National reference doses for dental cephalometric radiography

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Objectives: Diagnostic reference levels (DRLs) are an important tool in the optimisation of clinical radiography. Although national DRLs are provided for many diagnostic procedures including dental intra-oral radiography, there are currently no national DRLs set for cephalometric radiography. In the absence of formal national DRLs, the Health Protection Agency (HPA) has previously published National Reference Doses (NRDs) covering a wide range of diagnostic X-ray examinations. The aim of this study was to determine provisional NRDs for cephalometric radiography.

Methods: Measurements made by the Dental X-ray Protection Service (DXPS) of the HPA, as part of the cephalometric X-ray equipment testing service provided to dentists and dental trade companies throughout the UK, were used to derive provisional NRDs.

Results: Dose–area product measurements were made on 42 X-ray sets. Third quartile dose–area product values for adult and child lateral cephalometric radiography were found to be 41 mGy cm² and 25 mGy cm², respectively, with individual measurements ranging from 3 mGy cm² to 108 mGy cm².

Conclusion: This report proposes provisional NRDs of 40 mGy cm² and 25 mGy cm² for adult and child lateral cephalometric radiographs, respectively; these doses could be considered by employers when establishing their local DRLs.

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Since the introduction of the Ionising Radiation (Medical Exposure) Regulations in 2000 (IR(ME)R 2000) [1], employers responsible for the use of dental and medical X-ray equipment have been required to establish local diagnostic reference levels (DRLs) for each common radiographic procedure undertaken. Reviews of their radiography practices are required if DRLs are consistently exceeded. In effect, a diagnostic reference level can be considered the level of dose expected not to be exceeded for a standard procedure when good and normal practice regarding diagnostic and technical performance is applied. Local DRLs should be established by the employer in consultation with the appointed medical physics expert (MPE).

To assist employers to set appropriate local DRLs, the Department of Health adopted national DRLs for many common X-ray examinations [2]. National DRLs are normally set at the third quartile value of the patient dose distribution observed for a particular type of X-ray examination during a widescale survey (*i.e.* the patient dose value that only 25% of assessed X-ray sets exceed).

The national DRLs adopted by the Department of Health were primarily based on the Health Protection Agency's (HPA) 2000 review of the National Patient Dose Database (NPDD) [3]. However, at the time of the review, dental X-ray examinations were not included in the NPDD. Subsequently, the national DRL for dental intra-oral examinations was based on separate patient dose data published by the HPA in 1999 [4].

The NPDD was designed to collate measurements of patient radiation doses from common diagnostic X-ray

examinations carried out throughout the UK and to provide a major source of information for the review and adoption of new national DRLs. In July 2007, the HPA published the 2005 review of the NPDD [5]; this time, the review included dose data from dental X-ray examinations and proposed new National Reference Doses (NRDs) for intra-oral and panoramic examinations, which updated those first proposed in 1999 [4]. Although these NRDs for intra-oral and panoramic examinations have not been formally adopted by the Department of Health as national DRLs, the data collected are representative of current practice.

When setting a local DRL, national DRLs and NRDs should be considered and it would be expected that the local DRL should not normally exceed the national level. However, just ensuring that patient doses are below the national DRL or NRD does not mean that local practices are being optimised. Dental surgeries using modern equipment and techniques should be able to set a local DRL significantly lower than the national level, based on their local circumstances.

A national review of doses arising from dental cephalometric examinations has never been undertaken in the UK and cephalometric doses have not, to date, been included in the NPDD. For many years, however, the Dental X-ray Protection Service (DXPS) of the HPA has carried out the commissioning and routine quality assurance testing of cephalometric equipment installed throughout the UK. As part of the testing procedures, measurements are made of representative patient doses. This report proposes a patient dose measurement method together with rounded third quartile dose values for adult and child lateral cephalometric radiography based on the patient dose measurements made by DXPS.

