Visualisation of the soft tissue profile is needed on cephalometric radiographs. This can be done either by using a suitable wedge filter in front of the patient (preferred option from a dose reduction standpoint) or cassette, or by fitting graduated intensifying screens within the film cassette.

5.4 Patient dose and X-ray equipment - Diagnostic Reference Levels

An objective of the QA programme is to ensure doses are kept as low as reasonably achievable. It is, therefore necessary to ensure that patient doses are monitored on a regular basis.

Diagnostic Reference Levels (DRLs) are patient dose levels for medical diagnostic exposure that can be used as investigation levels as part of this optimisation process. The International Commission on Radiological Protection (ICRP) first introduced the term diagnostic reference level in 1996 (13) and has produced further advice (15). The requirement for DRLs has been included within the European Medical Exposures Directive (3) and the EC has produced further guidance on the setting of DRLs (5).

Essentially, the aim of DRLs is to provide reference levels of easily measurable patient dose quantities for facilities to compare their average doses against. DRLs are not intended to be applied to individual exposures of individual patients (5). They can be set at a range of levels, i.e. European, national, regional, or local level. The intention is to indicate an upper level of acceptability for current normal radiological practice. The use of DRLs is *"a simple means of identifying those situations well away from the optimum where corrective action is most urgently needed"* (61).

Having an average dose below a relevant DRL gives some confirmation that patient doses in a particular facility are reasonably in line with other facilities. It does not necessarily indicate that dose is optimised. However, doses consistently above a DRL would definitely indicate that patient dose is not in line with the ALARA principle and that action should be taken to reduce dose.

The concept of DRLs is now well established within general hospital radiology. The most usual method of setting a DRL is to base it on the third quartile of field measurements performed in a large number of establishments (5, 21, 62). Consequently, DRLs are based on current practice across a wide range of different establishment, not on results from a select group of facilities with a high level of equipment and expertise.

European wide DRLs have not, so far, been promulgated for dental projections, although some European countries have established national dental DRLs (or equivalent) (22, 36, 45).

5.4.1 Intraoral

5.4.1.1 Dose quantities

The majority of surveys of patient dose in intraoral film radiography have measured the dose in air or tissue at the end of the spacer cone (usually referred to as entrance surface dose (ESD) although often it is an

underestimate as backscatter from within the head is not always included). This is a relatively simple measure, readily performed by a medical physics expert (MPE). The MPE might visit the practice to perform the measurement using some form of electronic dosemeter, alternatively either a film or thermoluminescent device dosemeter (TLD) package can be provided by post for exposure by the dental practice staff. Germany (36) currently requires the measurement of dose at depth. Whilst being a better indicator of effective dose than entrance dose, this will not pick up the significant difference in skin dose caused by using low kV equipment.

5.4.1.2 European data

A summary of dose surveys and current national DRLs for European and North American data is given in table 5.7. It is evident that a wide variation in dose exists from practice to practice, with many surveys recording ESD at individual practices above 20 mGy. The distributions of the results tend to be skewed with just a few outliers at the higher doses (31, 37, 45).

It can be seen that the mean levels tend to be lower for the most recently performed surveys, probably reflecting the change from D- to E-speed film and the greater use of 60-70 kV X-ray equipment.

5.4.1.3 Suggested values

The majority of patient intraoral dose surveys have been in terms of cone end dose, measured in air, for average adult settings. Unfortunately, a range of projections has been chosen. The UK data is by far the most comprehensive survey of actual practice in Europe and the recommended DRL has been based on this. At this stage it is not suggested that the lower value currently being promoted within the UK be adopted as it is clear that within Europe there is significant variation in practice; for example the Danish, Greek and Portuguese surveys also encompassed a significant number of X-ray sets and indicate higher levels within these countries.

Recommendation 5 F

The Medical Directive requires the establishment of DRLs.
The working party recommends a DRL of 4 mGy absorbed dose in air measured at the end of the spacer cone for a standard maxillary molar projection.

