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A Comparison of Digital versus Standard
Radiographs from the Patient's Perspective

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ABSTRACT

There are a number of issues to be considered when examining digital versus standard radiographs from the perspective of the patient. This evidence based report examines the issues of caries diagnosis and radiation exposure. A methodological approach was used to locate 6 articles comparing the radiation dosages and diagnostic performance of these two imaging modalities. The null hypothesis that both modalities were equal in these areas was, confirmed with respect to caries diagnosis and rejected with respect to radiation dose. The evaluated evidence suggests that digital radiographs have great potential to improve patient care by providing equal diagnostic accuracy with a significantly reduced radiation dose. In light of this observed potential benefit, and a clear deficiency of research in this area, studies of higher quality and greater range of generalizability are needed to create an appropriate standard of care to maximize the potential patient benefits of this new technology.

INTRODUCTION

Dental radiography is an important diagnostic tool in assessing states of pathology. It has become part of the standard of care amongst practicing dentists as it offers diagnostic information not available from clinical examination. Conventional radiography utilizes x-ray radiation to penetrate tissues and ionize photographic emulsion film (Pharoah, MJ and White, SC, 2004). Several shortcomings of the conventional system have been demonstrated in the literature, including errors in exposing and processing films, relatively high levels of radiation exposure and imperfect diagnostic capabilities¹. With our increasing understanding of both the need to minimize unnecessary tooth destruction and the potential for new systems to provide less radiation for patients, the investigation of new modalities is warranted. Technological advances have allowed the ushering in of digital radiography. Digital radiography utilizes the same principle as conventional radiographs, however, instead of film, x-ray sensors are used to obtain a digital image (Leung, CC et al, 2005).

There are various issues to consider when comparing conventional

and digital radiography systems from a patient's point of view. Previous articles have claimed that digital systems offer the advantage of adequate diagnostic accuracy, reduced radiation dose, increased patient comfort, lower cost, and less time (Van der Stelt, PF, 2000). All of these factors directly benefit the patient. Patient comfort is largely subjective and any studies on this topic would be entirely dependent on the sample. The monetary cost to the patient for digital radiographs is the same as for conventional radiographs, as stated by the ODA fee guide. Time required to take radiographs, digital or conventional, is dependent on the operator. Although processing time is cut out in digital radiography, this does not affect the patient as another part of the appointment is generally conducted as radiographs are being processed. Therefore, excluding comfort cost and time for the aforementioned reasons and in an effort to provide adequate depth of analysis, this paper will limit itself to two areas of research of high priority: diagnostic accuracy and reduction of radiation dose.

With the current understanding of the advantages of providing minimally invasive dental care and the harm caused by over-treatment, the issue

of accurate diagnosis becomes one of utmost importance. When diagnostic errors are made, the idea of tooth preservation is compromised. When a lesion is missed on a radiograph and is not treated, it can lead to more invasive and severe damage. The over-treatment of false positives will lead to unnecessary destruction of healthy tooth structure. Both of these situations compromise the health of the tooth and the oral cavity of the patient.

While radiographic testing provides valuable information to facilitate accurate diagnosis, the information obtained by this method is proportionate to the amount of radiation to which the patient is exposed. A graphic representation of this is displayed in Figure 1 in appendix 1. One must decide when and how much radiation exposure can be risked based on the significance of the information obtained and the risk category of the patient or tissue that is exposed. The stochastic effect of radiation reveals that there is no safe dosage threshold under which ionizing radiation can be considered completely harmless. Furthermore, the populations at the highest risk for suffering from radiation damage (pregnant women) are not always identifiable since women in the 1st trimester often do not know they are pregnant. Thus every attempt must be made to maximize the amount of information obtained from radiographs while minimizing radiation dose.

The aim of this paper is to evaluate whether the current evidence suggests that digital radiography provides benefits to patients by either increasing diagnostic accuracy or reducing the dosage of radiation. These two issues will be addressed by

evaluating the current research to answer the following two questions:

- 1) Does the use of digital radiographs reduce radiation exposure to patients?
- 2) Does digital radiography increase, reduce or have no effect on diagnostic accuracy?

