TECHNICAL REPORT

Fish scale artefact on an intraoral imaging receptor

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Objectives: To describe an artefact, termed the fish scale artefact, present on an intraoral imaging receptor.

Methods: Thirty brand new DIGORA Optime photostimulable phosphor (PSP) plates (Soredex/Orion Corp., Helsinki, Finland) were imaged using the dental digital quality assurance radiographic phantom (Dental Imaging Consultants LLC, San Antonio, TX). All PSP plates were scanned at the same spatial resolution (dpi) using the high resolution mode. Two evaluators assessed all 30 plates. Each evaluator assessed the 30 PSP plates separately for purposes of establishing interrater reliability, and then together in order to obtain the gold standard result.

Results: The fish scale artefact was detected on 46.7% of the PSP plates. The kappa coefficient for interrater reliability was 0.86 [95% CI (0.69–1.00)], indicating excellent interrater reliability. For Evaluator 1, sensitivity was 0.85 [95% CI (0.55–0.98)]; specificity was 0.94 [CI (0.71–1.00)] and overall accuracy was 0.90 [95% CI (0.73–0.98)]. For Evaluator 2, sensitivity was 1.00 [95% CI (0.75–1.00)]; specificity was 0.94 [CI (0.71–1.00)] and overall accuracy was 0.97 [95% CI (0.83–1.00)]. These results indicate excellent agreement with the gold standard for both evaluators.

Conclusions: Utilizing a comprehensive quality assurance protocol, we identified a fish scale artefact inherent to the image receptor. Additional research is needed to determine if the artefact remains static over time or if it increases over time. Likewise, research to determine the potential sources contributing to an increase in the artefact is needed.

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Introduction

Quality assurance guidelines for digital imaging are limited and a general lack of knowledge about quality assurance procedures has been reported.^{1–3} The digital imaging chain is complex. For example, the answer to “why is this radiograph too light” is not always due to inadequate exposure settings. In reality it could be due to inadequate software settings or inadequate scanner settings. [Figure 1](#) provides an example of radiographs that are too light in density, simulating underexposure error, due to improper scanner settings. Quality assurance for digital imaging includes proper function and

calibration of the radiographic unit; accurate radiographic technique; calibration of computer monitors for adequate brightness/contrast and spatial resolution; proper software settings; ensuring that updates to computer operating systems, software and hardware provide equivalent diagnostic quality; consistent calibration of scanners when using a photostimulable phosphor (PSP) plate system and use of a radiographic phantom to monitor diagnostic quality. Quality assurance procedures also have to account for third party software when applicable. An example of how the settings within a third party software can effect image quality is given in [Figure 2](#). The National Council on Radiation Protection and Measurements Report 145

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Figure 1 All bitewing images were acquired with the same radiographic unit. (a, b) The set of bitewings acquired on this paediatric patient appear underexposed. (c, d) The set of bitewings taken on a different paediatric patient display appropriate contrast. The underexposed appearance of bitewings (a, b) was due to improper scanner settings. Recalibration of the scanner unit resolved the issue.

states that there must be a written protocol for quality assurance designed for the image receptor system; however, no specifics are given in reference to digital imaging.⁴ Therefore, it is not surprising that when evaluating the image quality of digital sensors, Walker and colleagues discovered that the exposure settings being used required adjusting, most required a reduction in exposure, in order to achieve optimum image quality while maintaining appropriate patient dose.¹ Additionally, as part of their quality assurance assessment, Walker and colleagues discovered four X-ray units operating with a fluctuation in kilovoltage (kV) exceeding the 10% allowed by law.¹ In another quality assurance study, Buchanan and colleagues reported a decrease in spatial resolution detected after 48 clinical uses, a finding that would not have been discovered without quality assurance measures.³ The findings of Walker et

Figure 2 Test images acquired on a manikin. Image (a): improper software settings result in an image that is too light. Image (b): adjusting the software settings improves the image contrast.

al and Buchanan et al confirm the need for standardized quality assurance procedures in digital imaging.^{1,3} Unfortunately, at the present time, a comprehensive resource on digital imaging quality assurance protocols is not available. Various subject matter experts in the field of dentistry recognize this need and are working to publish a new National Council on Radiation Protection and Measurements (NCRP) report for dentistry, NCRP Report SC 4-5: Radiation Protection in Dentistry Supplement: Cone Beam Computed Tomography, Digital Imaging, and Handheld Dental Imaging, which will include an update on digital imaging.⁵

Continued research on digital imaging quality assurance is essential. Research serves to establish a comprehensive and accurate knowledge base that advances didactic teaching and clinical practice. The purpose of this technical report is to describe an artefact, termed the fish scale artefact, discovered on an intraoral PSP plate imaging system.

