DOSE-AREA PRODUCT MEASUREMENTS IN PANORAMIC DENTAL RADIOLOGY

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In this study, dose-area product (DAP) measurements in panoramic dental radiology have been performed in Germany. The results obtained in this study were proposed as diagnostic reference levels (DRLs). A representative number of dental panoramic units, both with digital and conventional image receptors, have been chosen. Common statistical parameters such as mean, standard deviation and 3rd quartile have been calculated. For four different standard programmes, ‘large adult’, ‘adult male’, ‘adult female’ and ‘child’, the proposed DRLs are 101, 87, 84 and 75 mGy cm², respectively. No clear tendency to a generalised dose reduction from the transition to digital techniques has been observed. Effective doses have been calculated from E/DAP conversion factors published in literature. Even though these values differ by a factor of /C2, upper limits of 15.8–21.2 /C1µSv for the four different exposure settings were derived from the data.

INTRODUCTION

As a practical aid to quality assurance in diagnostic radiology, diagnostic reference levels (DRLs) are recommended by the International Commission of Radialogical Protection (ICRP)(1). In Germany, reference levels for standard radiological examinations have been published in 2001(2), but dental radiological facilities have not yet been investigated. For the establishment of reference levels, a representative number of X-ray units must be evaluated. Therefore, it is important to use an easy and well-defined method to measure the relevant parameters within an acceptable time. Normal dose quantities such as entrance surface dose (ESD) and entrance surface air kerma (ESAK) are often used to characterise the dose of an examination. Recently, Helmrot and Alm Carlsson(3) have shown that it is possible and convenient to use a DAP meter to measure the dose in intraoral and panoramic examinations and recommended the measurement of the DAP for the establishment of DRLs for dental radiology. Since dental panoramic examinations are usually carried out using fixed settings of tube voltage (kV), tube current (mA) and exposure time for specific categories of patients (‘large adult’, ‘adult male’, ‘adult female’ and ‘child’), the measurements of DAP can be performed in the absence of the patient using the same settings as if the patient were present. Several European countries have reported DRLs in panoramic dental radiography, using ESD(4), ESAK(5), dose width product(5) as well as DAP(6). So far no study has paid special attention to digital detectors.

This work has been carried out as part of a study (StSch 4436) initiated by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety to collect data in order to establish DRLs for dental radiology in Germany. From a database of ~2000 Northern German dentists, a representative number of panoramic units have been chosen. The selected dentists were visited and DAP measurements were performed without the patient in place. The DAP values for standard examinations performed in clinical routine have been collected for conventional as well as for digital detectors.

MATERIALS AND METHODS

A total of 50 panoramic units of different vendors have been chosen randomly from a database of 2000 North German dentists. A number of digital units both operating with storage phosphor plate and charge-coupled device (CCD) have been included in the study. A DAP meter consisting of a translucent transmission ionisation chamber and a mobile electrometer (Diamentor M4, PTW-Freiburg, Germany) was used to measure the DAP of the selected panoramic X-ray units. The calibration of the measurement device to diagnostic X-ray energies was done by the manufacturer. During the measurements, the ionisation chamber was placed directly in front of the exit slit of the X-ray tube. For each panoramic unit, four different programmes characterised by ‘large adult’,

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Table 1. Mean exposure parameters along with the mean, standard deviation and the 3rd quartile of the DAP values for each type of settings (‘large adult’, ‘adult male’, ‘adult female’ and ‘child’).

