
Total (100)	96 (24.5)	44 (11.2)	252 (64.3)	392 (100)
Respondents' classification	**Type of radiographic system used: No (%)**			
	FBR	SDR	FDR	Total
GDs	90 (33.3)	39 (14.4)	141 (52.2)	270 (100)
Endodontists	0 (0)	0 (0)	98 (100)	98 (100)
Endo postgrads	2 (33.3)	0 (0)	4 (66.7)	6 (100)
Others	4 (22.2)	5 (27.8)	9 (50)	18 (100)
Total	96 (24.5)	44 (11.2)	252 (64.3)	392 (100)

FBR: Film-based radiography, SDR: Semi-digital radiography, GDs: General dentists

TABLE 2. Patterns of using the colour-coded tool and associated factors

Respondents' classification	Patterns of colour-coded tool's usage: No (%)				
	Never	Few-times	Sometimes	Generally	Total
GDs	86 (48.3)	52 (29.2)	24 (13.5)	16 (9)	178 (100)
	138 (77.5)		40 (22.5)		
Endodontists	39 (38.2)	8 (7.8)	47 (46.1)	8 (7.8)	102 (100)
	47 (46.1)		55 (53.9)		
Others	7 (50)	3 (21.4)	2 (14.3)	2 (14.3)	14 (100)
Total	132 (44.9)	63 (21.4)	73 (24.8)	26 (8.8)	294 (100)
	195 (66.3)		99 (33.7)		
Weekly performed RCTs	**Patterns of colour-coded tool's usage: No (%)**				
	Never or few-times		Sometimes or generally		Total
1-3 cases	37 (71.2)		15 (28.6)		52 (100)
4-6 cases	50 (71.4)		20 (28.6)		70 (100)
7-12 cases	73 (72.3)		28 (27.7)		101 (100)
More than 12 RCTs	35 (49.3)		36 (50.7)		71 (100)
Total	195 (66.3)		99 (33.7)		294 (100)
Respondents' experience	**Patterns of colour-coded tool's usage: No (%)**				
	Never or few-times		Sometimes or generally		Total
Up to 7 years	66 (72.5)		25 (27.5)		91 (100)
More than 7 years	127 (63.2)		74 (36.8)		201 (100)
Total	195 (66.3)		99 (33.7)		294 (100)
Sector (place) of work	**Patterns of colour-coded tool's usage: No (%)**				
	Never or few-times		Sometimes or generally		Total
Private practice	157 (68.9)		71 (31.1)		228 (100)
Private academic	6 (66.7)		3 (33.3)		9 (100)
Governmental academic	14 (48.3)		15 (51.7)		29 (100)
Governmental practice	14 (60.9)		9 (39.1)		23 (100)
Total	195 (66.3)		99 (33.7)		294 (100)

RCTs: Root-canal-treatments, GDs: General dentists

Usage of the contrast tool

Significantly, the vast majority (84.2%) were using the contrast tool (Fig. 1a and 1c) either generally (67.8%) or sometimes (16.4%) (P<0.001) (Table 3). The percentage of endodontists who generally used this tool (77.5%) was greater than that of GDs (63.1%) (P=0.011). As the participants' experience after graduation decreased and the number of weekly performed cases increased, the trend of using this tool significantly increased (P=0.024 and 0.026, respectively); with the highest percentage of users was within those who had up to 3 years'

TABLE 3. Patterns of using the contrast tool and associated factors

Respondents' classification	Patterns of contrast tool's usage: No (%)				
	Never	Few-times	Sometimes	Generally	Total
GDs	15 (8.5)	16 (9.1)	34 (19.3)	111 (63.1)	176 (100)
Endodontists	0 (0)	11 (10.9)	12 (11.8)	79 (77.5)	102 (100)
Others	3 (21.4)	1 (7.1)	2 (14.3)	8 (57.1)	14 (100)
Total	18 (6.2)	28 (9.6)	48 (16.4)	198 (67.8)	292 (100)
	46 (15.8)		246 (84.2)		
Respondents' experience	Patterns of contrast tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Up to 3 years	2 (5.3)		36 (94.7)		38 100)
3.1-7 years	6 (11.3)		47 (88.7)		53 (100)
7.1-15 years	14 (14.3)		84 (85.7)		98 (100)
More than 15 years	24 (23.8)		77 (76.2)		101 (100)
Total	46 (15.8)		246 (84.2)		292 (100)
Weekly performed RCTs	Patterns of contrast tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
1-3 cases	10 (19.2)		42 (80.8)		52 (100)
4-6 cases	16 (22.9)		54 (77.1)		70 (100)
7-12 cases	15 (14.9)		86 (85.1)		101 (100)
More than 12 RCTs	5 (7.2)		64 (92.8)		69 (100)
Total	46 (15.8)		246 (84.2)		292 (100)
Sector (place) of work	Patterns of contrast tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Private practice	35 (15.5)		191 (84.5)		226 (100)
Private academic	4 (44.4)		5 (55.6)		9 (100)
Governmental academic	1 (4)		24 (96)		25 (100)
Governmental practice	6 (31.6)		13 (68.4)		19 (100)
Total	46 (15.8)		246 (84.2)		292 (100)

RCTs: Root-canal-treatments, GDs: General dentists

experience (94.7%) and performed more than 12 weekly RCTs (92.8%). There was no correlation between using this tool and the work sector (P=0.358).