Owing to the specialist applications of cephalometric radiography, there are only a relatively small number of

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units in use in the UK compared with intra-oral or panoramic equipment; consequently, the sample size considered in this report is fairly small. However, the dose measurements are considered reasonably representative of UK practice so that the third quartile values can be considered as provisional NRDs and provide a useful guide to employers when establishing their local DRLs. Furthermore, it is anticipated that the patient dose data presented in this report and any data subsequently collected on cephalometric radiography doses will be included in the NPDD so that future reviews of the database can propose NRDs for cephalometric radiography.

Methods and materials

Cephalometric dosimetry

A review was carried out to determine if reference levels for cephalometric radiography are applied in other countries. This analysis identified only three countries that have set reference levels (Table 1).

These reference levels use two different dosimetric quantities: entrance surface dose (ESD) and dose-area product (DAP). ESD is a measure of the radiation dose absorbed in air at the position at which the X-ray field is incident on the patient. DAP is the product of dose absorbed in air at a reference point and the area of the X-ray field at that point (hence, it is independent of the actual position used to make the measurement). The use of DAP as a measure of patient dose is advantageous because it is more closely related to effective dose than ESD is; DAP also reflects any steps taken to reduce the patient exposure by reducing the size of the X-ray beam incident on the patient. By collimating the radiographic image to only the area of diagnostic interest, the DAP can be significantly decreased. It has been shown that, by using an appropriate collimator, patient doses can be reduced by up to 47% [6] compared with a standard 30 × 24-cm sized cephalometric radiograph.

In fact, the use of DAP as a dose metric for setting DRLs is specifically recommended by the European Commission for establishing reference levels for cephalometric radiography [7], because the size of the X-ray field is readily measurable for cephalometric radiography, it is proposed that DAP is adopted as the quantity for measurement of the reference level.

National DRLs are typically established for both adult and child patients. Because cephalometric radiography is predominantly utilised for adolescent patients, it is important that reference levels are set for both child and adult radiography, separate third quartile DAP values are presented in this report.

Collection of cephalometric dose data

Radiation dose measurements made by DXPS between January 2008 and August 2009 are included in this analysis. The radiation dose measurements were made either during initial commissioning or during routine quality assurance testing. Where measurements were taken during commissioning, the equipment was operated using the exposure factors that were intended to be used for clinical imaging.

Cephalometric equipment can typically be operated in two modes, lateral and anteroposterior. It was established from discussions with clinicians that lateral radiography was the mode of operation in which the equipment was predominately used; many clinicians had never operated the equipment in anteroposterior mode. For this reason, patient dose data were collected only for the lateral mode of operation.

The cephalometric X-ray sets were operated using the dental practice's standard technique factors for adult and child lateral radiography. The child setting was taken to be the setting the dentist would use when taking a radiograph of a 13-year-old male patient, as this was considered to be a typical age for when cephalometric radiographs are taken.

The radiation dose was measured using a solid-state X-ray detector (Unfors Xi meter with R/F detector; Unfors Ltd, Billdøl, Sweden) and X-ray-sensitive film (Structurix; GE Technologies, Coventry, UK) was used to capture an image of the X-ray field size. These measurements were made at the film cassette position (or, for digital equipment, at the digital detector position) for ease of measurement and without a phantom present. The active width of the Unfors detector is approximately 2 mm, allowing it to be positioned within the X-ray beam for the full exposure even with the narrow X-ray beam used by some models that employ a scanning, narrow X-ray beam. The use of this solid-state detector means that the measured doses will not include backscatter from the imaging system, as the rear of the detector is shielded. If doses were measured for comparison using an alternative detector type, this would need to be considered.

Results

Table 2 presents a summary of the results obtained. Figures 1 and 2 show each patient dose measurement in ascending DAP value. The horizontal bars represent the third quartile DAP value.

Discussion

The difference in the number of X-ray sets included in the adult and child assessments is a consequence of developments in the data collection methods and the selection of representative examinations.

Table 1. Reference levels for cephalometric radiography in other countries

Country and reference	Year	No. of X-ray sets considered	Reference level
USA [9]	2005	Not stated	0.25 mGy (ESD without backscatter)
Germany [8]	2007	20	26.4 mGy cm ² (child) 32.6 mGy cm ² (adult) (DAP) (lateral)
Spain [10]	2004	78	0.40 mGy (ESD) (lateral)

DAP, dose-area product; ESD, entrance surface dose.