5.4.2 Digital equipment

Intraoral digital detectors are generally capable of operating optimally at lower doses compared with film (see Section 4.4.3.) DRLs derived from survey of practices using film will be higher than those achievable using digital radiography. When individual practices using digital sensors compare doses to European or national DRLs, the expected difference between film and digital sensor should be borne in mind.

Digital detectors, in particular phosphor plate systems, have very large latitude. Higher doses than necessary may be used without the operator being warned by a dark image (29). For this reason, it is of particular

Table 5.7: Summary of surveys of intraoral dose quantities and DRLs.

Country/ date of publication	Results of survey	Proposed/set DRLs or investigation levels	Ref
USA draft		Bitewing ESD in air: • 70 kVp, E-speed: 2.30 mGy • 70 kVp, D-speed: 3.50 mGy	(21)
UK draft	See UK 1999 below	Mandibular molar cone end dose: • 2.1 mGy	(12)
Luxembourg 2001		ESD for maxillary molar: • Investigation level >4 mGy • Suspension level >6 mGy	(22)
Spain 2001	ESD (average for all projections): • Mean 2.89 mGy • Third quartile 3.37 mGy	ESD: • 3.5 mGy	(34)
Finland 2000	Molar ESD: • Mean 3.5 mGy • Range 0.8-16.4 mGy		(32)
Finland 1999		ESD: • <7 mGy for any intraoral film • <3.5 mGy E-speed film and any digital system	(24)
UK 1999	Mandibular molar cone end dose: • Mean 3.3 mGy • Range 0.14 – 45.7 mGy • Third quartile 3.9 mGy For subgroup using 60-70 kV and E-speed film: • Third quartile 2.1 mGy	Mandibular molar cone end dose: • 4 mGy	(45)
Greece 1998	ESD (for mean exposure times): • 71%<5 mGy • 10%>10 mGy		(65)
Greece 1998	ESD for periapical: • Mean 6.9 mGy • Range 0.6-37 mGy D-speed: • Mean: 8.7 mGy E-speed: • Mean: 5.8 mGy		(57)
Luxembourg 1997	Cone end dose for maxillar molar: • Mean 3.2 mGy • Third quartile 3.8 mGy		(36)
IAEA 1996		Periapical ESD: • 7mGy	(14)
Denmark 1995	Cone end dose mandibular incisor: D-speed: • Mean 4.9 mGy • Third quartile 6.3 mGy E-speed: • Mean 3.2 mGy • Third quartile 3.5 mGy		(58)

Table 5.7 continued:

Country/ date of publication	Results of survey	Proposed/set DRLs or investigation levels	Ref
Portugal 1992	Cone end dose: • Posterior 1.63 mGy • Periapical 8.03 mGy		(53)
Portugal 1992	ESD for mandibular molar: • Mean 9.2 mGy • Median 6.3 mGy		(31)
New Zealand 1990	Cone end dose for bitewing Mean values for: • All kVs: 4.52 mGy, max >20 • 45-55 kV: 7.1 mGy • 60-70 kV: 4.0 mGy		(64)
France 1989	Range of projections: • Mean doses varied from 3.9-13.5 mGy Mandibular molar: • Mean 4.7 mGy		(27)
Holland 1989	• Mean 5.8 mGy • Range 0.7-43.2 mGy		(59)
Finland 1988	Cone end dose for bitewing projection: • Mean 6.2 mGy • Range 0.5-151 mGy		(40)

Table 5.8: Summary of surveys of panoramic dose quantities and DRLs.

Country/ date of publication	Results of survey	Proposed/set DRLs	Ref
Spain 2001	Occipital ESD: • Mean 0.53 mGy • Range 0.25-0.87 mGy • Third quartile 0.66 mGy	Occipital ESD: • 0.7 mGy	(34)
Finland 2000	DAP: • Mean 94 mGy cm^2 • Range 34-254 mGy cm^2		(32)
UK 1999	Dose-width product: • Mean 57.4 mGy mm • Range 1.7 – 328 mGy mm, Third quartile 66.7 mGy mm	Dose-width product: • 65 mGy mm	(45)
UK 2000	DAP: • Mean 11.3 cGy cm^2 Dose width product: • Mean 65.2 mGy mm • Third quartile 75.8 mGy mm		(63)

Table 5.9: Summary of surveys of cephalometric dose quantities and DRLs.