Usage of the ruler (linear measurement) tool

Significantly, most participants (65%) were using the ruler (Linear Measurement) tool (Fig. 1a, 1d and 1e) either generally (41.8%) or sometimes (23.1%) (P<0.001); with no significant differences between GDs and endodontists (P=0.809) (Table 4). Although there was a trend towards using this tool among those who had up to 7 years' experience after graduation, this trend was not statistically significant (P=0.63). There were no significant correlations of using this tool neither with weekly performed RCTs nor with the place of work (P≥0.05).

Usage of the highlight tool

Most participants (58.9%) either never used the highlight tool (Fig. 2a and 2b) (34.9%) or used it few-times (24%) (P=0.001). While the highest percentage of GDs (46%) never used this tool, the highest percentage of endodontists (34.3%) were using it generally (P<0.001) (Table 5).

The trend of using this tool significantly increased as the participants' experience after graduation decreased (P=0.016); with the highest percentage of those who were using it sometimes or generally was within those who had only up to 3 years' experience (60.5%). There were no significant correlations between using the highlight tool neither with weekly performed RCTs nor with the place of work (P≥0.05).

Usage of the magnification (Zoom-in) tool

The majority of participants (82.3%) were using the magnification (zoom-in) tool (Fig. 3a and 3b) either generally (55.1%) or sometimes (27.2%) (P<0.001); with the vast majority of endodontists (92.2%) were doing so which was significantly greater than that of GDs (77%) (P<0.001) (Table 5). There were trends towards using the magnification tool more by academics, as the number of weekly performed RCTs increased and the participants' experience after graduation decreased. However, these trends were not statistically significant (P>0.05).

Usage of the negative-view tool

The highest percentage (36.1%) was generally using the negative-view tool (Fig. 3a and 3c) (P=0.045); with more endodontists (63.7%) than GDs (20.8%) (P<0.001) (Table 6). Overall, most of those who were working in the governmental sectors (Academic or Practices) (72.4 or 73.9%, respectively) used the negative-view tool generally or sometimes, which were significantly greater than those who adopted the same usages

TABLE 4. Patterns of using the ruler (linear measurement) tool and associated factors

Respondents' classification	Patterns of ruler (linear measurement) tool's usage: No (%)				
	Never	Few-times	Sometimes	Generally	Total
GDs	39 (21.9)	27 (15.2)	33 (18.5)	79 (44.4)	178 (100)
	66 (37.1)		112 (62.9)		
Endodontists	14 (13.7)	17 (16.7)	32 (31.4)	39 (38.2)	102 (100)
	31 (30.4)		71 (69.6)		
Others	3 (21.4)	3 (21.4)	3 (21.4)	5 (35.7)	14 (100)
Total	56 (19)	47 (16)	68 (23.1)	123 (41.8)	294 (100)
	103 (35)		191 (65)		
Respondents' experience	Patterns of ruler (linear measurement) tool's usage: No (%)				
	Never or few-times	Sometimes or generally			Total
Up to 3 years	9 (23.7)	29 (76.3)			38 (100)
3.1-7 years	15 (28.3)	38 (71.7)			53 (100)
7.1-15 years	32 (32.3)	67 (67.7)			99(100)
More than 15 years	45 (44.1)	57 (55.9)			102(100)
Total	103 (35)	191 (65)			294 (100)
Weekly performed RCTs	Patterns of ruler (linear measurement) tool's usage: No (%)				
	Never or few-times	Sometimes or generally			Total
1-3 cases	18 (34.6)	34 (65.4)			52 (100)
4-6 cases	23 (32.9)	47 (67.1)			70 (100)
7-12 cases	35 (34.7)	66 (65.3)			101 (100)
More than 12 RCTs	27 (38)	44 (62)			71 (100)
Total	103 (35)	191 (65)			294 (100)
Sector (place) of work	Patterns of ruler (linear measurement) tool's usage: No (%)				
	Never or few-times	Sometimes or generally			Total
Private practice	83 (36.4)	145 (63.6)			228 (100)
Private academic	7 (77.8)	2 (22.2)			9 (100)
Governmental academic	7 (28)	18 (72)			25 (100)
Governmental practice	4 (21.1)	15 (78.9)			19 (100)
Total	103 (35)	191 (65)			294 (100)

RCTs: Root-canal-treatments, GDs: General dentists

patterns (frequencies) and were working in the private sectors (academic or practices) (55.6 or 41.2%, respectively) (P<0.001). As the number of weekly RCTs cases increased, the trend of using this tool significantly increased (P<0.001).

