

COVID-19 and beyond: implications for dental radiography

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Key points

The avoidance of intraoral radiographs during COVID-19 has been recommended due to the potential of inducing a patient aerosol.

Extraoral bitewings were found to be a suitable alternative to sectional panoramic radiographs as they provided high-quality images with a lower radiation dose.

Recommendations are suggested for the use of extraoral bitewings post-COVID-19.

Abstract

Due to the coronavirus pandemic, all routine dental care in the UK ceased on 25 March 2020. Liverpool University Dental Hospital (LUDH) responded by commencing an emergency dental service on the same date. Clinicians were redeployed within the Hospital to meet the needs of the service, including staffing of the radiology department. LUDH followed Royal College recommendations by taking extraoral radiographs in preference to intraoral radiographs due to the risk of inducing an aerosol. Issues were identified with clinical diagnosis from sectional panoramic radiographs, which led to the introduction of extraoral bitewings being taken as an alternative. A quality assurance audit found that these images provided a substantially lower radiation dose and produced excellent quality images with improved diagnostic accuracy. This article aims to summarise how our radiography practices changed in response to the coronavirus and how the lessons that we have learnt provide an opportunity to modify and improve future practice, beyond the pandemic.

Introduction

Due to the coronavirus (COVID-19) pandemic, Liverpool University Dental Hospital (LUDH) ceased routine dental care on 18 March 2020 following advice from NHS England.¹ It became one of the first emergency dental care providers in the UK from 25 March 2020 for patients aged 16 and over, before the establishment of urgent dental centres. In the first eight weeks of the service, there were approximately 3,000 telephone calls triaged, 1,500 patient attendances and 1,250 radiographs taken. The majority of the LUDH radiographers were redeployed as part of the Trust's response to COVID-19, and so consequently, LUDH clinicians who were part of the emergency dental

team staffed the radiography department following training.

During COVID-19, the Royal College of Surgeons of England advised that radiography should be kept as simple as possible in order to minimise staff-to-patient contact, while providing diagnostic quality radiographs.² The recommendations state that sectional or full-width dental panoramic (DPT/OPG) radiography should be considered as the first line of imaging and it should be adequate for managing patients in acute settings, where only emergency treatment is being provided. Intraoral radiographs should be taken with caution due to the potential to cause a patient aerosol from coughing, gagging, retching or vomiting.

The LUDH radiography department has two panoramic machines capable of taking sectional radiographs (Instrumentarium Orthopantomograph OP200D and OP300). During the first couple of weeks of the emergency service, sectional panoramic radiographs were taken; however, diagnostic problems were identified when the tooth causing the dental pain was not always clear from the images, especially in heavily restored dentitions and where there was crowding in

the buccal segments. Gijbels *et al.*³ reported that the premolar region in the upper jaw is the region where further radiographs can be needed in addition to a conventional panoramic radiograph. The LUDH machines have a bitewing setting but, unlike intraoral bitewings, the apices of the teeth are visible (Fig. 1). The bitewing function on a dental panoramic machine is an orthogonal view, which opens up the contact points better than a conventional panoramic radiograph of the same area by using improved interproximal angulation projection geometry.⁴ Figure 2 shows a patient with pain in the 25/26 region who had an extraoral bitewing taken following an undiagnostic sectional panoramic radiograph. The extraoral bitewing was much clearer, and so consequently, the team felt that these images were a better alternative to sectional panoramic radiographs for diagnosing problems in posterior teeth.

In line with UK legislation, radiation doses should be kept as low as reasonably practicable (ALARP) while maximising diagnostic benefit.^{5,6} As quality assurance is central to these regulations, an audit was undertaken to assess the introduction of this alternative technique.

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Aim

To assess the quality of sectional extraoral radiographs taken at LUDH during the COVID-19 pandemic, and to identify possible areas for change and improvement.

