RESEARCH ARTICLE

A clinical comparison of extraoral panoramic and intraoral radiographic modalities for detecting proximal caries and visualizing open posterior interproximal contacts

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Objectives: The purpose of this study was to compare extraoral panoramic bitewings (BW) to intraoral photostimulable phosphor (PSP) plate BWs for the detection of proximal surface caries and to establish if there was any difference between extraoral BWs, intraoral BWs and panoramic radiographs in visualizing open posterior interproximal contacts.

Methods: Extraoral panoramic and intraoral BW images were acquired on each of 20 patients, resulting in 489 total non-restored, readable surfaces that were evaluated by 4 observers. The ANOVA analysis to determine diagnostic variability between and within each subject was utilized. The surfaces included in the study extended from the distal of each canine to the last posterior contact in each arch with non-readable proximal surfaces excluded (*i.e.* surfaces where over half the enamel layer was overlapped or where those surfaces were not visible in one or both modalities).

Results: The statistical analysis indicated that the overall mean area under the receiver operating characteristic curves across all observers for the intraoral BWs and extraoral panoramic BWs were 0.832 and 0.827, respectively, and the difference of 0.005 was not significant at $p = 0.7781$. The percentage of non-readable proximal surfaces across the three modalities was 4.1% for intraoral BWs, 18.3% for extraoral panoramic BWs and 51.5% for the standard panoramic images.

Conclusions: The investigators concluded there was no significant difference in posterior proximal surface caries detection between the modalities. Extraoral panoramic BWs were much better than panoramic radiographs in visualizing open posterior interproximal contacts, 81.7% vs 48.5%, but below the 95.9% value for intraoral BWs.

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Introduction

Shortly following the discovery of the X-rays by Wilhelm Conrad Röntgen on 8 November 1895 the first

dental radiographs were produced which were somewhat similar to bitewing (BW) radiographs but lacking in diagnostic quality.¹ From these beginnings, intraoral BWs have become the primary diagnostic tool used for the detection of proximal surface caries which are not visible clinically. Radiographic proximal surface caries detection is principally based on a decreased attenuation

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of the X-ray beam in demineralized enamel and dentin, resulting in an increase in radiographic density which is interpreted as a sign of a dental caries.² Traditionally, the most useful BW examination has been accomplished using one or two size-2 “adult” film-based images per side to assess all the contact surfaces from the distal of the cuspid to the most distal molar interproximal contact.³

Intraoral BWs are used extensively despite several disadvantages, including patient discomfort, the possibility of cross contamination, radiation to the parotid glands and variable levels of skill shown by auxiliaries which may lead to the need for retakes with increased patient radiation dose.⁴ Modern digital radiology systems provide reduced patient radiation dose, time savings, image enhancement and ease of image storage, retrieval and transmission.⁵ Extraoral panoramic BWs demonstrate the teeth in their entirety, from the lateral incisor to the third molar without any duplication and include not only the crowns but also the peri-apical areas.

Additionally, the radiographic detection of proximal surface caries is only possible if a system can produce clearly readable images with visualized open interproximal contacts. The use of a single size-3 film or photostimulable phosphor (PSP) is not recommended because of an increase in proximal surface overlapping and “cone-cut” images.³ In the present study, four size-2 “adult” PSP plates were used on each patient (two for each side) resulting in a greater opportunity for individual contact points to be visualized as open, which is consistent with current practice.

Image quality is critical to caries detection and is based mainly on several factors which include spatial resolution, contrast resolution and noise. Compared with panoramic film, imaging with the advent of digital panoramic sensors has improved both contrast resolution and spatial resolution of panoramic imaging. However, intraoral sensors and, to a lesser degree, PSP plates can still provide better contrast resolution and spatial resolution than panoramic imaging. Noise is generally the result of an insufficient number of photons reaching the sensor. Newer intraoral direct current tubeheads typically have reduced the current used to an average of 7–8 mA with less than half the exposure time when compared with panoramic imaging, the Planmeca ProMax[®] (Planmeca Inc., Helsinki, Finland) panoramic bite wings are usually exposed at 13–14 mA. The highly collimated panoramic beam can produce a greater X-ray photon saturation of the tooth than the intraoral beam. This increased photon saturation of the tooth can result in decreased noise and thereby improve caries detection when compared with lower mA imaging systems. Most digital panoramic radiography machines use a charge-coupled device detector for image capture in a method which is analogous to film-based panoramic systems. In panoramic imaging systems, the narrow X-ray beam passes through a patient’s jaws onto a moving film, PSP or sensor and structures outside the

curved focal plane are generally removed or blurred. In panoramic imaging a relatively narrow layer in the dental arch is imaged with high resolution and high contrast, making patient positioning critical. With both film-based and digital-based panoramic radiography units, accurate patient positioning is essential to achieve a satisfactory image.^{6,7}

A number of previous investigators have concluded that intraoral BW radiography performs better than panoramic imaging, including extraoral panoramic BWs for the detection of posterior proximal surface caries.^{5,8,9} By contrast, our primary null hypothesis was that there is no difference in the diagnostic accuracy of intraoral BW images produced by ScanX[®] intraoral PSPs (Air Techniques, Inc., Melville, NY) and extraoral panoramic BW images produced by the Planmeca ProMax (Planmeca Inc) for the detection of posterior proximal surface demineralization. Our second null hypothesis was that there is no difference between the ability of intraoral BWs, extraoral panoramic BWs and standard panoramic radiographs in visualizing open contacts of posterior teeth for the detection of proximal surface demineralization.