Reasons for not using images-enahncement's tools

Overall, there were significant differences between GDs and endodontists in reporting reasons for not using the images-enhancement tools (P≤0.001) (Table 7). "I don't know how to use it" was the dominant reason reported by GDs for not using the colour-coded, highlight, ruler (Linear measurement) and contrast tools (45.8, 51.6, 50, and 50%, respectively). By contrast, lack of time was the dominant reason reported by endodontists for not using all tools except the colour-coded tool as the highest percentage of them (38.3%) reported "I don't know if it is available" as the main reason for not using this tool.

DISCUSSION

This study investigated the usage of the different radiographic image-enhancement tools by GDs and endodontists in Saudi dental practice when interpreting radiographs taken for RCTs procedures. Survey studies can be an important research tool as long as they are well designed and accomplished. The response obtained in this study (54.6%) can be one limitation as it was not as high as desired in survey studies (29). However, it can still be accepted and reliable for many reasons. Forty three percent response rate was reported to be reliable and prevents non-response bias (30). In addition results obtained from surveys with low response rates but with systematic samplings are better than those obtained from studies with high response rates, but without randomized sampling methods (31). In addition, formulating well-structured questionnaires that prevent multi-interpretation, hence eliminate or reduce response bias, is another important aspect (31). A pilot survey, in the current study, was distributed electronically to a group of academics and 50 dentists to ensure that the questions were easily understood. Nevertheless, the crucial measures that validates questionnaire studies' results is to compare the response between the early and late respondents (29). No significant differences were found between the percentage of early respondents who were using FDR (63.1%) and that recorded by late respondents.

The highest percentage of participants (64.9%) were using the FDR for RCTs procedures, which was quite better than those

TABLE 5. Patterns of using the highlight tool and associated factors

Respondents' classification	Patterns of highlight tool's usage: No (%)				
	Never	Few-times	Sometimes	Generally	Total
GDs	81 (46)	38 (21.6)	35 (19.9)	22 (12.5)	176 (100)
	119 (67.6)		57 (32.4)		
Endodontists	13 (12.7)	31 (30.4)	23 (22.5)	35 (34.3)	102 (100)
	44 (43.1)		58 (56.9)		
Others	8 (57.1)	1 (7.1)	5 (35.7)	0 (0)	14 (100)
Total	102 (34.9)	70 (24)	63 (21.6)	57 (19.5)	292 (100)
	172 (58.9)		120 (41.1)		
Respondents' experience	Patterns of highlight tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Up to 3 years	15 (39.5)		23 (60.5)		38 (100)
3.1-7 years	24 (45.3)		29 (54.7)		53 (100)
7.1-15 years	68 (70.1)		29 (29.9)		97 (100)
More than 15 years	63 (61.8)		39 (38.2)		102 (100)
Total	172 (58.9)		120 (41.1)		292 (100)
Weekly performed RCTs	Patterns of highlight tool's usage: No (%)				
	Never or few-times		Sometimes or Generally		Total
1-3 cases	22 (42.3)		30 (57.7)		52 (100)
4-6 cases	41 (58.6)		29 (41.4)		70 (100)
7-12 cases	69 (69.7)		30 (30.3)		99 (100)
More than 12 RCTs	40 (56.3)		31 (43.7)		71 (100)
Total	172 (58.9)		120 (41.1)		292 (100)
Sector (place) of work	Patterns of highlight tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Private practice	143 (63.3)		83 (36.7)		226 (100)
Private academic	6 (66.7)		3 (33.3)		9 (100)
Governmental academic	7 (28)		18 (72)		25 (100)
Governmental practice	14 (73.7)		5 (26.3)		19 (100)
Total	172 (58.9)		120 (41.1)		292 (100)

RCTs: Root-canal-treatments, GDs: General dentists

reported in previous studies (10-13). Authors discussed and explained the reasons for these findings thoroughly previously (manuscript has been accepted). The increased awareness of dental practitioners nowadays as well as implementation of FDR in undergraduate curricula are most likely reasons for such findings. This paper, however, will discuss aspects related to the implementation of radiographic-image enhancement tools and the influencing factors.

