Trends in Dental Radiography Equipment and Patient Dose in the UK and Republic of Ireland

A review of data collected by the HPA Dental X-Ray Protection Services between 2008 and 2011 for intra-oral and panoramic X-ray equipment

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ABSTRACT

The Dental X-ray Protection Services group (DXPS) of the Health Protection Agency (HPA) carries out equipment performance tests on all forms of dental radiography equipment in the UK and Republic of Ireland. In 2007, a review of data collected by DXPS between 2002 and 2004 was presented which provided information on dental radiography equipment and patient doses in the UK at that time. Since then, improved data collection methods have been used to obtain more detailed information about dental radiography in both the UK and Republic of Ireland.

This review presents a summary of the data collected by DXPS between 2008 and 2011 for intra-oral and panoramic radiography. The data is used to form a view on current dental radiography practices in the UK and Ireland and to consider future developments. For the first time data is provided on the use of digital imaging systems and, for intra-oral radiography, the use of rectangular collimation which has long been recommended in preference to circular collimation due to the significant reduction in patient effective dose that is achievable.

This review shows that since the 2007 review, patient doses have continued to decrease in intra-oral radiography, due in part to X-ray sets operating below 50 kVp becoming obsolete and the significant decrease in the use of speed group D films. The anticipated dose savings from using digital imaging are yet to be fully realised as many practices are either not selecting appropriate exposure settings on their X-ray equipment or their equipment cannot fully exploit the dose savings of digital imaging due to the unavailability of sufficiently low exposure settings.

For panoramic radiography, the patient dose measurements included in this review indicate that average patient doses have not decreased. The increased use of digital imaging systems does not appear to have had a significant effect on patient doses at present. However, the newer generation of digital systems which utilise very short exposure times may lead to reductions in doses over the next few years if more of these systems are introduced into dental practices.

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CONTENTS

1 INTRODUCTION

The Dental X-ray Protection Services group (DXPS) of the Health Protection Agency (HPA) has provided radiation protection services to the dental community in the UK for over 30 years. More recently, DXPS has also provided radiation protection services to dentists in the Republic of Ireland. As part of these services DXPS carries out equipment performance measurements of all types of dental X-ray equipment, with the most common types of X-ray equipment, intra-oral and panoramic, being assessed by using a remote 'test pack' method. The details of the assessment method have previously been discussed in detail (Gulson, Knapp and Ramsden, 2007).

Dental X-ray examinations are the most frequent radiography examination performed in the UK, and account for 26% of all radiographs (Hart, Wall, Hillier and Shrimpton, 2010). The radiation doses from individual dental radiographs are generally lower than other forms of medical X-ray examinations and consequently dental X-rays are responsible for only 0.4% of the UK collective dose from medical exposures (Hart, Wall, Hillier and Shrimpton, 2010).

Dentists, like all users of medical radiography equipment, are required by The Ionising Radiation (Medical Exposure) Regulations 2000 (and the subsequent amendments) to ensure that patient doses are kept as low as reasonably practicable (ALARP). One requirement of this legislation is that dental practices are required to set diagnostic reference levels (DRLs) for each common radiographic procedure undertaken. A diagnostic reference level can be considered the level of dose expected not to be exceeded for a standard procedure when good practice regarding diagnostic and technical performance is applied.

To assist dental practices to set appropriate DRLs, the HPA publishes National Reference Doses (NRDs) for many common radiographic procedures. NRDs are based on large scale surveys of patient doses and are equivalent to the third quartile value of the dose distribution. The NRD indicates a level of patient dose below which three quarters of users can achieve satisfactory radiographs. The NRD can therefore highlight to those dental practices that are using significantly higher patient doses than their peers that they should try to reduce their exposure settings to reduce the doses received by their patients. The latest NRDs for intra-oral and panoramic radiography were proposed in the 2010 review (Hart, Hillier and Shrimpton, 2012) and were based on data collected between January 2006 and December 2010. The values are presented in Table 1.

Table 1 Current UK National Reference Doses in Dental Radiography

Examination [dose measurement]	NRD
Intra-oral, adult mandibular molar [Patient Entrance Dose]	1.7 mGy
Standard adult panoramic [Dose Area Product]	93 mGy cm^2

The DXPS test pack provides an assessment of patient entrance dose and the dose data collected between July 2007 and July 2010 was submitted to the National Patient Dose Database (NPDD) to be included in the 2010 review. The purpose of this review is to provide a detailed analysis of the comprehensive data on current intra-oral and panoramic dental radiography equipment obtained by DXPS. The data is used to provide a view on current dental radiography practices in the UK and Ireland and to consider future developments.

2 METHOD

The DXPS test pack captures information regarding the operating parameters of the X-ray set: operating potential, beam filtration, collimation and radiation output. Additional information regarding the type of film or digital imaging system which is used and the standard exposure factors for a range of radiographic images is also obtained from a questionnaire which is completed by the person carrying out the test. As the NRDs are set for an intra-oral mandibular molar radiograph and a standard adult panoramic radiograph, patient entrance doses for these radiographs are assessed by DXPS and the results presented in this review.

In the UK, the Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment (National Radiological Protection Board [NRPB], 2001) recommended that dental X-ray equipment is tested at least once every three years, therefore, selecting a three year period should capture a good sample of equipment tested by DXPS. In Ireland equipment must be assessed every two years (Radiological Protection Institute of Ireland [RPII], 1996), however, as less data is available it was decided to use the same three year data collection period. Data collected by DXPS between October 2008 and September 2011 is analysed in this review.

The data in this review cover 6136 practices in the UK and 187 practices in Ireland. On 22 November 2011, there were 9667 dental practices in the UK (Office of Fair Trading, 2012) and on 1 January 2011 there were 933 practices in Ireland (RPII, 2011). Assuming these values are still accurate, DXPS undertakes assessments for approximately 63% of dental practices in the UK and 20% of practices in Ireland. The data presented in this review can therefore be considered to be representative of radiography practice throughout the UK and Ireland.

2.1 Data Analysis

Data was initially screened to remove multiple assessments of the same X-ray set with only the most recent assessment for an X-ray set being retained. Results that represented outlying values of the assessed parameters were individually reviewed to ensure that they were valid before including them in the data analysis.

The resulting data was then split into three groups: UK routine tests (UK R), UK Critical Examination and Acceptance Tests (UK CE) and Republic of Ireland tests (ROI). This is the first review of DXPS data to contain information from Ireland and from critical examinations. In the UK, The Ionising Radiations Regulations 1999 require that new installations of radiography equipment must be subject to a critical examination and acceptance test before being put into use. Previous reviews of DXPS data have excluded CE data as it was not considered to be representative of equipment currently in use. However, important information can be gained from this data as it represents the newest equipment and provides a useful indication of current trends. For this reason data from critical examinations is included in this review, but retained as a separate group. The breakdown of X-ray sets included in this analysis is presented in Table 2.

Table 2 Number of X-ray sets included in this review

Type of X-ray equipment	UK R	UK CE	ROI	Total
Intra-oral	7559	3981	286	11826
Panoramic	1366	829	90	2285
Total	8925	4810	376	14111

3 RESULTS AND DISCUSSION

Data are presented as both summary tables and charts. Charts which are presented as frequency distributions have a horizontal axis label which indicates the maximum value of data in that column. The vertical axis therefore indicates the number of X-ray sets whose assessed value falls between the column label and that of the column label to the left.

3.1 Intra-oral X-ray Equipment

A summary of all the relevant data for the intra-oral X-ray sets included in this review is presented in Table 3.

Patient entrance dose and the X-ray beam size was measured at the end of the director cone. Where digital imaging systems are used they are split into two types, either Computed Digital Radiography (CDR) or Direct Digital Radiography (DDR) systems. CDR systems normally utilise phosphor storage plates and DDR systems typically use either Charge Coupled Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) image sensors.

Table 3 Summary of intra-oral X-ray sets. Results are presented as the number of X-ray sets or mean (range) value

	UK R	UK CE	ROI
Number	7559	3981	286
Collimation			
Circular	4414	1559	159
Rectangular	3145	2422	127
Imaging system			
Self-developing film	2	0	3
D speed film	458	211	30
E speed film	2596	919	69
F speed film	1898	765	57
CDR (eg. Phosphor plate)	1390	1146	70
DDR (eg. CCD or CMOS)	991	584	50
Unknown digital system	78	121	3
Unknown film speed	146	235	4
Operating Potential (kVp)	68 (45 – 80)	67 (45 – 81)	65 (45 – 77)
Exposure time (s)	0.24 (0.02 – 2.0)	0.21 (0.01 – 1.8)	0.24 (0.02 – 1.6)
Beam diameter (mm)	58 (33 – 77)	58 (48 – 69)	56 (52 – 63)
Beam width (mm)	45 (33 – 55)	45 (33 – 51)	44 (33 – 55)
Beam height (mm)	35 (22 – 44)	35 (22 – 43)	34 (22 – 45)
Patient Entrance Dose (mGy)	1.4 (0.11 – 11.4)	1.4 (0.04 – 9.20)	1.5 (0.08 – 4.86)
Dose Area Product (mGy cm^2)	15 (1 – 108)	18 (1 – 90)	17 (1 – 80)
Cone length			
< 200 mm	18	3	0
200 – 299 mm	5739	2439	277
300+ mm	1802	1539	9

3.1.1 Operating Potential

In the UK (IPEM, 2005) and in Ireland (RPII, 1996), operating potentials are required to be 50 kVp or greater. Figure 1 shows the distribution of operating potential for the X-ray sets considered in this review. It can be seen that 20 UK R, 1 UK CE and 1 ROI assessments had operating potentials below 50 kVp. This indicates that practically all X-rays sets are capable of meeting the requirement. X-rays sets should also operate within 10% of the selected value (IPEM, 2005; RPII, 1996). Based on 6399 assessments, for which the selected operating potential was recorded, this requirement was met by 97% of X-ray sets.