METHODS

A systematic approach was used to search, identify, select and critically appraise relevant articles. Two separate searches were conducted for the two issues to be investigated, namely a comparison of radiation exposure in

digital dental radiographic systems versus conventional dental radiographic systems (issue 1) and a comparison of diagnostic accuracy between digital dental radiographic systems and conventional dental radiographic systems (issue 2).

Search Strategy:

Keywords:

For each issue, a list of keywords was compiled by which the searches were conducted.

Issue 1 (radiation exposure):

Radiation	Radiology	Radiography	Radiograph	Dose
Dosing	Exposure	Compare	Comparing	Comparison
Dental	Dentistry	Digital		

MeSH subheadings used for PubMed search: “Radiography, Dental, Digital”
Truncation of the terms radio* and dent* were used to simplify the searching.

Issue 2 (diagnostic accuracy):

Radiation	Radiology	Radiography	Radiograph	Dental
Dentistry	Digital	Sensitivity	Specificity	Accuracy
Diagnosis	Diagnostic	Diagnosing	Diagnose	Compare
Comparison	Comparing	Tomography	Tomograph	Compression

MeSH subheadings used for PubMed search: “Radiography, Dental, Digital” and “Diagnosis, Oral”.

Truncation of the terms radio* and dent* were used to simplify the searching.

Tomography, tomograph and compression were included as “not” terms since they were not desired in the results.

Searches:

Four major health science databases were searched through to identify articles for both issues, PubMed (1966 – present), Ovid MEDLINE (1950 – present), Cinahl (1982 – present) and EMBASE (1980 – present). Searches were limited to publications in English and review articles were excluded.

MeSH subheadings in the PubMed searches were used to reduce bias in search terminology. MeSH subheadings are available for PubMed and allow a consistent way to retrieve information which might use differing terminologies but has the same underlying concepts.

The PubMed database was searched using MeSH subheadings and keywords for both issues. The Medline, Cinahl and Embase databases were searched using keywords only.

Final search results yielded the following:

- i) PubMed search for issue 1 (radiation exposure): 38 articles
- ii) Medline/Cinahl/Embase search for issue 1 (radiation exposure): 81 articles
- iii) PubMed search for issue 2 (diagnostic accuracy): 57 articles
- iv) Medline/Cinahl/Embase search for issue 2 (diagnostic accuracy): 81 articles

Other sources of articles included reference lists from several articles found and from oral radiology textbooks which yielded 10 articles for issue 1 (radiation exposure) and 9 articles for issue 2 (diagnostic accuracy).

Determining Relevance:

The following process was used to narrow all the yielded articles to the relevant ones, which are included in this study. An article was considered relevant if it met the following four criteria; 1) The title approximated the general ideas

of the research topic, so for issue 1 (radiation exposure) the title had to be along the lines of comparing the radiation exposure from conventional radiography and digital radiography and for issue 2 (diagnostic accuracy) the title had to contain some sort of comparison between the diagnostic accuracies of conventional versus digital radiographs. 2) The article abstract was consistent with the research topic, as stated above. 3) The article reported primary research, so reviews, commentaries etc were excluded. 4) The articles' data was examined via statistical analysis and conclusions were based on significant statistical findings. 5) Study findings for issue 2 (diagnostic accuracy) were validated against the gold standard of histological sectioning and not a silver standard of radiographic expert opinion.

Validity:

The amount of relevant articles found were as follows, for issue 1 (radiation exposure), 6 articles were deemed relevant and for issue 2 (diagnostic accuracy) 7 articles were deemed relevant. These articles were then scored against two checklists, one for each issue.

Issue 1 (radiation exposure) articles were assessed against the “checklist to assess evidence of efficacy of therapy or prevention” which examines the strength of evidence for use of a new therapy in comparison to a traditionally used one. A cut off score of 7/10 was a requirement for an article to be included in the study. Three articles met this score and they are the ones which were finally included in the study. The checklist used to score these articles is located in appendix 1.

Issue 2 (diagnostic accuracy) articles were assessed against the

“checklist for assessing a diagnostic or predictive test” which examines the strength of evidence for use of a new diagnostic test in comparison to a traditionally used one.

A cut off score of 7/10 was again required to include an article in the study and three articles met this cut off. This checklist is also in appendix 1.

Tables 1 and 2 display the selection process and the amount of articles which were eliminated at each stage of selection.