The colour-coded, as one of the images-enhancement tools (Fig. 1a and 1b), relies on what is usually believed that human visual system is more sensitive to coloured differences than those in grey or in black-and-white scales (32). This tool has been investigated quit well in the periodontics and operative dentistry fields; with conflicting results (32-34). Like most of image-enhancement tools, the colour-coded one can be used for the detection of recently developed or small periapical lesions, extensions of large lesions, measurement of root-canals working length, and detection of root vertical fractures. However, there is lack of research work investigating this tool in endodontics. Scarfe et al found that this tool has limited value in the estimation of periapical lesions dimensions (35). Similarly, Pati et al found that it did not improve the accuracy of digital radiography (25). These findings may be reflected on the low usage of this tool among participants in the current study, as most of them (66.3%) either never used it (44.9%) or used it few-times (21.4%). However, radiographic imaging is used for many endodontic tasks, not only for detecting and measuring the size of periapical lesions. Hence the colour-coded tool may be useful for other tasks, which in turn explains why endodontists showed better adoption of this tool. Also, endodontists are usually more careful to provide high quality RCTs. This is especially true as endodontists usually perform more RCTs than GDs do. Interestingly, the current study showed that the trend of using the colour-coded tool significantly increased as the number of weekly performed RCTs increased; with the highest percentage of those who sometimes or generally used it, was within those who performed more than 12 RCTs (50.7%). This was the dominant factor related to the decision on using this tool, because there were no correlations with other factors, such as place of work and participants experience after graduation. However, none-users GDs and endodontists reported different reasons for not using this tool. While GDs did not

TABLE 6. Patterns of using the magnification (zoom-in) tools and associated factors

Respondents' classification	Patterns of magnification (zoom-in) tool's usage: No (%)				
	Never	Few-times	Sometimes	Generally	Total
GDs	15 (8.4)	26 (14.6)	40 (22.5)	97 (54.5)	178 (100)
	41 (23)		137 (77)		
Endodontists	2 (2)	6 (5.9)	35 (34.3)	59 (58.2)	102 (100)
	8 (7.8)		94 (92.2)		
Others	0 (0)	3 (21.4)	5 (35.7)	6 (42.9)	14 (100)
Total	17 (5.8)	35 (11.9)	80 (27.2)	162 (55.1)	294 (100)
	52 (17.7)		242 (82.3)		
Weekly performed RCTs	Patterns of magnification (zoom-in) tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
1-3 cases	8 (15.4)		44 (65.4)		52 (100)
4-6 cases	13 (18.6)		57 (81.4)		70 (100)
7-12 cases	25 (24.8)		76 (75.2)		101 (100)
More than 12 RCTs	6 (8.5)		65 (691.5)		71 (100)
Total	52 (17.7)		242 (82.3)		294 (100)
Sector (place) of work	Patterns of magnification (zoom-in) tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Private practice	46 (20.2)		182 (79.8)		228 (100)
Private academic	0 (0)		9 (100)		9 (100)
Governmental academic	0 (0)		25 (100)		25 (100)
Governmental practice	3 (15.8)		16 (84.2)		19 (100)
Total	52 (17.7)		242 (82.3)		294 (100)
Respondents' experience	Patterns of magnification (zoom-in) tool's usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Up to 3 years	7 (18.4)		31 (81.6)		38 (100)
3.1-7 years	4 (7.5)		49 (92.5)		53 (100)
7.1-15 years	11 (11.1)		88 (88.9)		99 (100)
More than 15 years	28 (27.5)		74 (72.5)		102 (100)
Total	52 (17.7)		242 (82.3)		294 (100)

RCTs: Root-canal-treatments, GDs: General dentists

know how to use it, endodontists did not know if this tool was available. These reasons may reflect their intention to better implement this tool in their daily endodontic work. Nevertheless, lack of research studies on this tool, as mentioned earlier, may be reflected on the low usage by dental practitioners.

On the other hand, the contrast tool (Fig. 1a and 1c), sometimes is named as sharpener, revealer, or filter (according to the different software), has received considerable research attention (18, 20-21, 24, 26-28, 36-38). This may explain the good popularity of this tool as revealed in the current study. The majority (84.2%) were using the contrast tool either generally (67.8%) or sometimes (16.4%). This is especially true for endodontists who used this tool more than GDs; the percentage of endodontists who generally used this tool (76.5%) was significantly greater than that of GDs (63.1%). Usually endodontists are more exposed to the literature during their postgraduate training programme. Human beings' eyes are usually more sensitive to slight brightness changes located within dark regions of an image (39). This could be another reason for using the contrast tool by the majority of the current study participants, since RCTs procedures are dependent on exploring and negotiating all root-canals and accurate measurements of their lengths in order to preserve the periapical tissues from potential injuries. This study revealed the demand for such a tool when the clinicians' time in practice is more devoted towards performing RCTs. The greater the number of weekly performed RCTs, the greater the usage of this tool, with the highest percentage of users was within those who performed more than 12 weekly RCTs (92.8%). The study also showed that the trend of using this tool increased significantly within less experienced practitioners. One possible reason is that the concept of radiographic image-enhancement was introduced in the last two decades, in the first instance, and this tool received research attention only in the last 10 years. Nevertheless, studies have shown conflicting results regarding the impact of this tool on the diagnostic accuracy of digital images in endodontics. Barayan et al, showed no significant impact on the diagnosis of vertical root fractures (28). Also, Ferreira et al showed that using the filter (termed contrast in this study) tool in enhancing CBCT images did not influence the diagnosis of vertical root fractures in teeth with metal posts (27). Farahadi et al concluded that the contrast tool decreases the accuracy