Standards

The standards used in this audit were based on the image quality rating system and performance targets set by the National Radiological Protection Board guidance notes⁷ (Table 1). The criteria were applied in particular reference to the tooth/teeth requiring investigation rather than to the overall image. However, on every occasion, the clinical data from the whole radiograph was analysed and reported by the referring clinician.

Methods

A retrospective audit to assess the quality of all sectional extraoral radiographs taken during one week of the COVID-19 emergency dental service at LUDH (13–17 April 2020). The audit was registered with the Trust and the following data were recorded for each patient: type of radiograph, tooth of interest, quality rating (with reasons when grade 2 or 3), radiation dose area product and any extra areas of exposure outside the target field of view. The radiographs were assessed by an experienced radiographer and a clinician.

Dose area product (DAP) is a quantity used in assessing radiation risk and is defined as the absorbed dose multiplied by the area irradiated, expressed in milligrays per square centimetre (mGycm²). DAP reflects not only the dose within the radiation field but also the area of tissue irradiated. The DAP has been used in this audit as the figures are displayed by the machines at the end of the examination. However, when considering the patient dose for a particular projection, it is normally the effective dose which is quoted as this takes into account the sensitivity of the tissues that have been irradiated.

Results

Over the data collection period, 108 sectional extraoral radiographs were taken; 58 extraoral bitewings and 50 sectional panoramic radiographs (Table 2). There was a fairly even split between left- and right-sided radiographs

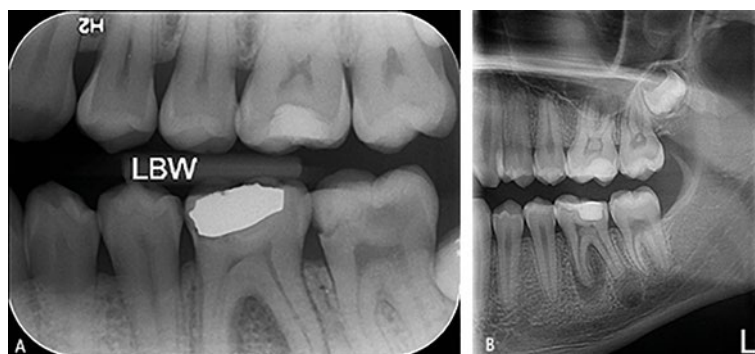


Fig. 1 a) Example of an intraoral bitewing. b) Example of an extraoral bitewing on OP300 panoramic machine

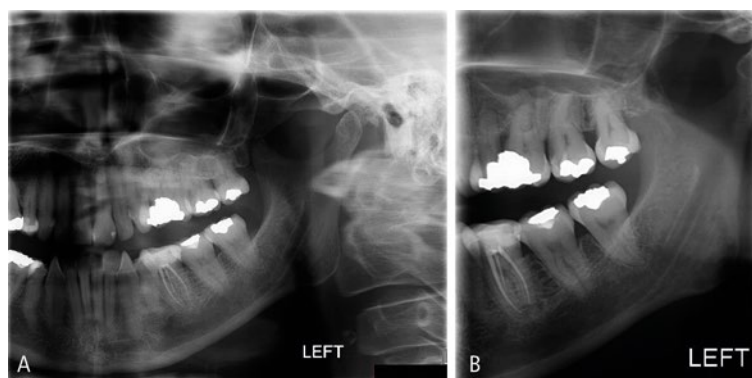


Fig. 2 a) Sectional panoramic radiograph. b) Extraoral bitewing for the same patient showing the differing field of view and improved separation of contact points

Table 1 Diagnostic quality rating of radiographs and performance targets (reproduced with permission from Public Health England)⁷

Rating	Quality	Performance targets
1	Excellent	Not less than 70%
2	Diagnostically acceptable with minor error	Not greater than 20%
3	Unacceptable/non-diagnostic	Not greater than 10%