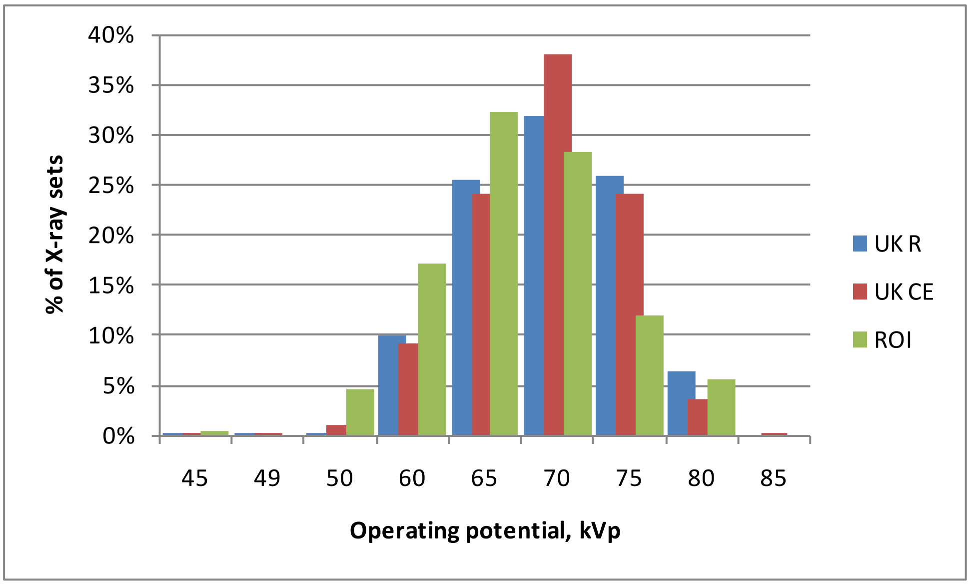

Figure 1 Distribution of operating potential (kVp) values for intra-oral X-ray sets

3.1.2 Beam Collimation

The use of rectangular collimation is recommended in both the UK (NRPB, 2001) and Ireland (RPII, 1996) due to the reduction in patient effective doses that can be achieved through the use of a smaller X-ray beam that matches more closely the shape of the intra-oral film or digital detector. Rectangular collimators should be provided as standard on newer equipment and retrofitted to older X-ray sets. Figure 2 gives the percentages of each type of collimator used for the X-ray sets included in this review.

Rectangular collimation is used in 42% of UK R assessments and 44% of ROI assessments, indicating that almost half of the intra-oral X-ray sets assessed utilise this technique to reduce patient doses. Encouragingly, 61% of UK CE assessments showed that rectangular collimation was fitted at the time of installation, indicating that an increasing proportion of new equipment is being provided with rectangular collimation as standard.

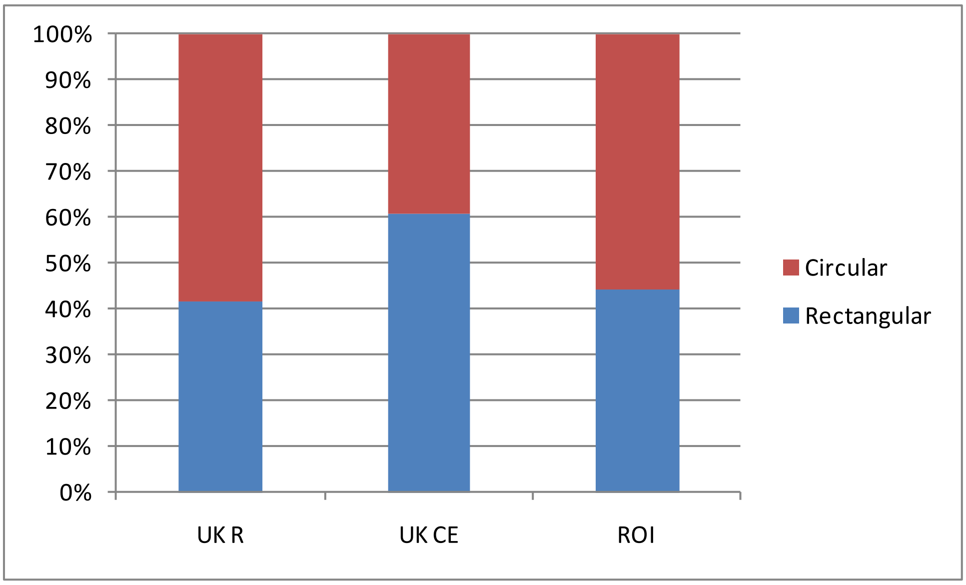

Figure 2 Percentage of intra-oral X-ray sets using circular and rectangular beam collimation

3.1.3 Imaging System

The use of E-speed film or faster imaging techniques is recommended in the UK (NRPB, 2001), with a similar recommendation being made in the Republic of Ireland (RPII, 1996). Figure 3 shows the imaging methods used for the X-ray sets included in this review. Only 6% of UK R assessments reported that the X-ray set was being used with slower D-speed film. In 1999, 75% of X-ray sets were used with D-speed film (Napier, 1999) and by 2004 this had reduced to 27% (Gulson, Knapp and Ramsden, 2007). This study shows that the use of D-speed film has reduced significantly once again. In Ireland, 12% of X-ray sets were used in combination with D-speed film indicating that many dentists are aware of the dose savings that can be obtained by using faster film speeds or digital imaging systems.

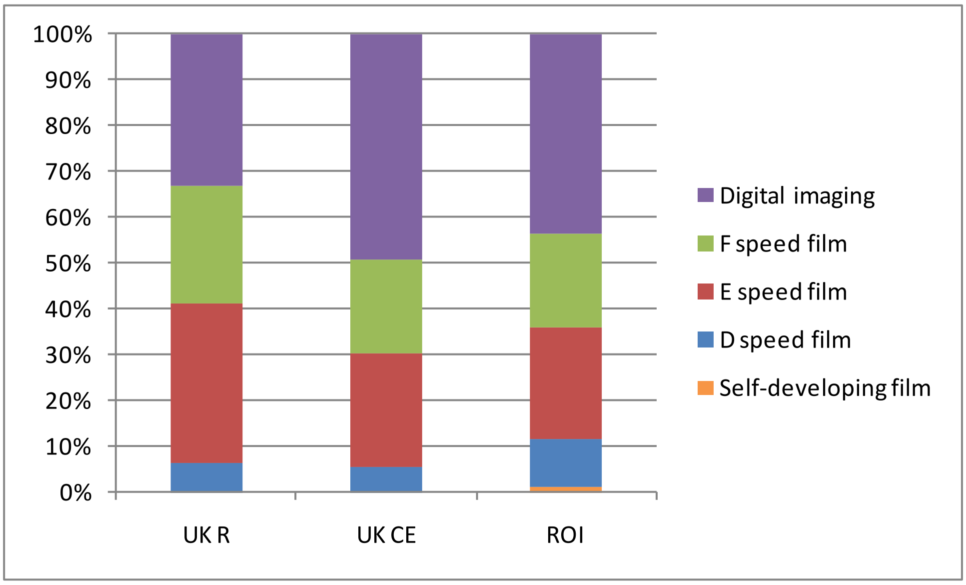

Figure 3 Percentage of intra-oral X-ray sets using the different imaging systems

Figure 4 shows the percentage of the different digital imaging methods in use. Most dentists who use digital imaging are using CDR systems. These systems will be associated with a lower cost of ownership in a larger practice where one 'reader' can be bought and shared between surgeries, whereas DDR systems will typically require at least one expensive sensor per surgery.