Methods and Materials

30 new DIGORA Optime PSP plates (Soredex/Orion Corp., Helsinki, Finland) were imaged using the Dental Digital Quality Assurance (DDQA) radiographic phantom (Dental Imaging Consultants LLC, San Antonio, TX). The construction of the DDQA phantom has been described in detail by Mah and colleagues.⁶ Prior to imaging the 30 PSP plates, the DDQA radiographic phantom was used to determine the appropriate exposure parameters required to achieve the maximum diagnostic yield from the PSP plate image receptor. The phantom was imaged at 63 kV/8 mA and varying exposure times until all seven steps were visible in the step-wedge, thus verifying that the maximum dynamic range was achieved. The exposure time resulting in seven visible steps was 0.2 s. All 30 PSP plates were imaged using the exposure settings of 63 kV/8 mA/0.2 s. The Planmeca Intra direct current X-ray unit (Planmeca Oy, Helsinki, Finland) was used to acquire all radiographs. Even though all X-ray units at our institution are inspected annually, we also verified the consistency of the exposure output using the Piranha 557 meter (RTI Electronics, Mölndal, Sweden) prior to exposing the 30 PSP plates. The exposure parameters used in this study, 63 kV/8 mA/0.2 s, resulted in an exposure output of 1.138 mGy. The construction of the DDQA radiographic phantom allows for a fixed distance between the X-ray source and the image receptor and repeatable geometry (*i.e.* the X-ray beam is positioned perpendicular to the image receptor). The environmental conditions for imaging the DDQA radiographic phantom were reproduced for each exposure in order to ensure that backscatter was equal in all radiographic images, thus allowing for comparison between them. [Figure 3](#) demonstrates the exposure setup. All PSP plates were scanned at the same spatial resolution (dpi) using the high resolution mode provided by the DIGORA

Figure 3 (a) Photograph of the exposure set-up using the DDQA radiographic phantom. (b) Diagram of the exposure setup using the DDQA radiographic phantom. DDQA, dental digital quality assurance.

Optime system (model unit DXR-50-001-06) and calibrated in our digital viewing software MiPACS (Medicor Imaging Charlotte, NC) with a histogram stretch of 0.5–2 and a gamma value of 1. Consistent with protocol at our institution, all PSP plates were scanned in subdued ambient lighting to ensure that no plate erasing or degradation occurs during the scanning process. All recordings of artefact presence, spatial resolution, dynamic range and contrast resolution were completed within MiPACS after a monitor calibration was performed to confirm that the contrast and brightness settings of the monitor were acceptable. Two evaluators assessed all 30 plates. Evaluator 1 is a board certified Oral and Maxillofacial Radiologist (A. B.) with 6.5 years of experience. Evaluator 2 is a 4th year dental student. Prior to conducting the present study, the dental student was educated on the appearance of the artefact and evaluated a series of 20 PSP plates, which contained PSP plates with and without the artefact, for calibration. Each evaluator assessed the 30 PSP plates separately for purposes of establishing interrater

reliability, and then together in order to obtain the gold standard result. When a difference was encountered, both evaluators inspected the image together and came to a consensus on the presence/absence of the artefact. This consensus finding was defined to be the gold standard result. Figures 4 and 5 provide an example of the fish scale artefact. The fish scale artefact is located adjacent to the centre of the PSP plate for both size 1 and 2 plates (note: neither size 0 nor size 3 plates were evaluated in this study). The appearance of the fish scale artefact is textured similar to an orange peel pattern. This textured appearance results in uneven density across the PSP plate that can simulate a worn-out damaged PSP plate. This research study did not involve human subjects, patient data or human tissue and therefore IRB approval was not applicable.

Statistical analysis

Interrater reliability was determined using the kappa coefficient with a 95% CI. Coefficient kappa = 1 if there is perfect agreement between the two raters, kappa = -1 if there is perfect disagreement, and kappa = 0 if

Figure 4 (a) Study image displaying artefact (arrows) on new PSP plate acquired with DDQA phantom. (b) Artefact (arrows) on a clinical radiograph. DDQA, dental digital quality assurance; PSP, photostimulable phosphor.

Figure 5 Same images provided in Figure 4. The artefact has been traced for improved visibility.

agreement is no better than chance. Fleiss *et al* characterized values greater than 0.75 as representing “excellent agreement”, values between 0.40 and 0.75 as “fair to good”, and values below 0.40 as “poor agreement”.⁷

Agreement of each evaluator with the gold standard was determined using sensitivity, specificity and overall accuracy, with 95% CIs for each one. A value of 0.75 is generally considered to be the minimally acceptable value for each of these measures of agreement. In the present study, sensitivity for a given evaluator is represented by the percentage of “positive” PSP plates that were correctly classified as positive by that evaluator. Specificity for the evaluator is given by the percentage of “negative” PSP plates that were correctly classified as negative by the evaluator. Overall accuracy is given by the percentage of all PSP plates that the evaluator correctly identified.