<table>
<thead>
<tr>
<th>Programme</th>
<th>Mean tube voltage (kV)</th>
<th>Mean tube current (mA)</th>
<th>Mean exposure time (t)</th>
<th>Mean DAP (mGy cm²)</th>
<th>3rd quartile value of DAP (mGy cm²)</th>
<th>Standard deviation of DAP (mGy cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>63.5</td>
<td>11.1</td>
<td>15.3</td>
<td>85.7</td>
<td>101.4</td>
<td>28.0</td>
</tr>
<tr>
<td>Adult female</td>
<td>67.5</td>
<td>11.7</td>
<td>15.3</td>
<td>76.4</td>
<td>87.0</td>
<td>24.0</td>
</tr>
<tr>
<td>Adult male</td>
<td>69.5</td>
<td>11.7</td>
<td>15.3</td>
<td>71.6</td>
<td>84.4</td>
<td>24.3</td>
</tr>
<tr>
<td>Large adult</td>
<td>73.1</td>
<td>11.6</td>
<td>15.0</td>
<td>59.3</td>
<td>75.4</td>
<td>23.7</td>
</tr>
</tbody>
</table>

‘adult male’, ‘adult female’ and ‘child’, differing in tube voltage, current and exposure time, have been evaluated.

Tube voltage, tube current and exposure time have been recorded for all machines and all exposure settings. Common statistical parameters have been calculated from the DAP values such as the mean, standard deviation and the 3rd quartile. According to the Radiation Protection Document No. 109 of the European Commission(7), the latter one is proposed as the DRls, which may be defined based on our results.

The calculation of the effective dose can be carried out by multiplying the DAP with a pre-determined conversion factor. Williams and Montgomery(8) calculated a conversion factor of 0.06 mSv Gy⁻¹ cm⁻² using the effective dose obtained by White(9). Helmrot and Alm Carlsson(3) published a conversion factor including salivary glands of 0.08 mSv Gy⁻¹ cm⁻² for panoramic examinations. Visser(10) made an extensive study with an anthropomorphic tissue-equivalent phantom and found a conversion factor of 0.21 mSv Gy⁻¹ cm⁻².

RESULTS

Mean exposure parameters along with the mean, standard deviation and the 3rd quartile of the DAP values for each type of setting (‘large adult’, ‘adult male’, ‘adult female’ and ‘child’) are given in Table 1. The 3rd quartiles together with the measured DAP values for all panoramic X-ray units for the four standard programmes are given in Figure 1. As expected, the 3rd quartile value for the ‘large adult’ setting is the highest, followed by the ‘adult male’ setting, the ‘adult female’ setting and the ‘child’ setting being the lowest. To distinguish between digital (CCD or storage phosphor plate based) and conventional film/screen systems, the image receptors employed are marked in different shades of grey. The lowest dose in all cases was measured at a machine based on CCD technique. On the other hand, no obvious dose reduction was measured on the digital systems based on storage phosphor plates. From the results of our measurements, the proposed DRLs for ‘large adult’, ‘adult male’, ‘adult female’ and ‘child’ settings are 101, 87, 84 and 75 mGy cm², respectively. The effective doses related to the proposed DRLs of the different settings are shown in Table 2.

DISCUSSION

The proposed DRLs for normal adult (‘adult male’ and ‘adult female’) settings are very similar. Proposed DRL for the group ‘large male’ is ~20% higher while proposed DRL for ‘child’ setting is ~15% lower than for normal adult settings.

Helmrot and Alm Carlsson(3) tested a Planmeca PM2002 CC/EC Proline (Planmeca OY, Finland) using a film/screen system of sensitivity 400. For a setting of 64 kV, 5 mA and 18.4 s irradiation time, they measured a DAP of 57 mGy cm². For the same panoramic unit with similar parameters (64 kV, 6 mA, 18.0 s), we measured a DAP of 55 mGy cm². By this comparison, the consistency of both studies can be assumed.