Table 2 Radiation doses and quality ratings

Type of radiograph	Panoramic machine	Average DAP (mGycm ²)	Number of images (%)			
			Quality rating			Total
			1	2	3	
Sectional panoramic radiograph	OP200D	24.6	23 (85)	4 (15)	0 (0)	27 (25)
	OP300	73.2	22 (96)	1 (4)	0 (0)	23 (21)
Extraoral bitewing	OP200D	11.9	18 (85)	2 (10)	1 (5)	21 (20)
	OP300	32.1	36 (97)	1 (3)	0 (0)	37 (34)
Total			99 (92)	8 (7)	1 (1)	108 (100)

(51% right; 49% left). Overall, 92% of the radiographs taken were of excellent quality, 7% were diagnostically acceptable and 1% were unacceptable. Only one radiograph

was deemed grade 3 as the apex of an upper molar was not visible. The clinical reason for the image was to assess the root morphology before extraction, but the clinician did not



Fig. 3 Example of an extraoral bitewing on OP200 machine missing the apices of 27/28

require a further image in this instance. Eight radiographs were deemed to be grade 2; one radiograph did not include 3 mm of bone above the maxillary molar apex, two images were blurred and five were not sharp. From the five radiographs that were not sharp, two of the images were also grainy.

There was a difference when examining the results based on the panoramic machine; 85% were grade 1 for OP200D and 97% were grade 1 for OP300. However, there was little or no difference in the quality of images when comparing extraoral bitewings and sectional panoramic radiographs for both machines. The average DAP for an extraoral bitewing was less than half than that of a sectional panoramic radiograph for both machines. The DAPs on the OP200D were lower than the OP300 for each type of radiograph.

Sixty-eight percent of sectional panoramic radiographs had a greater field of view taken than was clinically necessary. Half of the sectional panoramic radiographs had the condyles included, 36% included the anterior section (canine-canine) and, in 22% of the images, the orbit was partially visible.

Discussion

It is encouraging that the results well surpassed the audit standards in terms of image quality. The OP300 machine is the updated model of the OP200D machine; therefore, it may not be surprising that it outperformed its predecessor in terms of radiographic quality. The images were sharper and less granular. The grade 2 images taken on the OP300 machine were due to blurring, which is most likely to have been caused by patient movement during the exposure.



Fig. 4 Image of control panel for OP300 showing five sections for possible selection

At LUDH, the bitewing setting had rarely been used before the COVID-19 pandemic, with increasing experience of taking bitewings on both the OP200D and 300 machines, it became apparent that, on the OP200D machine, the apices of the upper posterior teeth would be missed off and would therefore be undiagnostic and of grade 3 quality (Fig. 3). This is likely to be a localised issue with this model of machine as the chin rest does not lower for a bitewing setting. In the OP300 machine, the chin rest lowers compared to the tube head and sensor, which reduces the angulation of the x-ray beam and makes it more perpendicular to the teeth and sensor. The areas conventionally visible on an extraoral bitewing setting are the premolars, molars, the bottom of the maxillary sinus, the mandibular canal and the mental foramen. From our experience, the images did not always capture the first premolars in patients with larger jaws. A 2/5 sectional panoramic radiograph was therefore taken in preference for first premolars, which included the anterior segment but not the condyle, to avoid the need for possible further exposure (Fig. 4).

A study by Abdinian *et al.*⁴ showed that extraoral bitewings were superior to conventional panoramic radiographs for detection of proximal caries. In the literature, there are contrasting views regarding the use of intraoral and extraoral bitewings for detection of proximal caries; there is evidence to support intraoral bitewings being better,^{8,9,10} evidence of no difference¹¹ and evidence that states extraoral bitewings are the preferred method.¹²