TABLE 7. Patterns of using the negative-view tool and correlation with influencing factors

Respondents' classification	Patterns of negative-view tool's usage: No (%)				
	Never	Few-times	Sometimes	Generally	Total
GDs	47 (26.4)	65 (36.5)	29 (16.3)	37 (20.8)	178 (100)
Endodontists	29 (28.4)	8 (7.8)	0 (0)	65 (63.7)	102 (100)
Others	5 (35.7)	2 (25.5)	3 (21.4)	4 (28.6)	14 (100)
Total	81 (27.6)	75 (25.5)	32 (10.9)	106 (36.1)	294 (100)
Weekly performed RCTs	Patterns of negative view's tool usage: No (%)				
	Never or few-times		Sometimes or generally		Total
1-3 cases	29 (55.8)		23 (44.2)		52 (100)
4-6 cases	39 (55.7)		31 (44.3)		70 (100)
7-12 cases	65 (64.4)		36 (35.6)		101 (100)
More than 12 RCTs	23 (32.4)		48 (67.7)		71 (100)
Total	156 (53.1)		138 (46.9)		294 (100)
Sector (place) of work	Patterns of negative-view's tool usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Private practice	134 (58.8)		94 (41.2)		228 (100)
Private academic	4 (44.4)		5 (55.6)		9 (100)
Governmental academic	8 (27.6)		21 (72.4)		29 (100)
Governmental practice	6 (26.1)		17 (73.9)		23 (100)
Total	156 (53.1)		138 (46.9)		294 (100)
Respondents' experience	Patterns of negative-view's tool usage: No (%)				
	Never or few-times		Sometimes or generally		Total
Up to 3 years	28 (73.7)		10 (26.3)		38 (100)
3.1-7 years	24 (45.3)		29 (54.7)		53 (100)
7.1-15 years	41 (41.4)		58 (58.6)		99 (100)
More than 15 years	61 (59.8)		41 (40.2)		102 (100)
Total	156 (53.1)		138 (46.9)		294 (100)

RCTs: Root-canal-treatments, GDs: General dentists

TABLE 8. Reasons for not using images-enhancement's tools

DR tools	Respondents' classification	Reasons for not using images enhancement's tool: No (%)				Total
		Don't know how to use it	Not needed in Endo	I don't know if it's available	Lack of time	
Colour-coded	GDs	66 (45.8)	23 (16)	30 (20.8)	25 (17.4)	144 (100)
	Endodontists	10 (21.3)	5 (10.6)	18 (38.3)	14 (29.8)	47 (100)
Highlight	GDs	66 (51.6)	14 (10.9)	36 (28.1)	12 (9.4)	128 (100)
	Endodontists	0 (0)	7 (18.9)	12 (32.4)	18 (48.6)	37 (100)
Ruler	GDs	36 (50)	2 (2,8)	17 (23.6)	17 (23.6)	72 (100)
	Endodontists	0 (0)	2 (6.5)	6 (19.4)	23 (74.2)	31 (100)
Contrast	GDs	18 (50)	0 (0)	7 (19.4)	11 (30.6)	36 (100)
	Endodontists	0 (0)	0 (0)	0 (0)	6 (100)	6 (100)
Magnification	GDs	11 (26.2)	6 (14.3)	4 (9.5)	21 (50)	42 (100)
	Endodontists	0 (0)	2 (25)	0(0)	6 (75)	8 (100)
Negative View	GDs	25 (21)	27 (22.7)	21 (17.6)	46 (38.7)	119 (100)
	Endodontists	6 (16.2)	6 (16.2)	6 (16.2)	19 (51.4)	37 (100)

GDs: General dentists

of the small endodontic files length' measurement and did not recommend using it for such a step (26). On the other hand, two other studies showed that the contrast tool significantly improved the image accuracy (21, 36). One possible reason for such conflicting findings is different research methodologies, including using different software.

The magnification (zoom-in) (Fig. 3a and 3b) was the second most common tool used by the current study's participants as 82.3% were using it either generally (55.1%) or sometimes (27.2%). This may reflect the valuable advantage of using such a tool when interpreting radiographs taken during RCTs procedures. This is especially true as the vast majority of endo-

dontists (92.1%) were using it, which was significantly greater than GDs (77%). As endodontists usually perform more RCTs per week than GDs do, unsurprisingly as the number of weekly performed RCTs increased, the trend of using this tool increased. Moreover, there was a trend towards using the magnification tool more often by academics. This may be reflected on the increased preference of using it by young dentists (up to 7 years' experience). Nevertheless, these trends were not statistically significant. Endodontists usually use such a tool to identify minute details, such as extension of the file used for measuring the working length, portal of canals' exit, especially lateral ones, proximity of caries to pulp chambers, or to follow the path of narrow canals (personal communication). Further research work to confirm such preferred applications of this tool and its impact on correct diagnostic usage is needed.