Abstracts matching search terms for issue 1 (radiation exposure)	PubMed	Medline/Cinahl/Embase	Other
	38	81	10
Articles rejected at title stage	92		
Articles rejected at abstract stage	14		
Articles retrieved and copied for review	23		
Articles rejected at first reading	17		
Articles scored	6		
Articles meeting cut-offs (7/10)	3		

Table 1: Selection process for issue 1 (radiation exposure)

Abstracts matching search terms for issue 2 (diagnostic accuracy)	PubMed	Medline/Cinahl/Embase	Other
	57	81	9
Articles rejected at title stage	112		
Articles rejected at abstract stage	22		
Articles retrieved and copied for review	13		
Articles rejected at first reading	6		
Articles scored	7		
Articles meeting cut-offs (7/10)	3		

Table 2: Selection process for issue 2 (diagnostic accuracy)

RESULTS

The six articles which met all the criteria were included in the study and are listed below in 3 tables. Table 3 is a summary of critical appraisals for all 6 articles. Table 4 contains the evidence tables for issue 1 (radiation exposure) articles and Table 5 contains the evidence tables for issue 2 (diagnostic accuracy) articles.

ARTICLE	CRITICAL APPRAISAL SCORE	WEAKNESS
Berkhout WE, Sanderink GC, Van der Stelt PF. A comparison of digital and film radiography in Dutch dental practices assessed by questionnaire. <i>Dentomaxillofac Radiol</i> 2002; 31:93-99.	8/10	Questionnaire – self-report bias.
Visser H, Rodig T, Hermann KP. Dose reduction by direct-digital cephalometric radiography. <i>Angle. Orthod.</i> , 2001 Jun;71(3):159-63.	8/10	Study population on phantom-heads. (i.e. non-human study)
Bhaskaran V, Qualtrough AJE, Rushton VE et al. A laboratory comparison of three imaging systems for image quality and radiation exposure characteristics. <i>Int Endod J.</i> 2005 Sep; 38(9):645-52.	7/10	Study population on phantom-heads. (i.e. non-human study)
Tyndall DA, Ludlow JB, Platin E, Nair M. A comparison of Kodak Ektaspeed Plus film and the Siemens Sidexis digital imaging system for caries detection using receiver operating characteristic analysis. <i>Oral Surg Oral Med Oral Pathol, Oral Rad Endod</i> 1998;85(1):113-8.	8/10	Did not account for conditions other than caries.
Hintze H, Wenzel A. Influence of the validation method on diagnostic accuracy for caries. A comparison of six digital and two conventional radiographic systems. <i>Dentomaxillofac Radiol</i> 2002; 31: 44-9.	8/10	Difficult to apply with patients since histological sections of patients teeth to confirm caries cannot be done.
Syriopoulos K, Sanderink GC, Velders XL, Van der Stelt PF. Radiographic detection of approximal caries: a comparison of dental films and digital imaging systems. <i>Dentomaxillofac Radiol</i> 2000;29(5):312-8.	7/10	Small sample size.

Table 3: Critical Appraisal results for radiation dose and diagnostic accuracy articles.

AUTHOR	ANALYSIS	POPULATION	OUTCOME	LIMITATIONS	APPRAISAL
Berkhout WE, Sanderink GC, Van der Stelt PF (2002)	Questionnaire sent out to two groups of dentists regarding the number of radiographs taken	Digital: N=473 Standard: N=105	Significant increase in number of radiographs taken among digital users. P=0.003	Not strongest design. Assume all dentists cover same range of procedures and take same number x-rays.	Level II-2 Grade B 8/10
Visser H, Rodig T, Hermann KP (2001)	Radiation doses between digital and standard radiographic systems.	Phantom head 108 thermo-luminescent detectors on left side of the face	Standard system had twice as much absorption at: skin of left parotid (132µGy/58µGy) left parotid gland (103µGy/45µGy) skin below left eye (11µGy /6µGy)	Non-human study. Unsure how well phantom simulates a patient.	Task Force levels not intended for non-human studies. Grade B 8/10
Bhaskaran V et al (2005)	Radiation doses between digital and standard radiographic systems using different exposure times.	Phantom head with human mandible. 21 Images per system, at same location.	Dose reduction vs. standard: Visualix USB (CCD) = 20% Digora FMX (phosphor) = 70%	Non-human study. Dose values based on radiographs of highest quality, not total.	Task Force levels not intended for non-human studies. Grade B 7/10

Table 4: Evidence table summary of dose comparison analysis.