Table 2. Summary of lateral cephalometric dose data

	Adult	Child
No. of X-ray sets	42	27
Minimum dose (mGy)	0.07	0.03
Maximum dose (mGy)	2.85	2.21
Minimum beam size (cm ²)	6	6
Maximum beam size (cm ²)	832	832
Minimum DAP (mGy cm ²)	3	3
Maximum DAP (mGy cm ²)	108	102
Mean DAP	32	25
Third quartile DAP	41	25

DAP, dose–area product.

The dose and beam size measurements show a significant range of values. This variation is primarily due to the image capture process utilised by cephalometric equipment; the image capture process for the majority of direct digital equipment is significantly different from film and computed radiography. Film and computed radiography typically capture the entire radiographic image in a single subsecond exposure, whereas direct digital equipment uses a narrow X-ray beam that scans the patient either horizontally or vertically to acquire the image over a number of seconds. Consequently, the doses measured for scanning digital systems are significantly higher than for other systems; however, the measured beam sizes are lower, which explains the significant differences in the dose and beam size results presented in Table 2. Nonetheless, the DAP measurements, which are the product of dose and beam size, should be comparable between the two types of image capture process.

Table 3 shows the third quartile dose values for the different image capture techniques. Of the 42 X-ray sets where adult dose measurements were made, 12 used film-based imaging and 30 used either direct digital or computed radiography imaging. The adult third quartile DAP value for equipment that uses digital imaging (either direct digital or computed radiography) was found to be 40 mGy cm² compared with a value of 42 mGy cm² for film-based systems. However, both the highest and lowest DAP measurements were from X-ray sets utilising digital imaging. This could suggest

Figure 1. Summary of dose–area product (DAP) measurements using adult exposure parameters, ordered by increasing DAP. The horizontal bar represents the third quartile DAP value. **Figure 2.** Summary of dose–area product (DAP) measurements using child exposure parameters, ordered by increasing DAP. The horizontal bar represents the third quartile DAP value.

either that different digital imaging devices require significantly different doses to obtain optimum diagnostic images or that technique factors are not being optimised for digital imaging systems, resulting in significantly higher patient doses.

The peak DAP measurements were obtained from equipment that uses large direct digital sensors that can capture the entire radiographic image without scanning. These machines typically use a larger X-ray field size than the majority of film or scanning digital systems that, combined with comparable or even higher exposure parameters, lead to the higher DAP measurements.

Comparing the adult and child third quartile DAP values in Table 2 with the German reference levels presented in Table 1 shows that there is good agreement for the child value and reasonable agreement for the adult value.

The method presented in this paper uses a solid-state detector and an X-ray-sensitive film to derive the DAP. Care should be taken to ensure that any inhomogeneity shown on the developed film is taken into account when calculating the DAP (e.g. the reduction in dose owing to additional filtration over part of the image area).

An alternative method that has been shown to be appropriate for the measurement of DAP of cephalometric equipment is to use a dedicated DAP meter attached to the front of the X-ray tube port [8]. The use of a DAP meter would not require separate dose and beam size measurements to be made and would compensate for any inhomogeneity within the X-ray beam.

Conclusion

Provisional NRDs of 40 mGy cm² and 25 mGy cm² for adult and child lateral cephalometric radiography, respectively, are considered to be representative of current equipment performance and might be referred to when setting local DRLs. X-ray sets provided with static digital imaging systems were associated with the highest DAP measurements, all of which exceeded the provisional NRDs. Extra care should be taken to ensure that exposures are optimised for these X-ray sets, and, where variable collimation is provided, the smallest

Table 3. Third quartile dose values, separated by image capture method

Imaging system	Third quartile value (adult)	Number of X-ray sets	Third quartile value (child)	Number of X-ray sets
Film	42	12	24	8
All digital	40	30	38	19
Digital (scanning)	20	24	19	14
Digital (static)	81	6	57	5
All	41	42	25	27

collimation option should be selected consistent with accurate diagnosis.

Data from cephalometric X-ray sets will be stored in the NPDD and will be included in future reviews of the NPDD.

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