The ruler (linear measurement) (Fig. 1a, 1d and 1e) was the third most common tool used by participants; as most of participants (almost 70%) using it either generally or sometimes (41.8 and 23.1%, respectively). Such a tool is usually used for working length measurement's modalities or estimating the dimensions of periapical lesions. Measuring the size of periapical lesion may not have impact on the RCTs procedures. By contrast, a correct measurement of the working length is a crucial step towards correct and sufficient cleaning and shaping then tight-seal obturation of the root-canal systems (40). The apical terminus of RCTs procedures can influence the treatment outcomes (41). Unfortunately, there has been no study on the impact of this tool on accuracy of working length measurements or to what extend using such a tool can help in achieving or facilitating this crucial step. Nevertheless, this study showed no significant difference between GDs and endodontists in using the ruler tool. A further research work to explore reasons for such preference on using this tool, especially for specific procedures is important. There was a trend, but not significant, towards using the ruler tool among young practitioners. Such a group of clinicians may have not gained enough experience in reading radiographs and estimating dimensions of anatomical structures.

The highlight tool enables the clinicians to read specific area of the radiograph (Fig. 2a and 2b). The current study revealed quit low usage of this tool, especially by GDs, as most of them (59%) either never used it or used it few-times (24%). However, endodontists showed significant better preferences, as most of them (56.9%) used it either generally (34.3%) or sometimes (22.5%). When asked for the reasons for not using it, most of none-users GDs reported that they don't know how to use it. Another possible reason is that they may obtain the information they need by using other tools, such as the contrast, magnification, or ruler. On the other hand, most endodontists were using it and the higher percentage of none-users reported lack of time as the main reason for not using it. It can be speculated that endodontists benefit of such tool for better accuracy in interpreting radiographs. Whether this tool is used solely or as supplementary method to confirm the findings obtained by other tools, is an interesting aspect for further investigation. Nevertheless, the results showed increased usage of this tool among those who had less experience years after graduation. This again may be due to the fact that image-enhancement tools have been improved in the last decade.

Similarly, the results showed conflicting preferences between endodontists and GDs in using the negative-view tool (Fig. 3a and 3c). While the highest percentage of GDs (36.5%) were using it few-times, most of endodontists (63.7%) were generally using it. Current observations of cases shown on social media reveals an increased trend towards using this tool, especially the cone fit and root-canal fillings' radiographs. The negative-view, also known as inverted or reverse-contrast, shows the radiopaque objects (white) as complete radiolucent (black) ones. A previous study showed no significant improvement in observers' diagnostic ability (42). Similarly, Tofangchiha et al found that the reverse-contrast and colour-coded tools did not significantly enhance the accuracy of original images in diagnosis of vertical root fractures (43). They concluded that such images-enhancement tools should be regarded as an adjunct to other diagnostic modalities, not as a main diagnostic aid. However, the limited number of studies investigating the impact of the negative-view tool on the diagnostic accuracy suggests the need for further research. In addition, more investigations are needed to identify reasons that trigger most endodontists to use such a tool. This is especially true as results related to the correlation of using this tool with other factors, in the current study, were perplexing. For example, unlike the private sector, results showed the increased trend of using this tool in governmental sectors (Academic or Practices). One may explain this due to the enough time available for clinicians in these sectors (governmental) to use this tool. However, the results also showed that, as the number of weekly RCTs cases increased, the trend of using this tool significantly increased.

Overall, there were significant differences between GDs and endodontists in reporting reasons for not using the images-enhancement tools provided in the DR software. While I don't know how to use it was the dominant reason reported by GDs, lack of time was the dominant one reported by endodontists. It can be speculated that GDs had the intention to use them. More importantly, these results reflect the importance of appropriate educational measures on two main levels. First, by better implementation of DR in undergraduate training courses, hence students are more exposed to different modalities of radiographic images-enhancement. Second, by involving GDs to the postgraduate continuous education activities such as lectures and hands-on courses. Previous studies indicated the importance of better educational measures in increasing employment of dental-dam and endodontic rotary systems in daily endodontic practice (44-46). A recent study (In press) showed that educational factors were the second most important measure that contribute to better adoption of DR in Saudi dental practice.

CONCLUSION

Within the limitations of the current study, it can be concluded that the contrast, magnification (Zoom-in) and ruler (linear measurement) were the most common image-enhancement tools used in Saudi dental practice. Endodontists reported greater preferences on using all images-enhancement tools than GDs. Unawareness and lack of time were the dominant reasons, reported by GDs and endodontists, respevtively, for not using image-enhancement tools. Further studies are required to determine the exact application(s) of each tool and

to investigate the impact of image-enhancement tools on diagnostic accuracy of radiographic images.

Disclosures

Conflict of interest: No conflict of interest.