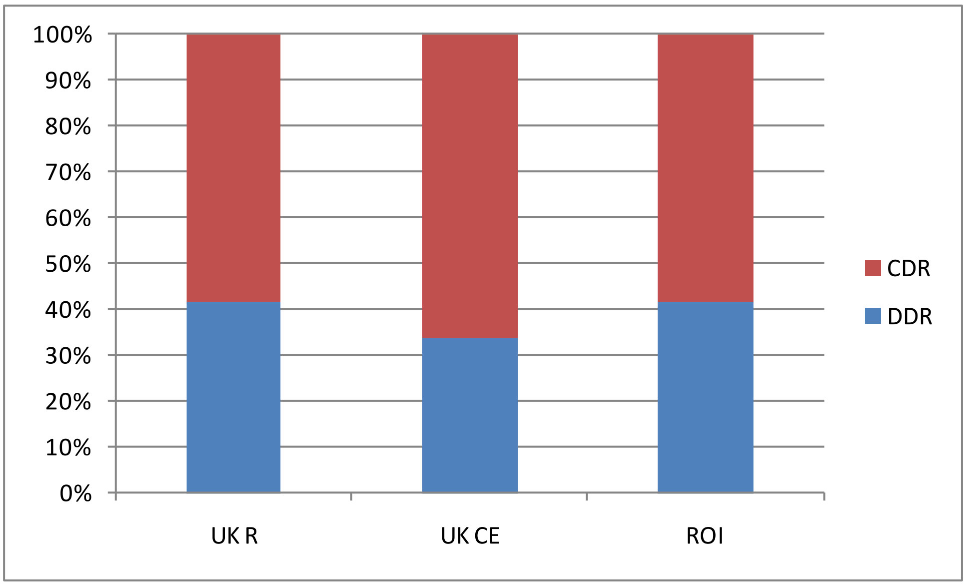

Figure 4 Percentage of intra-oral X-ray sets that are used with digital imaging systems distinguished by the type of digital imaging system used

To determine whether the use of different imaging systems changed over the three year period considered in this review, Figure 5 and Figure 6 below show the percentage of UK X-ray sets used in combination with either digital imaging or D speed film for each of the three years reviewed. ROI data was purposefully excluded due to the relatively small number of X-ray sets assessed each year, which does not allow year on year trends to be identified.

The use of digital imaging has increased year on year, from 17% of UK R assessments conducted in 2008 to 45% of UK R assessments conducted in 2011. In 2011, 60% of UK CE assessments identified that digital imaging was the being used and this is a trend which is expected to continue as more dentists replace film with digital systems. The use of D speed has continued to decrease year on year.

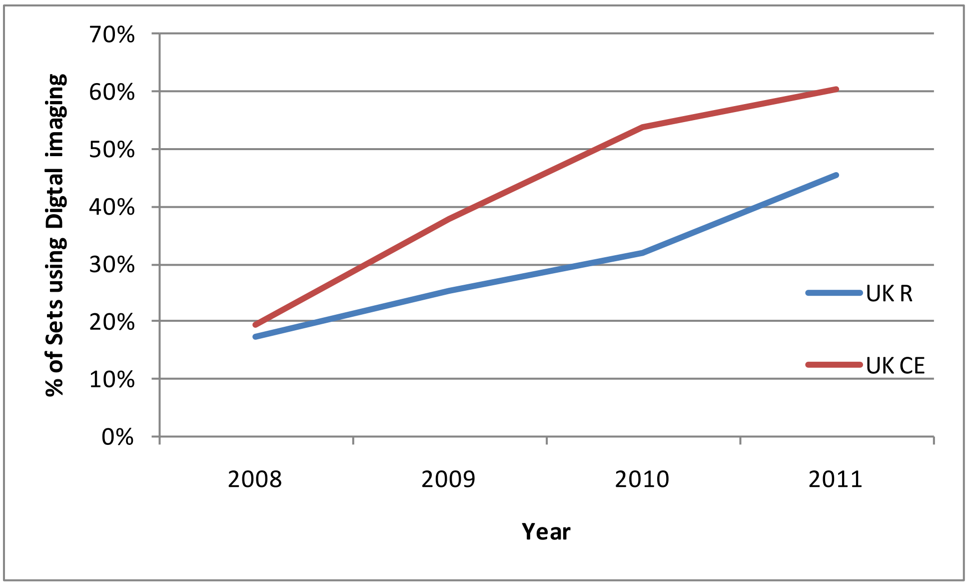

Figure 5 Change in the percentage of intra-oral X-ray sets that are used with digital imaging systems in the period 2008 to 2011

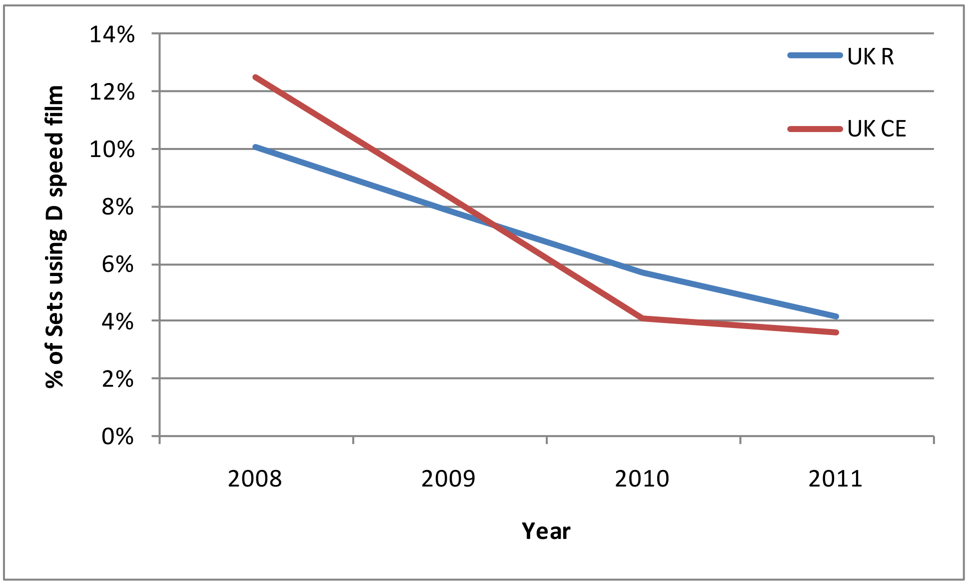

Figure 6 Change in the percentage of intra-oral X-ray sets that are used with D-speed film in the period 2008 to 2011

3.1.4 Patient Dose

Figure 7, Figure 8 and Figure 9 show the distribution of patient entrance doses for adult mandibular molar radiographs for UK R, UK CE and ROI assessments respectively. These figures show that dentists are delivering a wide range of doses to their patients for similar radiographic examinations.

Some variation in patient dose may be explained by the different speeds of imaging system being used (i.e. how responsive they are to radiation exposure). In order to establish whether this is a major reason for the different patient doses reported in this review, the doses were separated according to the speed of imaging system used and the results are presented in Figure 10. This data indicates that a wide range of patient doses are still being delivered when imaging systems of equivalent speed are being used. It can be inferred that a number of dental practices could reduce the doses delivered to their patients, using their current imaging systems, without any detriment to the diagnostic quality of their radiographs.

Figure 11 shows no observable difference in patient doses during the time period reported in the review.

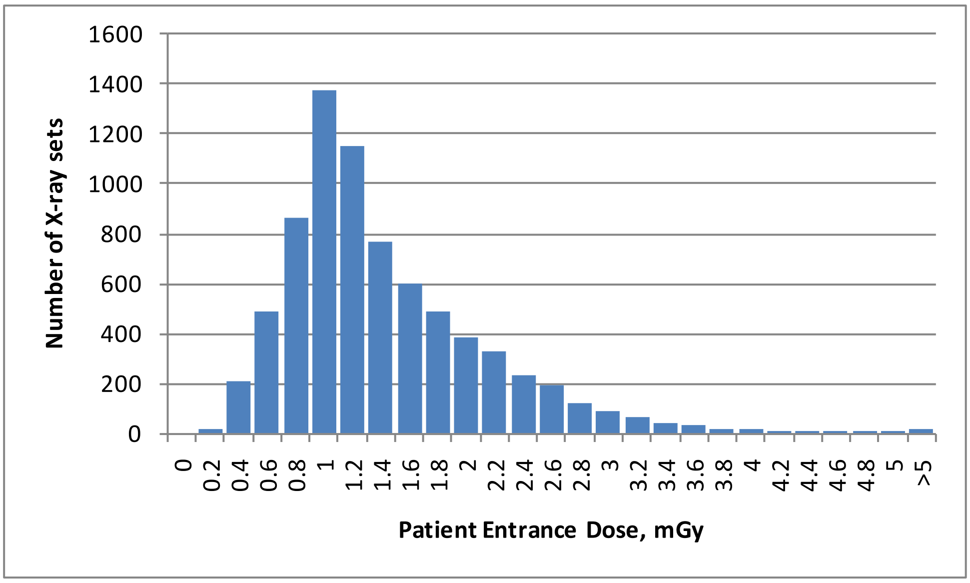

Figure 7 Distribution of intra-oral patient entrance dose measurements for adult mandibular molar radiographs from UK R assessments