Once panoramic radiographs have been taken, dental imaging software can be used to enhance images before saving them to a picture archiving and communication system. The adjustment of image contrast and density in post-processing can potentially improve the quality of the radiographs, along with other filter adjustments such as sharpen and noise reduction. There have been mixed opinions in the literature about whether post-processing enhances the image; a few studies found post-processing had no effect on the quality,^{3,13} but our experience aligns with the majority of studies that find post-processing enhances the image quality.^{14,15,16,17,18} Harvey *et al.*¹⁹ reported problems of ghost artefacts in a couple of case reports when using 'non-standard' panoramic programmes, like the bitewing setting, but we found no such issues. A minority of clinicians initially expressed a preference to conventional sectional panoramic radiographs rather than extraoral bitewings, but this was due to lack of familiarity when viewing the images and the early images were sometimes a little blurred. The sharpen function was subsequently used to enhance the radiographs using CLINIVIEW software and this post-processing resolved the issue. However, care must be taken as multiple sequential sharpening operations may degrade the image quality and cause excessive artefacts (Fig. 5).

National Diagnostic Reference Levels (NDRLs) are an indicative dose that is not expected to be exceeded under normal imaging conditions. The current NDRL in the UK for an adult full panoramic radiograph is 81 mGycm².²⁰ All images taken at LUDH were under this. The dosage was significantly higher on both the bitewing setting and sectional panoramic setting for the OP300 machine compared to the OP200D machine. On discussing this finding with the radiographers, it was discovered that this difference would not usually be so great, as they routinely manually increase the kilovoltage (kV) and milliamp (mA) on the OP200D machine in order to improve image quality. Due to the short-notice redeployment of the radiographers, emergency dental staff were trained to safely use the machines with standard settings and finer adjustments were beyond the scope of training. This may have accounted for a higher number of grade 2 images on the OP200D, with a grainy appearance occurring due to the settings being slightly low.

The extraoral bitewing setting reduced the radiation dose by more than 50% on each respective machine compared to the sectional panoramic radiographs, in line with the ALARP principle. This is in accordance with Lecomber and Faulkner²¹ who reported that, by limiting the radiograph to the tooth-bearing region of the jaws, the effective dose could be reduced by more than 50%. To allow comparison, Table 3 shows the average DAP for extraoral and intraoral (Instrumentarium Focus) bitewing radiographs for both adult and paediatric patients. The figures demonstrate that the radiation doses are very similar for extraoral and intraoral bitewings, particularly when round collimation is used.

At the beginning of the COVID-19 pandemic, emergency dental service clinicians were working in unfamiliar settings in both the radiography department and the emergency dental department. If the clinical history on the radiography request form was not specific, a 3/5 left-or right-sided panoramic radiograph was taken, rather than a more focused sectional view. Approximately two-thirds of the sectional panoramic radiographs therefore had a greater field of view taken than was necessary. Subsequently, information was communicated to all clinicians on the importance of specifying the symptomatic tooth/teeth to ensure that the radiation dose was justified and ALARP. The Ionising Radiation (Medical Exposure) Regulations (IR[ME]R) practitioner is responsible for the justification of the medical exposure, and in a hospital setting, the clinician is the IRMER referrer and the practitioner is usually a member of staff within the radiology department.⁶

The adult panoramic radiograph setting on the LUDH machines has a large field of view, which can be reduced in a transverse direction by deselecting fifths. Fifty percent of sectional panoramic radiographs included the condyles in the field of view, which is potentially unnecessary radiation exposure if only a dental problem is being investigated. Condyles should only be included for cases such as suspected temporomandibular joint (TMJ) pathology or trauma. It was identified that the orbit was partially visible in 20% of images, but the machines do not allow the field of view to be reduced in a superior/inferior direction on an adult programme. The paediatric programme does allow reduction, but the radiation settings are not optimal for adults.