Results

The fish scale artefact was present on 14 of the 30 PSP plates (46.7%). The kappa coefficient for measuring agreement between the two evaluators was 0.86 [95% CI (0.69–1.00)], indicating excellent interrater reliability. For Evaluator 1, sensitivity was 0.85 [95% CI (0.55–0.98)]; specificity was 0.94 [95% CI (0.71–1.00)] and overall accuracy was 0.90 [95% CI (0.73–0.98)]. For Evaluator 2, sensitivity was 1.00 [95% CI (0.75–1.00)]; specificity was 0.94 [95% CI (0.71–1.00)] and overall accuracy was 0.97 [95% CI (0.83–1.00)]. All of these results indicate excellent agreement with the gold standard for both evaluators. There were no significant differences between the gold standard agreement results for Evaluator 1 and Evaluator 2.

Discussion

Artefacts from PSP plate imaging are not uncommon and can result from user error or damage to the phosphor itself.^{8–10} Damage to the phosphor can be the result of improper handling, surface contamination from disinfectants, the adhesive on the barrier envelope and residue from gloves or ungloved hands.^{9,11} Chi and colleagues found that the incidence of artefact formation, resulting from PSP plate defects, was 9.3% in their clinic.⁸ These image artefacts consisted of damage from scratches, teeth, positioning devices and partial peeling of the phosphor.⁸ In fact, they had to replace 12 out of 50 PSP plates due to damage from scratches, teeth and positioning devices at the beginning stage of their research study.⁸ Bedard and colleagues discovered a high incidence of artefacts on PSP plates due to surface scratches.¹⁰ Specifically, they found that 95% of radiographic images became non-diagnostic due to surface scratches after 50 uses.¹⁰ Kalathingall *et al* also reported on artefact formation on PSP plates and found that 26%

of images were poor or unsatisfactory due to surface scratches and contamination.⁹

To the best of our knowledge, our study is the first to report on an artefact inherent within the phosphor itself. Artefacts, presumably due to defective sensors, have been reported for direct digital sensors. Mah and colleagues and Walker and colleagues found a Swiss-cheese and honeycomb artefact when using direct digital sensors.^{1,6} Therefore, we appear to be the first to report on an inherent PSP plate artefact. We found that the fish scale artefact was present on 46.7% of PSP plates. Examination of [Figures 4 and 5](#) indicates that the fish scale artefact is more prominent on the clinical images than on our study images (which were acquired with new PSP plates). This suggests the possibility that the artefact may increase in severity over time. Factors that might contribute to the degree of the artefact present on the phosphor plate may include normal wear and tear with clinical use as well as the disinfection and handling process and manufacture quality. It is also possible that the artefact is a result of the combination of these factors. However, additional research is needed to determine the causes of the artefact and to evaluate if the artefact can indeed become more prominent over time. Such a project is currently being conducted at our institution.

As part of a comprehensive quality assurance program, in addition to exposing the image receptors to assess image quality, radiographic units should be periodically inspected and X-ray output measured. Excessive exposure output from an intraoral X-ray unit has been reported in the literature.¹ Additionally, this X-ray unit could not achieve an acceptable entrance skin exposure upon calibration.¹ We measured the exposure output of the X-ray unit used in the present study and obtained a value of 1.138 mGy. The recommended entrance skin dose for intraoral periapical and bitewing radiographs is 1.6 mGy and the recommended achievable dose for intraoral radiography is 1.2 mGy.¹² Therefore the optimum exposure for our PSP plates, calculated with the DDQA phantom, are in compliance with the recommendations of the NCRP. When a quality assurance program is not in place, it is very likely that the optimum exposure is not being utilized for the image receptor. Udupa and colleagues reported wide-ranging values of optimum exposure for three different sensor models produced by the same manufacturer.¹³ Additionally, when evaluating optimum exposure in a private practice setting it was discovered that the exposure settings being used required an adjustment, most of which required a reduction in exposure.¹ Therefore, quality assurance is important not just from a diagnostic perspective of optimum performance of the image receptor but also from a radiation protection standpoint. The findings of our study and others corroborate the importance of continued research on digital imaging with the goal of developing reference standards for a comprehensive quality assurance protocol.

Conclusion

Utilizing a comprehensive quality assurance protocol, we identified a fish scale artefact inherent to the image

receptor. Additional research is needed to determine if the artefact remains static over time or if it increases in severity over time. Likewise, research to determine the potential sources contributing to an increase in the artefact is needed.

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