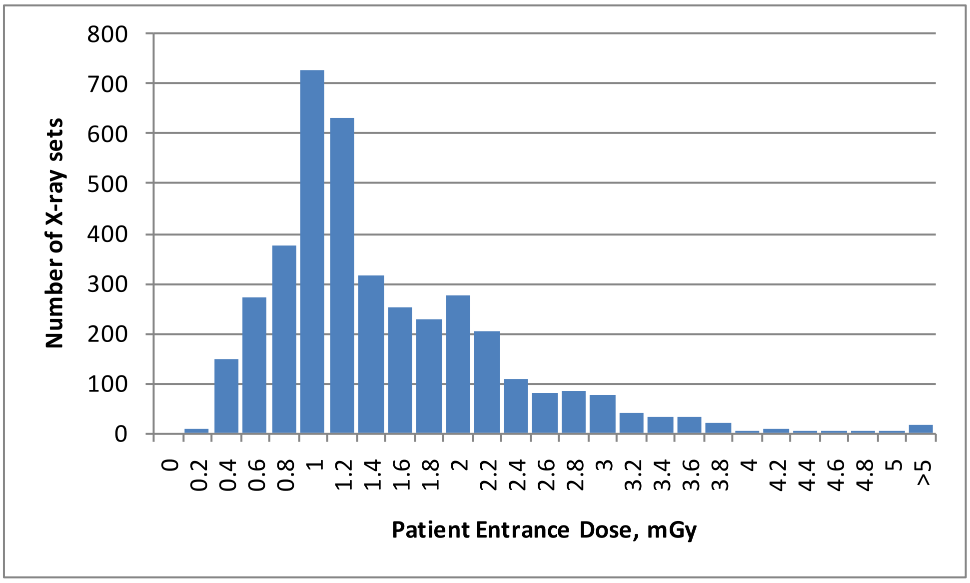

Figure 8 Distribution of intra-oral patient entrance dose measurements for adult mandibular molar radiographs from UK CE assessments

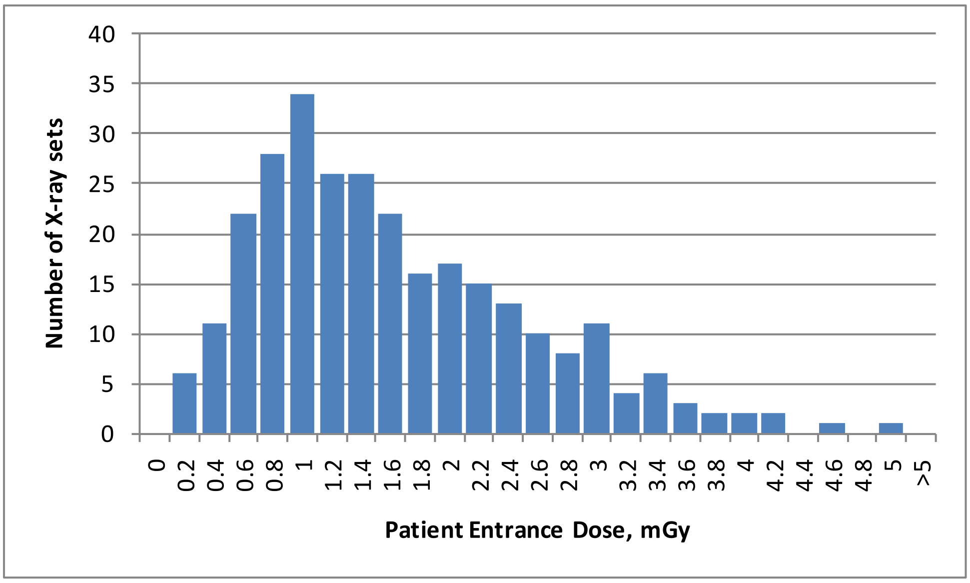

Figure 9 Distribution of intra-oral patient entrance dose measurements for adult mandibular molar radiographs from ROI assessments

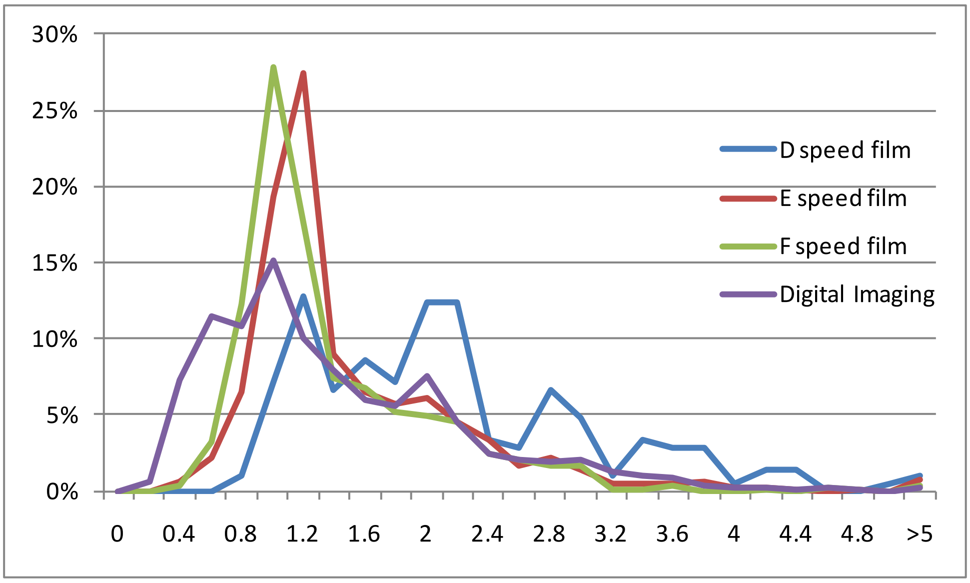

Figure 10 Distribution of intra-oral patient entrance dose measurements for adult mandibular molar radiographs from UK CE assessments, separated by choice of imaging system

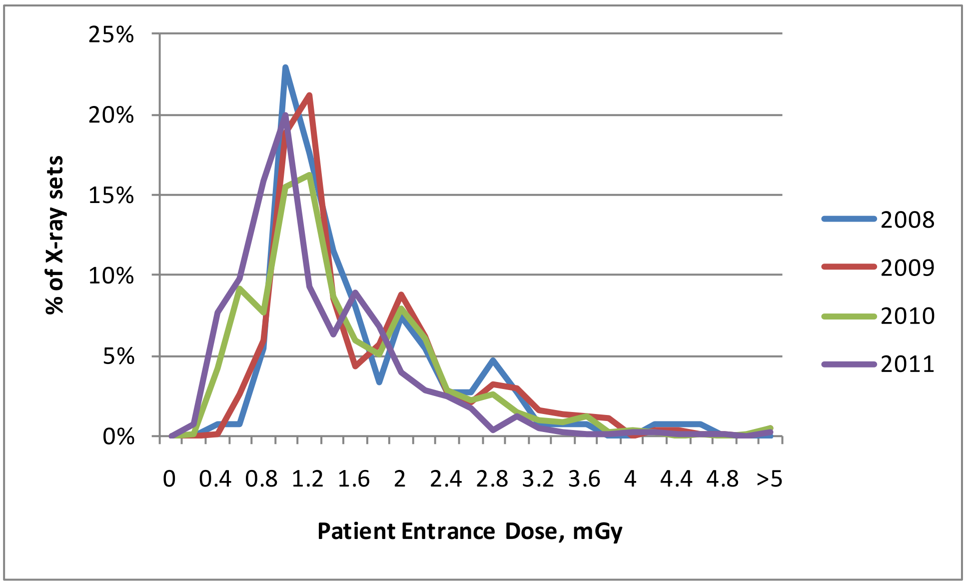

Figure 11 Distribution of intra-oral patient entrance dose measurements for adult mandibular molar radiographs from UK CE assessments, separated by year of assessment

The 2010 review of the NPDD which considered patient doses recorded between January 2006 and December 2010 suggested a national reference dose of 1.7 mGy for an adult mandibular molar radiograph, based on the third quartile values of a dose distribution for intra-oral radiography (Hart, Hillier and Shrimpton, 2012). The third quartile patient entrance dose measurements for the data analysed in this review are shown in Table 4.

Table 4 Summary of third quartile patient entrance dose (mGy) measurements for adult mandibular molar radiographs

	UK R	UK CE	ROI
D speed film	2.4	2.7	2.2
E speed film	1.7	1.8	2.3
F speed film	1.7	1.6	2.3
DDR (eg. CCD or CMOS)	1.5	1.7	1.7
CDR (eg. Phosphor plate)	1.5	1.8	1.8
All	**1.7**	**1.8**	**2.1**

These doses are similar to the adult NRD of 1.7 mGy presented in the 2010 review of the NPDD (Hart, Hillier and Shrimpton, 2012). This is not unexpected as the majority of the UK R data in this review was included in the NPDD review. There is no difference between the third quartile doses associated with the use of E speed film, F speed film and digital imaging systems arising from the UK CE assessments and only a small decrease when considering digital imaging compared to film imaging for UK R data. For ROI data, there is a more noticeable decrease in the third quartile dose value between E and F speed films and digital imaging, although the actual third quartile values for digital imaging are similar to the UK values.

It would be expected that the reported doses for X-ray sets used with digital imaging systems would be noticeably lower than those used with film imaging. It has long been acknowledged that digital imaging systems can produce diagnostic radiographs with lower doses than film imaging (Doyle and Finney, 2005; Berkhout et al., 2004; Yoshiura et al., 1999; Alcaraz et al., 2009); however, lower doses do not appear to be achieved in practice. Reported optimum doses for digital imaging systems suggest that a dose of 20-50% of the optimum dose for film imaging (Doyle and Finney, 2005) or a 30-70% reduction in patient dose compared to speed group E film (Berkhout et al., 2004) are achievable with digital imaging systems.