AUTHOR	ANALYSIS	POPULATION	OUTCOME	LIMITATIONS	APPRAISAL
Tyndall DA et al (1998)	Diagnostic accuracy of proximal caries between digital and standard radiographic systems	Extracted teeth, N=60 6 observers: 3 dentist 2 oral diagnosticians 1 endodontist	No statistical difference. P=0.211	Diseases that may be confused with caries were not evaluated.	Level II-1 Grade C 8/10
Hintze H, Wenzel A (2002)	Comparing histology (gold standard) with an expert radiographic interpretation (silver standard) using 6 digital and 2 standard systems.	Proximal surfaces: N=338 Occlusal surfaces: N=145 4 observes: 2 dentists 2 dental students	Histological section superior than expert interpretation. P<0.001	Histological sections of patients teeth to confirm caries is not possible. Did not account for disease that might be confused with caries.	Level II-3 Grade B 8/10

Syriopoulos K et al (2000)	Diagnostic accuracy detecting proximal caries between digital and standard systems Compared to histological sections	Extracted premolars: N=56 8 Observers: 4 radiologists 4 dentists	No significant difference. P= 0.026	Small sample size. Conditions closely related to caries were not taken into account.	Level II-1 Grade B 7/10
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Table 5: Evidence table summary of diagnostic accuracy analysis.

The articles examined in this review confirmed the hypothesis that digital and standard radiographs have comparable caries diagnostic potential. Furthermore the studies analyzed indicate that digital radiographs provide patients with the additional benefit of reduced radiation exposure.

The hypothesis that further studies in the area of caries diagnosis could use the silver standard of expert opinion in lieu of the costly gold standard of histological sections was rejected by Hintze, H, Wenzel, A, (2002) who found there was a statistically significant difference between these two standards. This led to the exclusion of silver standard studies in this review.

DISCUSSION

According to this literature review there is evidence suggesting potential patient benefit from the transition from standard to digital imaging modalities. It should be noted however, that while this evidence is promising it is considerably weak due to the inadequacies and inconsistencies in available studies. In particular, there was considerable variance between studies with respect to: the type of digital systems reviewed; anthropomorphic heads were used in place of human subjects in radiation dosage studies; the qualifications of the operators and the

degree of operator control varied between studies or was not stated and thus cannot be said to reflect the skills of general practicing dentists; and the populations studied were limited to adult patients capable of full compliance. Accordingly, a conclusive judgment cannot be made with respect to the safety and accuracy of all digital systems as they would be used in general practice. The evidence available does suggest, however, significant patient benefit exists with respect to reduced radiation dosage, without compromising diagnostic value of the images. In accordance with the current view that all reasonable attempts should be made to reduce radiation exposure for all patients, further research in this area is warranted. Further studies should employ stronger designs and include investigations into issues such as:

- The efficacy of these systems with respect to populations with smaller mouths or who are less able to cooperate with the positioning of the new intraoral receptor.
- The ability of dentists to utilize the digital technology appropriately with respect to the increased control over elements such as contrast control, image size and even auto enhancement programs provided by these new devices, as well as the lack of financial penalties for retakes provided by the new systems.

- Where ethically possible investigation of radiation dose on human subjects.
- The efficacy of this technology as it relates to non-carious diagnostic tests required by general practicing dentists as well as different specialists (i.e. endodontists, oral surgeons, orthodontists etc).
- The potential benefits and risks associated with new digital devices produced and marketed with the aim of improving sales in an extremely competitive market.

CONCLUSION

In conclusion, the limited research available comparing digital and standard radiographs suggest that digital radiography may benefit patients by reducing their exposure to radiation while maintaining diagnostic accuracy. There is presently insufficient research to make a definitive recommendation with respect to implanting digital radiographs as the new standard of care. As noted above further studies should be made in an attempt to understand how to use these new technologies to optimize patient care.