Methods and materials

In accordance with the protocol approved by the University of Texas Health Science Center at San Antonio Institutional Review Board, 20 volunteer subjects (age range 20–53 years with a mean age of 28.8 years) requiring posterior BW and panoramic radiographic evaluation, with a minimum of one carious proximal surface radiolucency, were selected for this study (Figures 1 and 2). The following individuals were excluded: females of child-bearing age who were either pregnant or uncertain of pregnancy status, patients undergoing orthodontic treatment or with gross misaligned teeth, anyone with a history of head and neck radiation therapy or oral cancer. A total of four intraoral BWs were acquired on each subject using a Planmeca Intraoral tubehead (Planmeca Inc.) and ScanX intraoral PSPs. Extraoral panoramic BWs and a standard panoramic digital radiograph were acquired on each subject using the Planmeca ProMax device.

All images were saved as TIFF files and imported into the MiPACS[®] (Medicor Imaging Charlotte, Charlotte, NC) software. A total of four observers consisting of three oral and maxillofacial radiology residents with 36, 33 and 9 years’ of practice experience, respectively, and one general dentistry faculty member with 13 years’ of experience evaluated the images. Observers used a computer with a calibrated monitor for the detection of carious lesion presence using the following criteria: (1) definitely present, (2) probably present, (3) uncertain, (4) probably absent and (5) definitely absent. Each observer was able to use all software tools available in the MiPACS software to optimize the digital images and was given as much as

Figure 1 Intraoral and panoramic bitewing radiographs.

time as was needed for the review. Only the unrestored surfaces that could be visualized on both the intraoral and panoramic BWs with ‘visualized open’ contacts (*i.e.* overlap no more than halfway through the enamel layer) were included in the study. At least 2 weeks elapsed between the observer’s evaluation of the intraoral and extraoral panoramic BWs.

The “gold standard” for this study was established by a consensus of two experts consisting of board-certified oral and maxillofacial radiologists, with 47 years’ and

24 years’ of experience, respectively. The experts were not involved in the evaluation of the images that was performed by the four different readers.

An ANOVA statistical test for repeated measures was completed for all four observers providing receiver operating characteristic (ROC) curves. Fisher’s least significant difference and Shapiro–Wilks test for normality of residual homogeneity of variance with a plot of residuals *vs* predicted values were used to verify the validity of this analysis. Based on curve fitting of sample

Figure 2 Panoramic radiograph.

Table 1 Area under the curve (AUC) receiver operating characteristic (ROC) mean values for intraoral and panoramic bitewing (BW) Observers 1–4

Observer	Type of BWs	AUC ROC mean	p-value
1	Intraoral	0.834	0.0609
	Panoramic	0.783	
2	Intraoral	0.847	0.0375 ^a
	Panoramic	0.791	
3	Intraoral	0.796	0.0636
	Panoramic	0.847	
4	Intraoral	0.852	0.2115
	Panoramic	0.886	

^aNot significant at $p > 0.05$.

sizes in table 2 of Obuchowski¹⁰ with small variance among the 4 observers, we expect 20 patients to be able to detect differences among the 4 observers of 0.116 area under the ROC curve with power of 0.80 and two-tail significance level of 0.05. All statistical analyses were performed using Statistical Analysis Software® (SAS Institute Inc., Cary, NC) v. 9.3 for Windows.

Results

The ANOVA test showed two observers had a greater mean ROC value for the panoramic BW, whereas the other two had a higher value for intraoral BWs. The results from one observer, number 2, who favoured the intraoral BWs were not statistically significant (Table 1). The overall intraoral vs extraoral panoramic BW ROC area under the curve means of 0.832 and 0.827, respectively, were not significant at $p = 0.7781$. These results demonstrate that while there were significant differences in the mean ROC curves between and within the individual observers (Figures 3–7), there was no overall

difference between the intraoral BWs and extraoral panoramic BWs for the detection of interproximal carious lesions at all depths including incipient lesions.