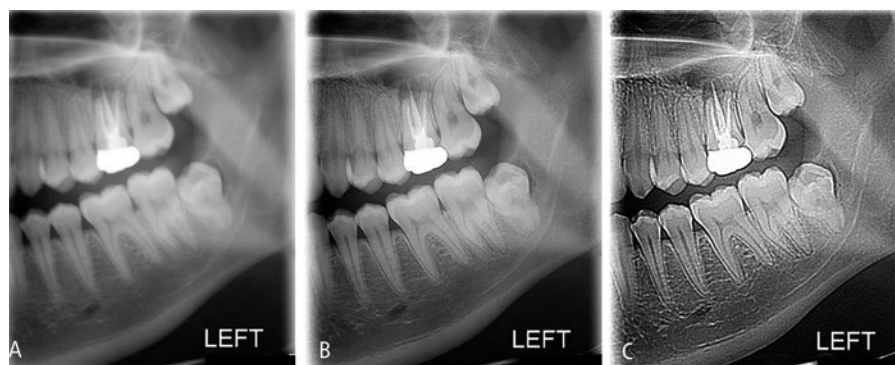


Fig. 5 a) Example of extraoral bitewing with no post-processing. b) Same image with one sharpen. c) Same image with multiple sharpens

Table 3 Radiation doses for extraoral and intraoral bitewings

Type of radiograph	Machine/equipment	Average DAP (mGycm ²)	
		Adult	Child
Extraoral bitewing	OP300	32.1	16.0
Intraoral bitewing	Long cone, round collimation	30.9	19.8
	Long cone, rectangular collimation	17.2	11.0

The use of extraoral bitewing radiographs at LUDH has increased substantially since the start of the COVID-19 pandemic and our experience in using this technique has highlighted its potential use moving forwards. In line with recent guidance on returning to general dental practice,²² paediatric patients and those with a learning/cognitive disability would benefit greatly from an extraoral imaging technique. Patients with a strong gag reflex or those who struggle to tolerate the bulk and size of intraoral films would also benefit. Additionally, they could be used instead of vertical bitewings to assess alveolar bone levels posteriorly, which can be uncomfortable for patients with multiple images needing to be taken. Furthermore, there is a reduced need for sterilisation of the intraoral film holders, leading to a small cost efficiency saving.

To the best of our knowledge, the following panoramic machine brands have the ability to capture extraoral bitewings: Carestream, Gendex, Instrumentarium, KaVo, Planmeca, Sirona, Soredex and Vatech. Dental practitioners may wish to review whether their own panoramic machines have this functionality. Machines must be tested and audited locally to assess the quality and to review radiation doses in relation to NDRLs.

Conclusions and recommendations

The quality of sectional extraoral radiographs taken at LUDH during the pandemic surpassed the gold standard, with 92% of all images being grade 1. It has been suggested that the COVID-19 pandemic provides a unique opportunity for change in healthcare.²³ The avoidance of intraoral radiographs during COVID-19 has highlighted the usefulness of extraoral bitewings. Their radiation dose is lower than sectional panoramic radiographs and is comparable to intraoral bitewings, while providing a greater field of view. Ionising radiation has the potential to damage human tissue, including fatal malignant change; therefore, minimising the radiation dose while maintaining diagnostic images is paramount for patient safety.

The following recommendations are suggested:

- In a secondary care setting, ensure all the teeth of interest are specified when requesting a radiograph to allow the IRMER practitioner to minimise the field of view on the panoramic radiograph and minimise radiation dose
- During the COVID-19 pandemic and recovery phase, consider using an extraoral bitewing setting on a panoramic machine if available, in circumstances where an

intraoral periapical radiograph would usually be taken or if multiple teeth are symptomatic in a posterior quadrant(s)

- Remove the condyles from the field of view for any sectional panoramic radiograph if there is no TMJ pathology noted, or simply reduce the field of view to the tooth-bearing region of the jaws
- Post-COVID-19, consider extraoral bitewings as an alternative to vertical bitewings or for children and adults who struggle to tolerate intraoral radiographs, in order to enhance diagnostic information and patient experience.

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