Country Date of publication	Results of survey	Proposed/set DRLs	Ref
USA draft		ESD in air: • 0.25mGy	(21)
UK 2002	Skull AP/PA: • Mean 2.3mGy • Third quartile 2.8 mGy Skull lat: • Mean 1.2 mGy • Thirdquartile 1.6 mGy	Skull AP/PA: • 3 mGy Skull lat: • 1.5mGy	(38)
EU 1999		Skull AP/PA: • 5 mGy Skull lat: • 3 mGy	(7)
Portugal 1992	Skull lat: • 7.2 mGy		(53)

importance that users of digital detectors monitor dose levels to provide continued assurance that they are being used optimally.

5.4.3 Panoramic radiography

5.4.3.1 Dose quantities

The establishment of DRLs for panoramic radiography is not as well developed as for intraoral film radiography. The UK have adopted the concept of dose width product i.e. the maximum dose at the film cassette slit multiplied by the width of the beam at the slit (45) measured without a patient. However, the methodology has not been well defined and significant differences in results occur due to the different measurement methods adopted (63). This will be particularly true for the newer panoramic units with narrow slits and a non-uniform dose profile across the slit. Other approaches suggested have been to use the product of dose and beam area as measured by a dose area product (DAP) meter or TLD stack (63) or to perform surface dose measurements on patients (34). This latter approach is thought to be of limited value as the surface dose distribution varies widely dependent of the type of panoramic unit in use (44) and will not give a good representation of the distribution of depth dose within the head.

5.4.3.2 European data

A summary of the dose surveys for panoramic radiography is given in Table 5.8. This indicates a scarcity of data and no clear agreement on approach. The working party feels unable to recommend a DRL at this stage.

Recommendation 5 G

The working party recommends that further work be carried out on establishing a measurement method (probably adopting the DAP approach) for panoramic dosemetry and to undertake further field measurements so that a European DRL can be adopted.

5.4.4 Cephalometry (teleradiography)

5.4.4.1 Dose quantities

Although a European DRL does exist for both PA and lateral skull radiography using ESD measurements (5), specific DRLs for cephalometry have yet to be established. Limited survey data exists for cephalometry as indicated in Table 5.9. Given the absence of the anti-scatter grid and the longer FFD employed in cephalometry, it is likely that any entrance surface dose would be lower than for skull radiography (usual FFD of 1 m). Differences might also be expected due to different contrast requirement requiring different kV selection. Finally, it is normally considered good practice to limit the field for cephalometry (see Section 4.3.3.). Although this will make little difference to

the ESD, a measurement of DAP would be a better indicator of dose optimisation and would be preferred for use as a DRL.

Recommendation 5 H

The working party recommends that dose surveys be undertaken within Europe using both ESD and DAP to facilitate the setting of a European DRL for standard cephalometry projections.

5.4.5 Using DRLs

Dentists should be aware how their average doses compare with the European and any national DRLs. It is not expected that dental practices will have the facilities to be able to assess this themselves and so will require the services of a medical physics expert. These assessments should be carried out on a regular basis, at least every 3 years or as required by national legislation.

These measurements can be seen to be a part of any QA programme adopted by the dental practice. Results above established DRLs should be investigated, again with the help of a medical physics expert, and any resultant recommendations should be implemented.

Recommendation 5 I

It is recommended that dentists arrange to audit their doses for comparison with European/National DRLs.

5.5 Dental X-ray equipment

This section relates to the maintenance and testing of dental radiology equipment.

Dental X-ray equipment should be designed, constructed and installed to be in compliance with recognised European standards pertaining to all aspects of equipment safety (e.g. electrical, mechanical and radiation protection (18)). It must meet the relevant essential requirements for safety and performance of the Medical Devices Directive (17). All products that fall within the scope of the Directive must meet certain essential safety and administrative requirements and are to be CE marked to show that they comply. Such products may then be freely sold throughout the EU without being subject to additional national regulations. It is required that suppliers, erectors or installers of dental X-ray equipment provide adequate information pertinent to