The difference between the patient doses being delivered in practice and the reported optimum doses may be explained by a lack of knowledge of appropriate exposure factors for digital systems, or an attempt to use higher doses to get better image quality radiographs rather than using exposure settings which provide an adequate diagnostic image (Berkhout et al., 2004). Additionally, some older X-ray sets do not have sufficiently short exposure times available to take advantage of the digital imaging system being used and are therefore being used with higher exposure settings than necessary. Some DDR systems will stop the image capture process before the sensor becomes saturated, therefore the operator could be unknowingly giving a patient a higher dose than necessary as the diagnostic quality of the image would not be impaired.

Although the NRD can highlight high patient doses in a UK dental practice when compared to other UK dental practices, it does not indicate how patient doses in the UK compare to other countries. Patient doses in the UK should be compared to reference doses in other countries to ensure UK practices are acceptable. In Korea a value of 3.2 mGy has been proposed for a mandibular molar radiograph (Han et al., 2009). In

Germany a value of 1.5 mGy (Poppe et al., 2006a) has been recommended for a mandibular molar radiograph and in the USA a dose of 2.3 mGy for a bitewing radiograph (Gray et al., 2005) was proposed. The third quartile dose values derived from this review and the latest UK intra-oral NRD are comparable to those in Germany and lower than both the USA and Korea DRLs.

3.2 Panoramic X-ray Equipment

A summary of all the panoramic X-ray sets included in this review is presented in Table 5. Dose and beam size were measured at the film cassette or digital sensor position.

Table 5 Summary of panoramic X-ray sets. Results are presented as the number of X-ray sets or mean (range) value.

	UK R	UK CE	ROI
Number	1366	829	90
Imaging system			
Film	840	160	45
Digital	526	669	45
Operating Potential (kVp)	71 (55 – 109)	72 (56 – 100)	70 (56 – 84)
Tube current (mA)	8 (2 – 16)	9 (4 – 16)	10 (4 – 16)
Beam width (mm)	3.7 (2.1 – 20.7)	3.8 (1.9 – 15.4)	3.8 (2.0 – 7.6)
Beam height (mm)	130 (105 – 166)	131 (112 – 167)	131 (100 – 161)
Dose Width Product (mGy mm)	62 (9 – 247)	62 (11 – 172)	63 (19 – 248)
Dose Area Product (mGy cm^2)	80 (13 – 388)	81 (14 – 226)	84 (22 – 399)

3.2.1 Operating Potential

Figure 12 shows the distribution of operating potential values used with the equipment considered in this study. In the UK, panoramic X-ray sets should preferably not be used at operating potentials lower than 60 kVp (NRPB, 2001). This requirement was met by 99% of assessments. Panoramic X-ray sets provide a range of operating potential values which can be selected by the operator, usually in the range of 60 to 90 kVp so it is not surprising that the majority of assessments meet this requirement. Additionally X-ray sets should operate within 10% of the user selected operating potential (IPEM, 2005; RPII, 1996) and this requirement was met by 95% of X-ray sets.

The highest operating potentials were found on some combined panoramic and cone beam CT machines with a default operating potential of 105 kVp for panoramic radiography, which is the optimum operating potential for the digital sensor used.

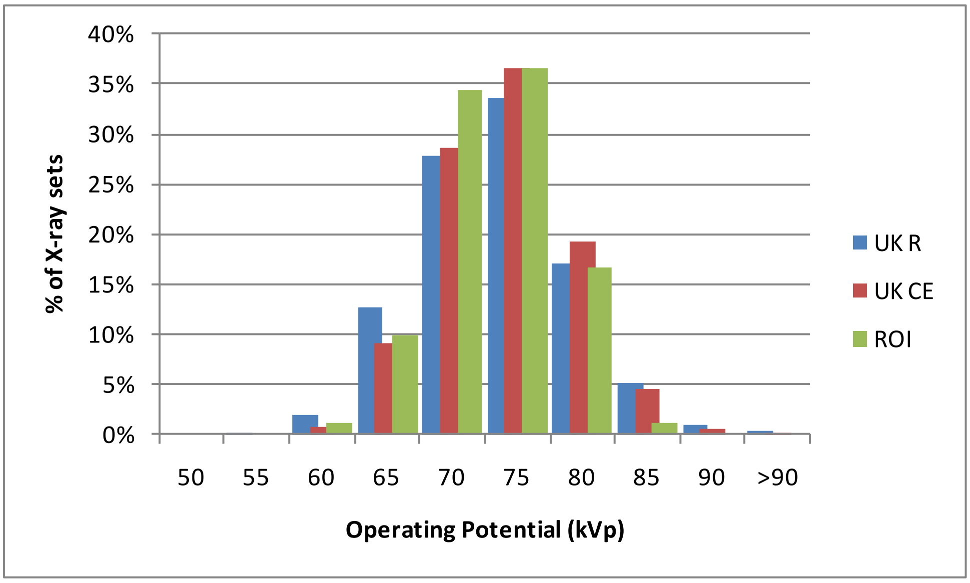

Figure 12 Distribution of operating potential (kVp) used for adult panoramic radiography

3.2.2 Beam Collimation

The distributions of measured beam dimensions are shown in Figure 13 and Figure 14. The average width of panoramic X-ray beams was found to be 3.8 mm and the average height 130 mm. The beam width tended to be larger for digital imaging systems and cover a wider range of widths as can be seen in Figure 15. There was no difference in the measured heights between the use of film and digital imaging as shown in Figure 16.