Ethics Committee Approval: The ethical approval was obtained from the Research Ethics Committee (REC) at Taibah University College of Dentistry (No: TUCD- REC.15.12.2016).

Peer-review: Externally peer-reviewed.

Financial Disclosure: None declared.

REFERENCES

1. Petrikowski CG. Introducing digital radiography in the dental office: an overview. J Can Dent Assoc 2005; 71(9):651.
2. Kfir A, Basrani B. General Principles of Radiology in Endodontics. In: Bettina Basrani, editors. Endodontic Radiology. John Wiley & Sons; 2012. p. 3–54. [CrossRef]
3. Rollins W. X-light kills. Boston Medical and Surgical Journal 1901; 144:173.
4. Kathren RL. William H. Rollins (1852-1929): x-ray protection pioneer. J Hist Med Allied Sci 1964; 19:287–94. [CrossRef]
5. Rollins W. Some conclusions from experiments on guinea pigs which are of importance in the treatment of disease by x-light. Boston Medical and Surgical Journal 1902; 146:430. [CrossRef]
6. Sonoda M, Takano M, Miyahara J, Kato H. Computed radiography utilizing scanning laser stimulated luminescence. Radiology 1983; 148(3):833–8.
7. Naoum HJ, Chandler NP, Love RM. Conventional versus storage phosphor-plate digital images to visualize the root canal system contrasted with a radiopaque medium. J Endod 2003; 29(5):349–52. [CrossRef]
8. Wenzel A, Gröndahl HG. Direct digital radiography in the dental office. Int Dent J 1995; 45(1):27–34.
9. Wenzel A, Møystad A. Decision criteria and characteristics of Norwegian general dental practitioners selecting digital radiography. Dentomaxillofac Radiol 2001; 30(4):197–202. [CrossRef]
10. Russo JM, Russo JA, Guelmann M. Digital radiography: a survey of pediatric dentists. J Dent Child (Chic) 2006; 73(3):132–5.
11. Brady DT. Digital radiography: a survey of dentists in Hawai'i. Hawaii Dent J 2007; 38(4):10–3.
12. Gupta R, Rai R. The adoption of new endodontic technology by Indian dental practitioners: a questionnaire survey. J Clin Diagn Res 2013; 7(11):2610–4. [CrossRef]
13. Ting NA, Broadbent JM, Duncan WJ. Dental radiography in New Zealand: digital versus film. N Z Dent J 2013; 109(3):107–14.
14. White SC, Pharoah MJ. The evolution and application of dental maxillofacial imaging modalities. Dent Clin North Am 2008; 52(4):689–v. [CrossRef]
15. Versteeg KH, Sanderink GC, van Ginkel FC, van der Stelt PF. Estimating distances on direct digital images and conventional radiographs. J Am Dent Assoc 1997; 128(4):439–43. [CrossRef]
16. Nair MK, Leven MD, Nair PU. Radiographic Interpretation. In: Hargreaves KM, Berman LH, editors. Cohen's Pathways of The Pulp. Canada: Elsevier; 2016. p. 33–70.
17. Versteeg CH, Sanderink GC, van der Stelt PF. Efficacy of digital intra-oral radiography in clinical dentistry. J Dent 1997; 25(3-4):215–24. [CrossRef]
18. Alves WE, Ono E, Tanaka JL, Medici Filho TE, de Moraes LC, de Moraes ME, et al. Influence of image filters on the reproducibility measurements of alveolar bone loss. J Appl Oral Sci 2006; 14(6):415–20. [CrossRef]
19. Brüllmann DD, Röhrig B, Sulayman SL, Schulze R. Length of endodontic files measured in digital radiographs with and without noise-suppression filters: an ex-vivo study. Dentomaxillofac Radiol 2011; 40(3):170–6.
20. Tihanyi D, Gera I, Eickholz P. Influence of individual brightness and contrast adjustment on accuracy of radiographic measurements of infrabony defects. Dentomaxillofac Radiol 2011; 40(3):177–83. [CrossRef]
21. Raitz R, Assunção Junior JN, Fenyo-Pereira M, Correa L, de Lima LP. Assessment of using digital manipulation tools for diagnosing mandibular radiolucent lesions. Dentomaxillofac Radiol 2012; 41(3):203–10. [CrossRef]
22. Razi T, Mohammadi A, Ghojazadeh M. Comparison of Accuracy of Conventional Periapical Radiography and Direct Digital Subtractions Radiography with or without Image Enhancement in the Diagnosis of Density Changes. J Dent Res Dent Clin Dent Prospects 2012; 6(2):54–8.
23. Mehdizadeh M, Khademi AA, Shokraneh A, Farhadi N. Effect of digital noise reduction on the accuracy of endodontic file length determination. Imaging Sci Dent 2013; 43(3):185–90. [CrossRef]
24. Nascimento MC, Nejaim Y, de Almeida SM, Bóscolo FN, Haiter-Neto F, Sobrinho LC, et al. Influence of cone beam CT enhancement filters on diagnosis ability of longitudinal root fractures. Dentomaxillofac Radiol 2014; 43(3):20130374. [CrossRef]