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APPENDIX 1

Checklist to Assess Evidence of Efficacy of Therapy or Prevention

Citation: _____

1. Was the study ethical? _____
2. Was a strong design used to assess efficacy? _____
3. Were outcomes (benefits and harms) validly and reliably measured? _____
4. Were interventions validly and reliably measured? _____
5. What were the results?
Was the treatment effect large enough to be clinically important? _____
Was the estimate of the treatment effect beyond chance and relatively precise? _____
If the findings were “no difference” was the power of the study 80% or better? _____
6. Are the results of the study valid?
 - Was the assignment of patients to treatments randomised? _____
 - Were all patients who entered the trial properly accounted for and attributed at its conclusion? _____
 - i) Was loss to follow-up less than 20% and balanced between test and controls? _____
 - ii) Were patients analysed in the groups to which they were randomised? _____
 - Was the study of sufficient duration? _____
 - Were patients, health workers, and study personnel “blind” to treatment? _____
 - Were the groups similar at the start of the trial? _____
 - Aside from the experimental intervention, were the groups treated equally? _____
 - Was care received outside the study identified and controlled for? _____
7. Will the results help in caring for your patients?
Were all clinically important outcomes considered? _____
Are the likely benefits of treatment worth the potential harms and costs? _____

Adapted from: Fletcher, Fletcher and Wagner. *Clinical epidemiology – the essentials*. 3rd ed. 1996, and Sackett et al. *Evidence-based medicine: how to practice and teach EBM*. 1997

Checklist for Assessing a Diagnostic or Predictive Test

Citation: _____

1. Was the study ethical? _____
2. Is the test clearly described (including the cut-off values)? _____
3. Was the test evaluated against a valid gold standard? _____
4. Were the test results and disease status determined independently? _____
5. Was the test evaluated using patients with a range of severity of disease?

6. Was the test evaluated among patients with diseases that might be confused with, or are closely related to, the disease of interest? _____
7. Is the test performance reported using sensitivity/specificity, likelihood ratios or ROC curves? (Note: if predictive values, only, are reported, was the background prevalence of disease similar to that of your patients) _____
8. Is the effect of moving the cut-off point reported? _____
9. Does this test give better results than the current or standard test? _____
10. Is the test likely to be acceptable to patients? _____

Adapted from: Fletcher, Fletcher and Wagner. Clinical epidemiology – the essentials. 3rd ed. 1996, and Sackett et al. Evidence-based medicine: how to practice and teach EBM. 1997

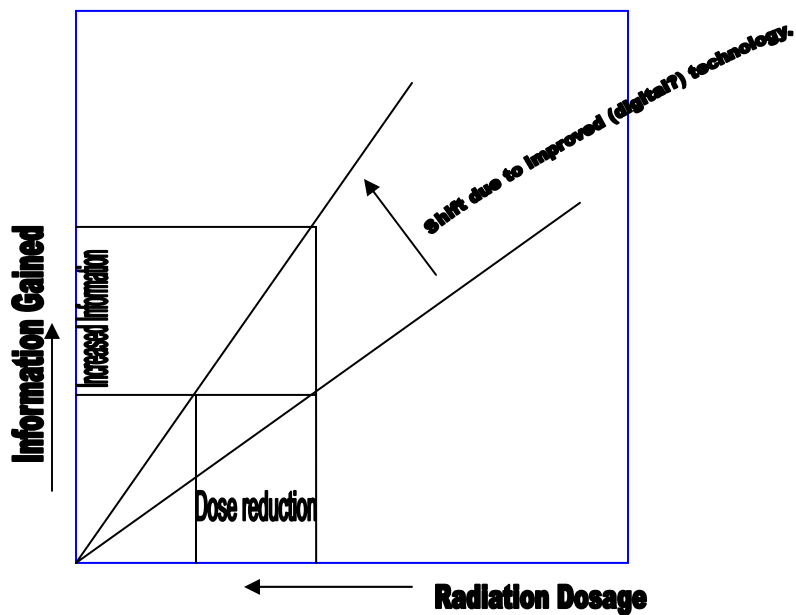


Figure 1: Depicts the relationship between radiation dose and information obtained. While there is a radiation “cost” proportional to information gained in all known radiographic modalities at this time the goal of new modalities is reduce the dose per unit of information provided.

¹ The accuracy of bitewing radiographs have been found to be as low as 65% (White et al) with sensitivities as low as 45%(Kang et al.) and overall decreasing positive predictive value (likely due to a decrease in prevalence of caries (Grondahl et al).