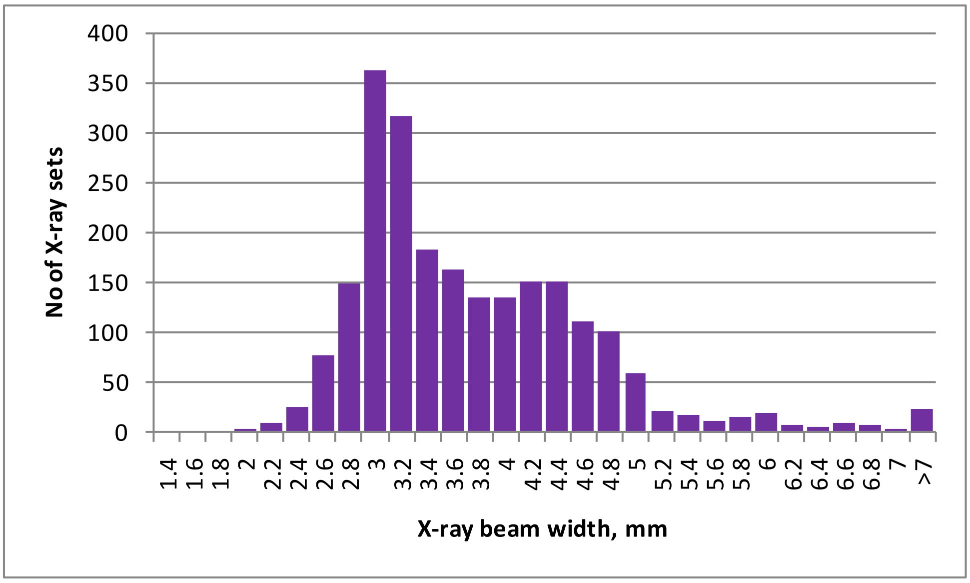

Figure 13 Distribution of X-ray beam widths for adult panoramic radiography

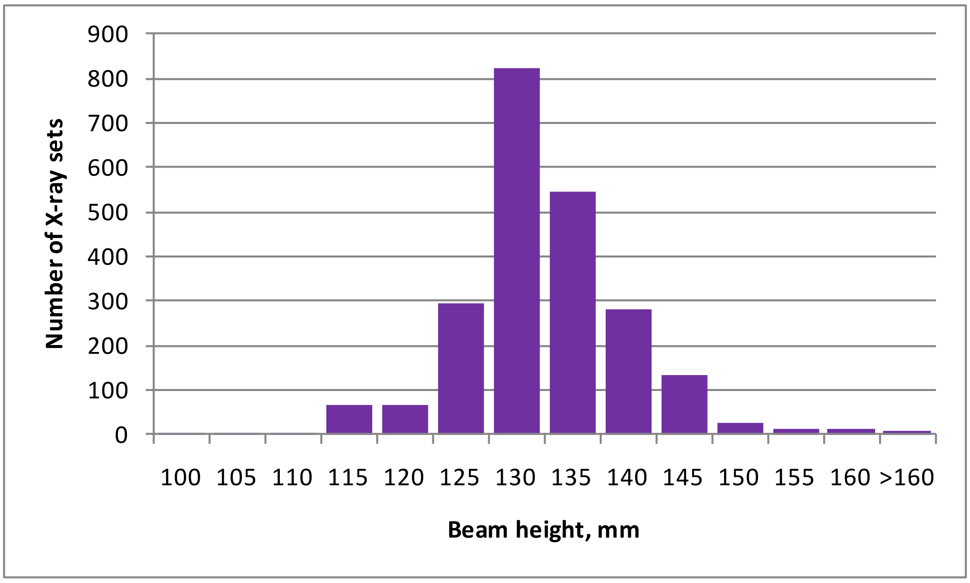

Figure 14 Distribution of X-ray beam heights for adult panoramic radiography

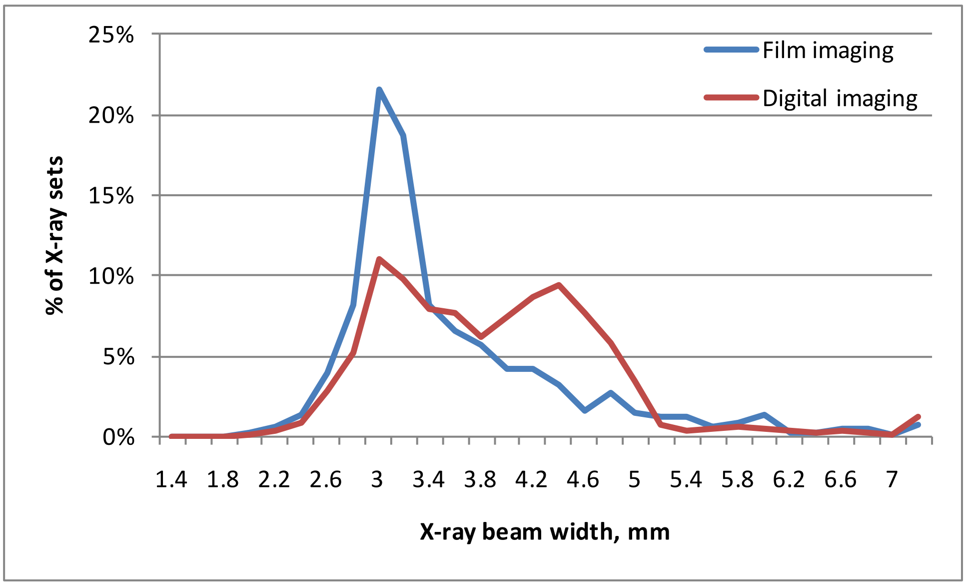

Figure 15 Distribution of X-ray beam widths for adult panoramic radiography, separated by choice of imaging system

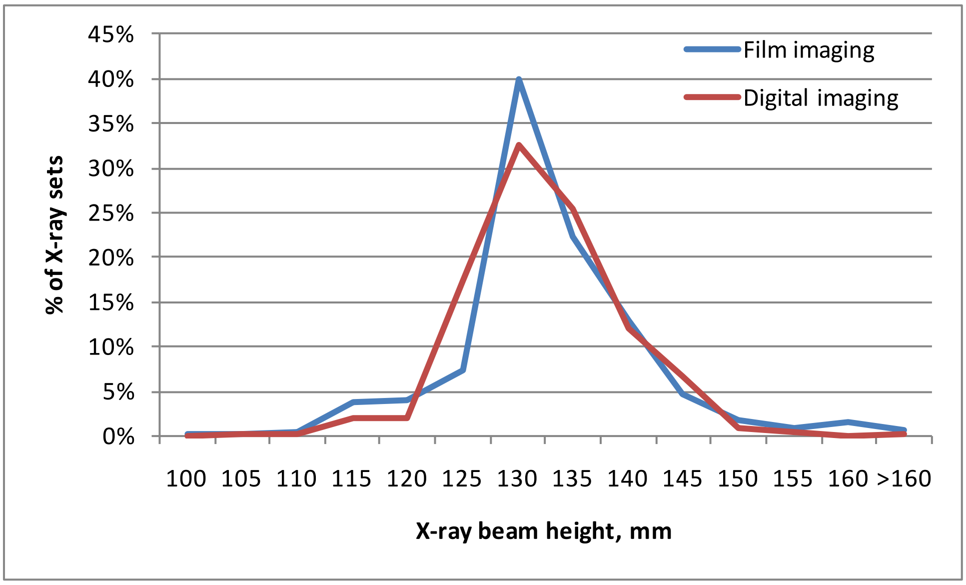

Figure 16 Distribution of X-ray beam heights for adult panoramic radiography, separated by choice of imaging system

3.2.3 Imaging System

Figure 17 shows that digital imaging systems are used for 40% of UK R, 50% of ROI and 80% of UK CE X-ray sets. Figure 18 shows a small year on year increase in the percentage of UK R assessments where digital imaging is used, whereas for CE assessments this has remained fairly constant. This does, however, indicate that for the first time digital imaging is used more than film imaging and as 8 out of 10 new panoramic X-ray sets that are being installed use digital imaging, the proportion of digital systems looks likely to continue to increase. Many manufacturers no longer sell film based imaging systems for panoramic sets. Unlike intra-oral radiography where the X-ray unit and imaging system are independent, panoramic X-ray sets usually combine the X-ray unit and imaging system, therefore when a new panoramic X-ray set is purchased it is likely to have a digital imaging system.

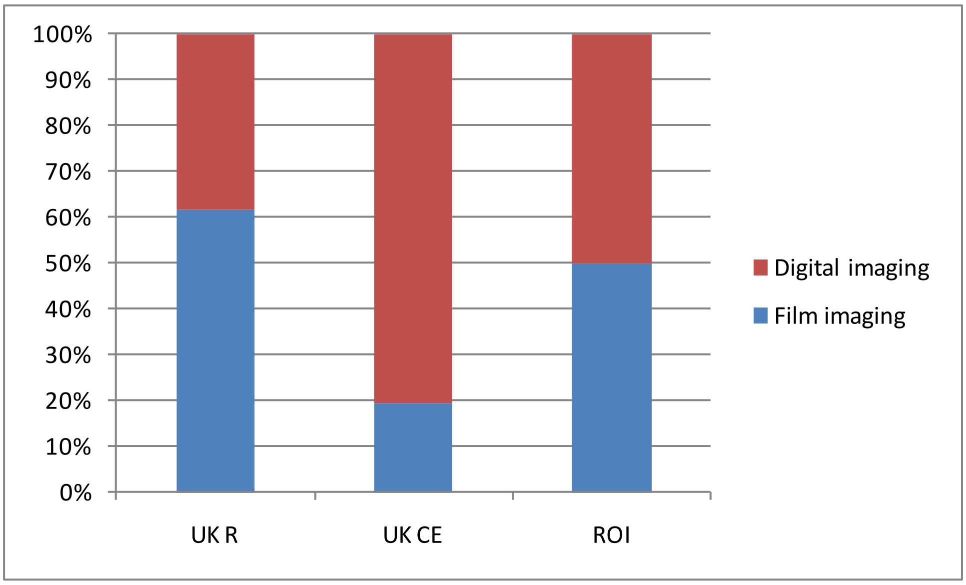

Figure 17 Percentage of panoramic X-ray sets using film or digital imaging

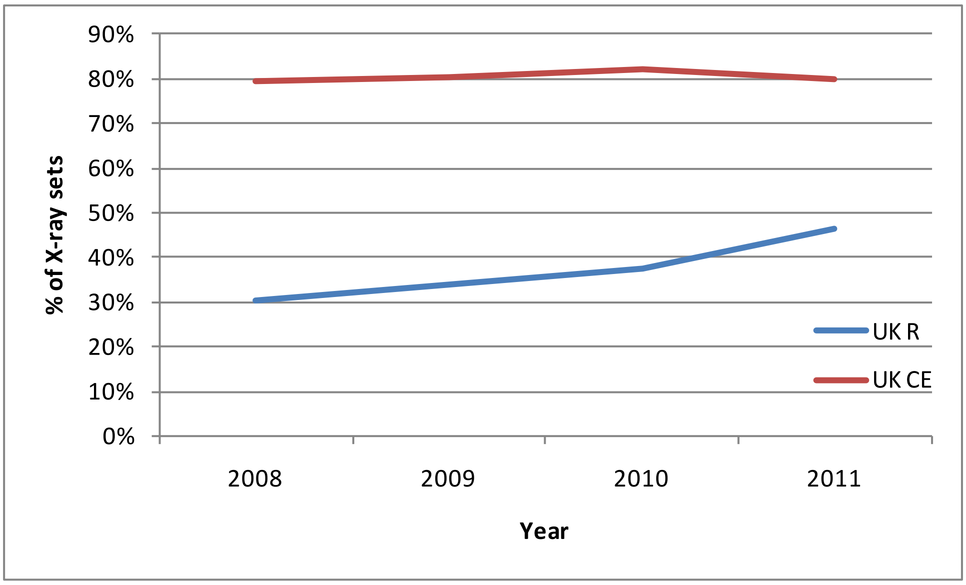

Figure 18 Percentage of panoramic X-ray sets using digital imaging, separated by year of assessment

3.2.4 Patient Dose

Figure 19, Figure 20 and Figure 21 show the distribution of dose area product (DAP) measurements for UK R, UK CE and ROI assessments respectively. Figure 22 compares the dose area product measurements for all three groups of assessments and shows a similar dose distribution for each group.