25. Pati AR, Mubeen, K R V, et al. A comparative study on diagnostic accuracy of colour coded digital images, direct digital images and conventional radiographs for periapical lesions - an in vitro study. J Clin Diagn Res 2014; 8(11):ZC55–9. [CrossRef]
26. Farhadi N, Shokraneh A, Mehdizadeh M. Effect of Contrast Inversion Enhancement on the Accuracy of Endodontic File Length Determination in Digital Radiography. J Clin Diagn Res 2015; 9(5):ZC102–5. [CrossRef]
27. Ferreira LM, Visconti MA, Nascimento HA, Dallemolle RR, Ambrosano GM, Freitas DQ. Influence of CBCT enhancement filters on diagnosis of vertical root fractures: a simulation study in endodontically treated teeth with and without intracanal posts. Dentomaxillofac Radiol 2015; 44(5):20140352.
28. Barayan M, Nasseh I, Geha H, Noujeim M. The Effects of Imaging Enhancement Tools in the Detection of Horizontal Root Fractures. J Clin Diagn Res 2017; 11(8):ZC98–101. [CrossRef]
29. Parashos P, Morgan MV, Messer HH. Response rate and nonresponse bias in a questionnaire survey of dentists. Community Dent Oral Epidemiol 2005; 33(1):9–16. [CrossRef]
30. Hovland EJ, Romberg E, Moreland EF. Nonresponse bias to mail survey questionnaires within a professional population. J Dent Educ 1980; 44(5):270–4. [CrossRef]
31. Lydeard S. The questionnaire as a research tool. Fam Pract 1991; 8(1):84–91.
32. Li G, Engström PE, Welander U. Measurement accuracy of marginal bone level in digital radiographs with and without color coding. Acta Odontol Scand 2007; 65(5):254–8. [CrossRef]
33. Shi XQ, Eklund I, Tronje G, Welander U, Stamatakis HC, et al. Comparison of observer reliability in assessing alveolar bone changes from color-coded with subtraction radiographs. Dentomaxillofac Radiol 1999; 28(1):31–6.
34. Shi XQ, Li G. Detection accuracy of approximal caries by black-and-white and color-coded digital radiographs. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 107(3):433–6. [CrossRef]
35. Scarfe WC, Czerniejewski VJ, Farman AG, Avant SL, Molteni R. In vivo accuracy and reliability of color-coded image enhancements for the assessment of periradicular lesion dimensions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999; 88(5):603–11. [CrossRef]
36. Schmitd LB, Lima Tde C, Chinellato LE, Bramante CM, Garcia RB, de Moraes IG, et al. Comparison of radiographic measurements obtained with conventional and indirect digital imaging during endodontic treatment. J Appl Oral Sci 2008; 16(2):167–70. [CrossRef]
37. Rahmi-Fajrin H, Puspita S, Riyadi S, Sofiani E. Dental radiography image enhancement for treatment evaluation through digital image processing. J Clin Exp Dent 2018; 10(7):e629–34. [CrossRef]
38. Moreira-Souza L, Michels M, Lagos de Melo LP, Oliveira ML, Asprino L, Freitas DQ. Brightness and contrast adjustments influence the radiographic detection of soft tissue calcification. Oral Dis 2019; 25(7):1809–14. [CrossRef]
39. Baxes G. Digital Image Processing: Principles and Applications: John Wiley and Sons;1994.
40. Wu MK, Wesselink PR, Walton RE. Apical terminus location of root canal treatment procedures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000; 89(1):99–103. [CrossRef]
41. Ng YL, Mann V, Gulabivala K. Outcome of secondary root canal treatment: a systematic review of the literature. Int Endod J 2008; 41(12):1026–46.
42. Kamburoğlu K, Murat S, Pehlivan SY. The effects of digital image enhancement on the detection of vertical root fracture. Dent Traumatol 2010; 26(1):47–51. [CrossRef]
43. Tofangchiha M, Bakhshi M, Shariati M, Valizadeh S, Adel M, Sobouti F. Detection of vertical root fractures using digitally enhanced images: reverse-contrast and colorization. Dent Traumatol 2012; 28(6):478–82.
44. Ahmed HM, Cohen S, Lévy G, Steier L, Bukiet F. Rubber dam application in endodontic practice: an update on critical educational and ethical dilemmas. Aust Dent J 2014; 59(4):457–63. [CrossRef]
45. Madarati AA. Why dentists don't use rubber dam during endodontics and how to promote its usage?. BMC Oral Health 2016;16:24. [CrossRef]
46. Madarati AA, Habib AA. Modalities of using endodontic nickel-titanium rotary instruments and factors influencing their implementation in dental practice. BMC Oral Health 2018; 18(1):192. [CrossRef]