We evaluated the interproximal overlap of the enamel at the contact points of the posterior teeth in the intraoral BW, extraoral panoramic BWs and standard panoramic images for each of the 20 patients in the study. We found that non-readable proximal surfaces due to excess overlap more than halfway through the interproximal contacts or surfaces not captured on the image occurred in 4.1% of the surfaces with intraoral BWs compared with 18.3% with extraoral panoramic BWs and 51.5% of the interproximal surfaces on the standard panoramic radiographs.

Discussion

The clinical examination is effective in the detection of occlusal, facial and lingual surface carious lesions, yet it may not be used for small proximal surface caries which cannot be visualized directly. Therefore, BW radiographs are accepted as an important adjunct in the diagnosis of approximal (interproximal) carious lesions.^{9,11} The purpose of this study was to compare the ability of extraoral panoramic BWs and intraoral BWs to produce clinically diagnostic images for the detection of proximal surface caries on 20 test subjects. We further sought to establish if there were any differences in the ability of intraoral BWs, extraoral panoramic BWs or standard panoramic radiographs to open posterior interproximal contacts and allow for proximal surface caries evaluation.

In the past, various investigators have used differing definitions of what constitutes a radiographic carious

Figure 3 Mean intraoral and extraoral bitewing (BW) receiver operating characteristics (ROCs) for Observer 1.

Figure 4 Mean intraoral and extraoral bitewing (BW) receiver operating characteristics (ROCs) for Observer 2.

lesion. For example, Steward and Bieser¹² defined a carious lesion as a radiographically detectable lesion which should be restored, whereas Galal et al¹³ accepted a diagnostic criteria that any amount of decalcification present on the proximal surface of a tooth is caries. Since the early detection of small carious lesions is an important goal in dentistry and to establish clear criteria, we instructed our observers that, for the purposes of this study, any decalcification of the proximal surface constituted a lesion. The diagnostic criteria in the

present study are validated by Douglass et al,¹⁴ who concluded that including or excluding incipient lesions in the diagnostic criteria had only minimal effect on sensitivity and showed no difference for specificity.

The use of a panoramic machine for caries detection is not a new concept, and many authors tried to explore this possibility. In 2006 Akkaya et al⁹ presented evidence that the panoramic image may not be as effective as intraoral bitewing images for the diagnosis of interproximal caries. In our study, the ability of

Figure 5 Mean intraoral and extraoral bitewing (BW) receiver operating characteristics (ROCs) for Observer 3.

Figure 6 Mean intraoral and extraoral bitewing (BW) receiver operating characteristics (ROCs) for Observer 4.

extraoral BW images acquired with the panoramic machine was slightly lower than intraoral BW images in detecting interproximal carious lesions but with no statistically significant difference. This finding is different from the results obtained by Akkaya *et al*⁹ and Scarfe *et al*¹⁵ and suggest the efficacy of using the BW mode on the current generation of ProMax panoramic machines.

The ability to detect proximal surface caries in intraoral and extraoral panoramic BW radiography can depend on various factors including caries' depth, tooth

position, superimposition of adjacent structures, artefacts, X-ray beam saturation and angulation, and individual patient factors. Also, with panoramic radiography, the focal trough shape and location in relation to the teeth, and the jaw arch shape and size are also important and are adjustable in the ProMax panoramic machine settings.⁵ Scarfe *et al*¹⁶ found that in the premolar region, classic standard panoramic machines demonstrated a 15–45° variation in the beam direction from the ideal that was needed to consistently open the interproximal contacts. The marked premolar

Figure 7 Mean intraoral and extraoral bitewing (BW) receiver operating characteristics (ROCs) for all observers combined.

overlapping that frequently occurs in current standard panoramic imaging is consistent with this finding.¹⁵

To obtain diagnostically useful panoramic radiographs, a patient must be correctly positioned in the image layer.¹⁷ In this study 81.7% of extraoral panoramic BW contacts were open compared with only 48.5% with the standard panoramic projection, demonstrating a marked ability of the panoramic BW modality to visualizing open the posterior contacts as compared with standard panoramic radiology. The operator who captured the panoramic BW images for this study received detailed instruction but had no previous hands on experience in using the BW modality prior to beginning the study. There are three jaw sizes and three jaw shapes for a total of nine settings to select from. In addition, the correct patient alignment in all three planes is needed to assure acceptable images.

Future studies could examine the effects of patient positioning and choices of settings based on jaw size and shape and evaluate the effects that these factors have on

opening contacts in panoramic BW images. In addition, the detectability of interproximal caries in the overlapped contacts could be compared in the panoramic vs intraoral BW images. Another possible future study topic could be to evaluate if extraoral BW operator experience affects the percentage of open contacts.

Conclusion

The results of this study indicate that there is no significant difference in posterior proximal surface caries detection between the tested intraoral and extraoral panoramic BW systems. Extraoral panoramic BWs were able to open posterior proximal surface contacts to a much greater extent than standard panoramic imaging but not as well as intraoral BWs. The investigators believe that further training and more clinical practice may have resulted in more open panoramic BW contacts.

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