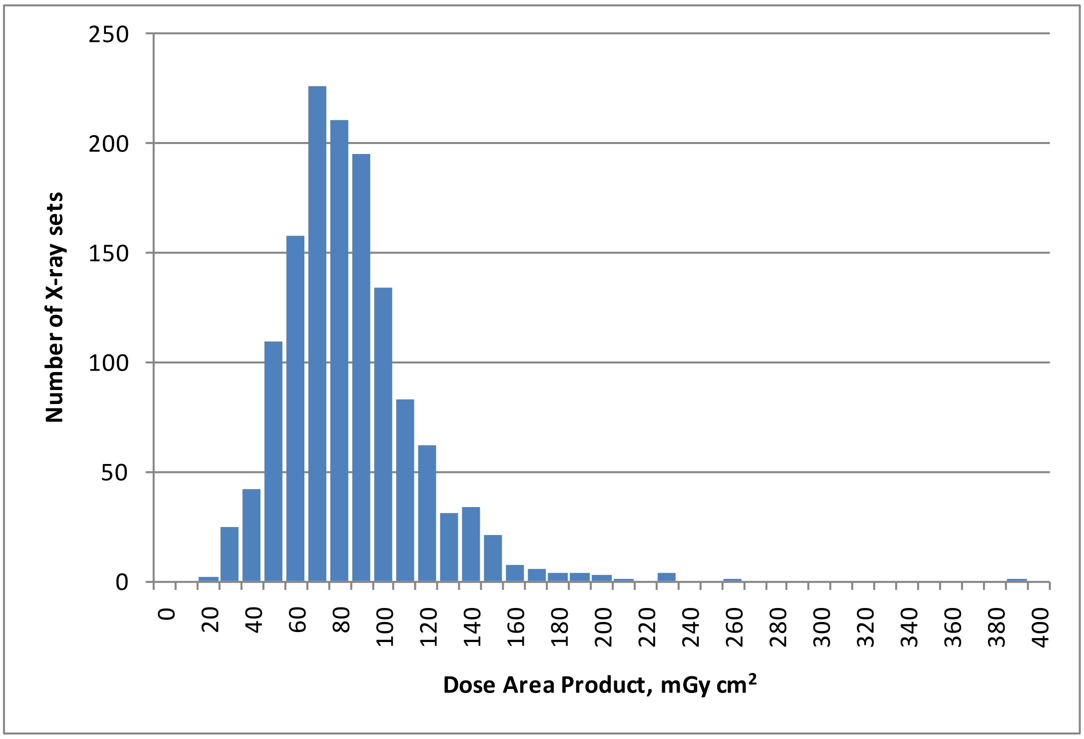

Figure 19 Distribution of dose area product measurements for adult panoramic radiographs from UK R assessments

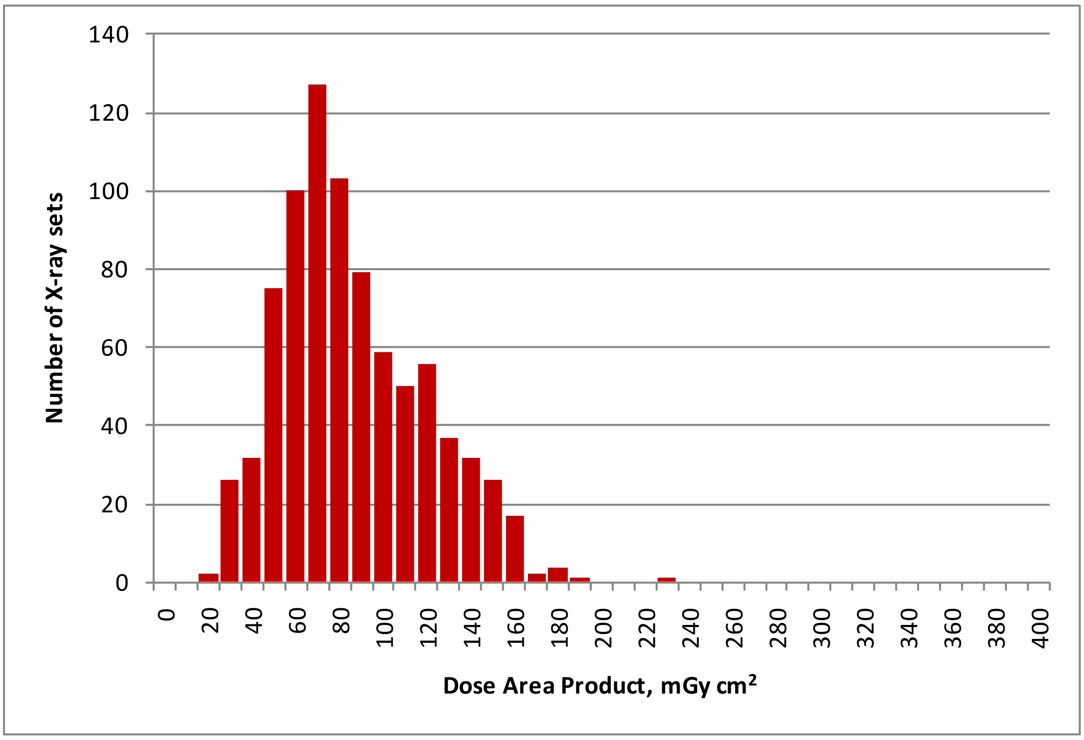

Figure 20 Distribution of dose area product measurements for adult panoramic radiographs from UK CE assessments

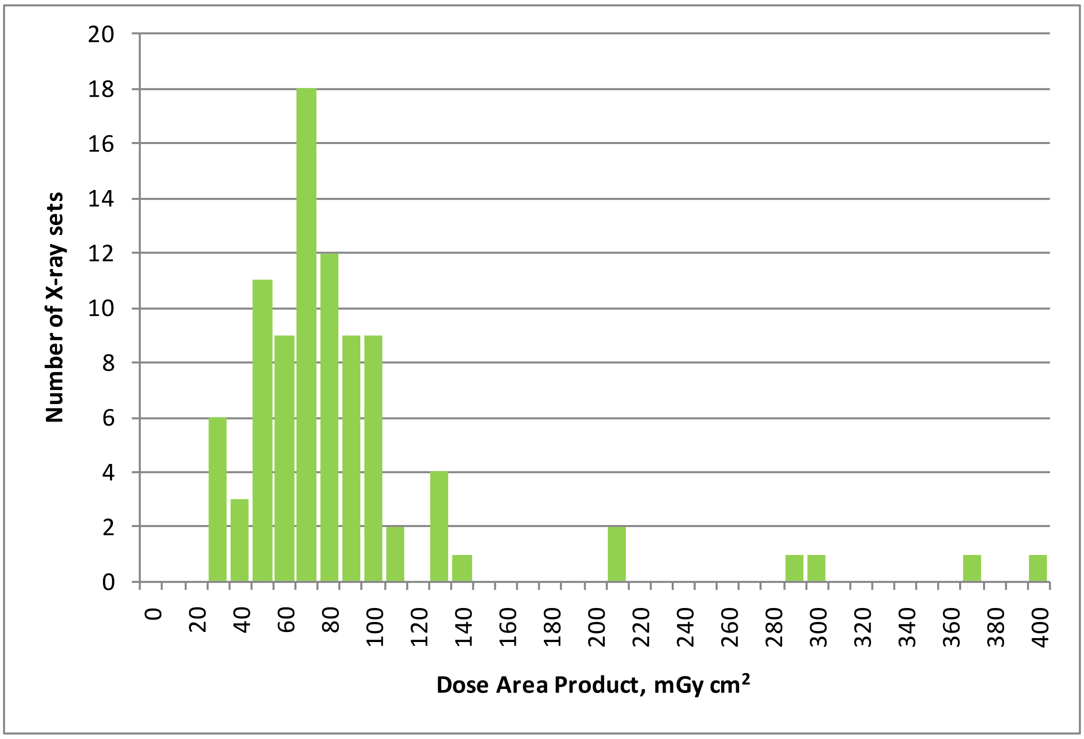

Figure 21 Distribution of dose area product measurements for adult panoramic radiographs from ROI assessments

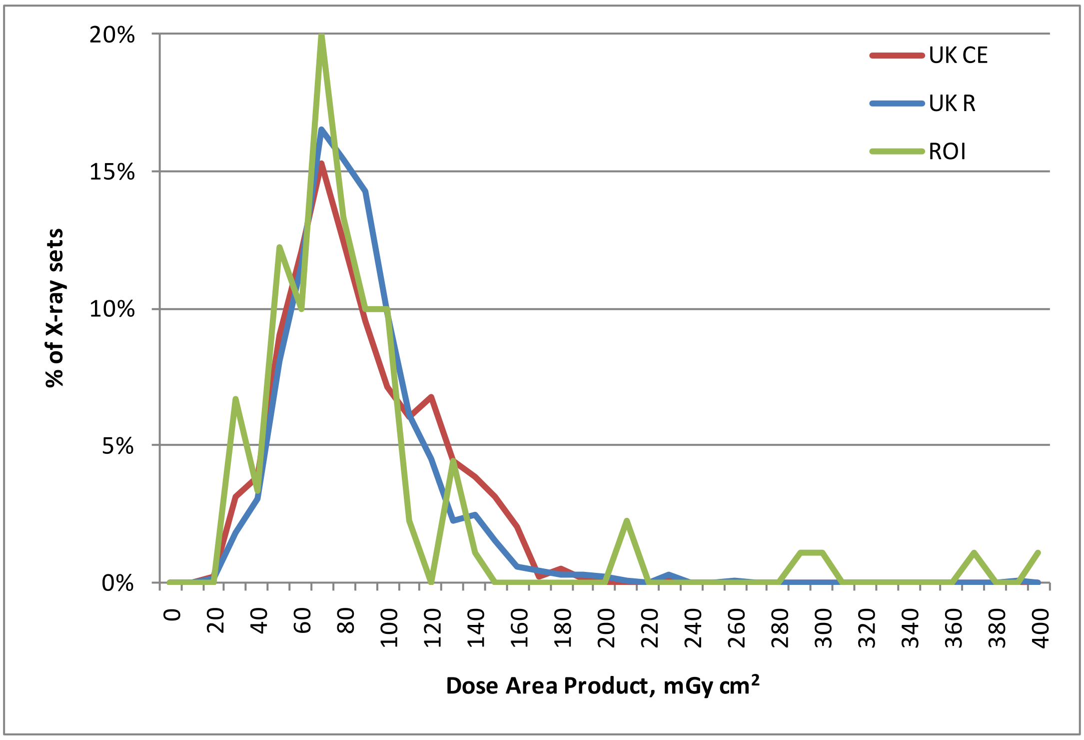

Figure 22 Percentage of dose area product measurements for adult panoramic radiographs, separated by group of assessment

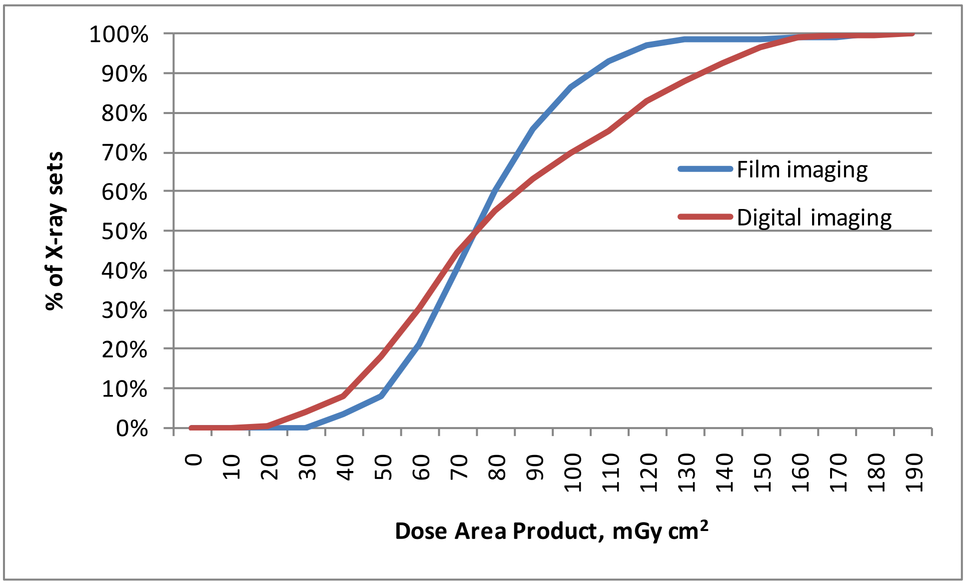

Figure 23 Cumulative percentage of panoramic X-rays sets as dose area product increases for adult panoramic radiographs from UK CE assessments, separated by choice of imaging system

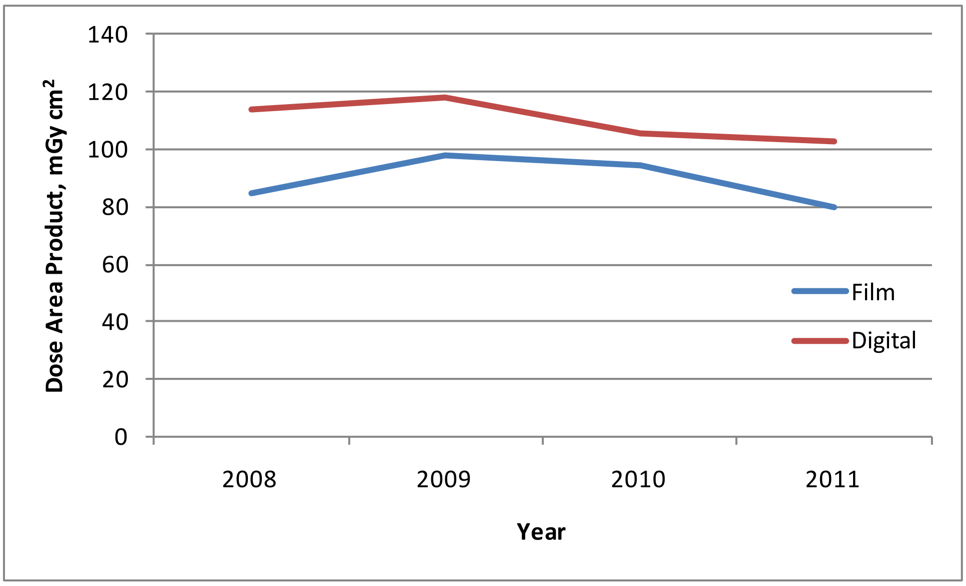

Figure 24 Change in third quartile dose area product over the three year period for adult panoramic radiographs from UK CE assessments

The 2010 review of the NPDD suggests a national reference dose of 93 mGy cm^2 for adult panoramic radiography, based on the third quartile values of a dose distribution for panoramic radiography (Hart, Hillier and Shrimpton, 2012). This value has increased since that presented in the previous review (Hart, Hillier and Wall, 2007). This is considered to be primarily due to a change in the method used by DXPS to measure X-ray beam size (Holroyd, 2012), rather than an actual increase in patient doses. The third quartile dose area product measurements for the data analysed in this review are shown in Table 6.

Table 6 Summary of third quartile dose area product measurements for standard adult panoramic radiographs (mGy cm^2)

	UK R	UK CE	ROI
Film	93	89	87
Digital	95	109	89
All	**94**	**104**	**89**

The doses in this review compare well with those presented in the 2010 review of the NPDD. This is to be expected as the majority of the UK R data from this review was included in the NPDD review. For UK R and ROI assessments, there is no difference in the third quartile dose area product measurements for film and digital imaging. The third quartile value for UK CE digital imaging is higher than for UK R and ROI digital imaging. This may suggest that many dentists are able to significantly reduce exposure settings for digital imaging below manufacturers' default settings, after they have gained experience of using the equipment, hence reducing patient doses whilst still obtaining adequate diagnostic quality (Dannewitz et al., 2002).

Figure 23 shows that the range of patient doses is greater for X-ray sets using digital imaging than for film imaging. This could be explained by the different types of digital imaging (DDR and CDR) as well as advances with modern X-ray sets that use DDR systems, low operating potentials, low tube currents and very short exposure times of less than 5 seconds to deliver lower patient doses.

Figure 24 shows that there has been a slight decrease in the third quartile value over the three year period considered in this review for UK CE assessments, with a more significant reduction for X-ray sets using digital imaging than film imaging.

As for intra-oral equipment, patient doses in the UK and ROI should be compared to reference doses in other countries to ensure UK practices are at least as good as international practice. In Korea, a DRL of 120 mGy cm^2 for an adult patient (Han et al., 2011) has been proposed. In Germany DRLs of 87 mGy cm^2 for an adult male and 84 mGy cm^2 for adult female were proposed (Poppe et al., 2006b) and in Greece DRLs of 117 mGy cm^2 for adult male and 97 mGy cm^2 for adult female were proposed (Tierris et al., 2004). It can be seen that the UK and ROI results show good agreement with the German DRLs and are lower than the Korean and Greek values.

4 CONCLUSION

4.1 Intra-oral X-ray Equipment

Patient doses have continued to decrease in the UK since the last review of DXPS data. This is mainly due to fact that D speed film is used by only a small number of dentists and the use of X-ray equipment which operates at 50 kVp and below is virtually nonexistent.

The downward trend in patient doses can only continue through the adoption of digital imaging methods. However, as the patient doses in this review show, users of digital imaging systems are not fully optimising their systems to take full advantage of the dose savings that are available from digital imaging.

It is promising to see that almost two thirds of new X-ray sets are being sold with rectangular collimation fitted as standard to further reduce patient effective doses.

4.2 Panoramic X-ray Equipment

The use of digital imaging is increasing and it is conceivable that film imaging could become obsolete this decade. The increased use of digital imaging has not led to significant reductions in patient doses; however, the newest digital machines that provide short exposure times combined with low operating potential and tube current settings could lead to a reduction in patient dose if their use increases. Future DXPS data will separate DDR and CDR equipment to establish if there are differences in equipment performance and patient dose between these different types of digital imaging systems.

4.3 National Reference Levels in the Republic of Ireland

There are currently no national reference levels (NRLs) established in Ireland, although values of 2.4 mGy for an adult intra-oral mandibular molar radiograph and a dose width product (DWP) of 60 mGy mm for an adult panoramic radiograph have been proposed based on third quartile dose values (Walker and van der Putten, 2010). The third quartile dose values in this report of 2.1 mGy for intra-oral mandibular molar radiographs and 68 mGy mm for adult panoramic radiographs support these values and imply that these would be appropriate national reference levels for Ireland, however it would be preferable for the panoramic NRL to be set using DAP instead of DWP as this quantity is more closely linked to patient dose (Williams and Montgomery, 2000).

4.4 Measurements of Radiation Doses to Children

The 2005 dose review (Hart, Hillier and Wall, 2007) introduced child NRDs for the first time in dental radiography. In response to this, DXPS has started to routinely record child dose measurements and results from these measurements will be included in future reviews of DXPS data.

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