Tierris et al.(6) found reference levels for ‘male’, ‘female’ and ‘child’ settings of 117, 97 and 77 mGy cm², respectively. Their reference levels for adult settings are higher than ours. Closer analysis of the data published by Tierris et al.(6) shows that there are eight machines with DAP values that are noticeably higher than those of the other evaluated units. These eight X-ray units have DAP values between 200 and 250 mGy cm² for ‘male’ settings and between 170 and 200 mGy cm² for ‘female’ settings. The highest value we obtained in our study within both programmes is ~140 mGy cm². Therefore, the DRLs of Tierris et al.(6) are strongly influenced by the machines with higher doses. By excluding these eight units and recalculating the 3rd quartile values it can be demonstrated that their values lie in the same range with our value. Williams and Montgomery(8) have measured DAP using TLDs on 16 panoramic units with different exposure settings. They found an average DAP of 113 mGy cm². Compared with the E/DAP conversion factors published by Williams and Montgomery(8) and the conversion factors published by Helmrot and Alm
Carlsson\(^{(3)}\), the factor derived by Visser\(^{(10)}\) differs by a factor of 3.5 and a factor of 2.6 from their values, respectively. Visser\(^{(10)}\) made an extensive study with an anthropomorphic phantom, made from materials that were specially designed for X-ray energies, where Helmrot and Alm Carlsson\(^{(3)}\) used a multi-material compound hard tissue phantom. The effective dose derived by White\(^{(9)}\) used by Williams and Montgomery\(^{(8)}\) to establish the E/DAP conversion factor resulted from a literature survey and not from measurements. The discrepancy of the conversion factors published by different authors may result from the different measurement techniques used and different calculation schemes adopted when calculating effective doses. It has been shown that the salivary gland is exposed to high doses in panoramic dental radiology\(^{(11)}\), and its inclusion in the list of remainder organs when calculating effective dose has been questioned. Effective dose calculated using the conversion factor from Visser\(^{(10)}\) (Table 2) shows that the risk associated with a panoramic radiography is equivalent to a chest examination\(^{(12)}\). We, therefore, suggest taking the values derived by Visser\(^{(10)}\) as an upper dose limit as his study has been carried out under extensive consideration in order to most closely resemble the realistic conditions of application in dental procedures.

A remarkable observation is that digital techniques do not lead automatically to a reduced patient dose. Comparing the two different digital techniques

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**Table 2. The effective doses related to the proposed DRLs for different settings calculated from the E/DAP conversion factors derived by different authors.**

<table>
<thead>
<tr>
<th>Programme</th>
<th>Proposed DRL (mGy cm(^2))</th>
<th>E ((\mu)Sv)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Williams and Montgomery</td>
<td>Helmrot and Alm Carlsson</td>
</tr>
<tr>
<td>Large adult</td>
<td>101</td>
<td>6.1</td>
</tr>
<tr>
<td>Adult male</td>
<td>87</td>
<td>5.2</td>
</tr>
<tr>
<td>Adult female</td>
<td>84</td>
<td>5.0</td>
</tr>
<tr>
<td>Child</td>
<td>75</td>
<td>4.5</td>
</tr>
</tbody>
</table>

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Figure 1. Proposed DRL (3rd quartile) and measured DAP values of panoramic X-ray units for each setting ('large adult', 'adult male', 'adult female' and 'child'). The used image receptors are marked in different shades of grey.
showed that in general CCD-based systems could achieve lower doses than storage phosphor plate based systems. Many clinics using conventional film/screen techniques expose the patient with comparable or even lower doses than digital systems. In many cases, after making the transition from film/screen to digital systems using storage phosphor plate, the exposure parameters were not changed adequately to achieve dose optimisation. Overexposure may not be recognised by the operators as it can occur without an adverse impact on image quality. Furthermore, higher doses may decrease the image noise for digital receptors in a certain range of dose. Thus, a tendency to increase doses can occur to achieve higher image quality\textsuperscript{(13)}. This emphasises the presently well-recognised concern that careful attention needs to be paid to radiation protection issues in digital radiology. Both the dentists and their staff demonstrated a lack of information on how dose reduction can be realised. Operators conducting the X-ray examinations should be careful not to incur higher dose than necessary to patient when using digital image receptors.

CONCLUSION

As already mentioned by other authors, the usage of a DAP meter allows an easy and reliable method to collect the necessary data for standard examinations without the presence of a patient. The collected data are comparable to and consistent with studies published so far in literature. We realised that the transition to digital systems is not necessarily associated with a significant dose reduction even if properly adjusted machine parameters would allow this. ICRU publication No. 93\textsuperscript{(13)} suggests promoting training actions before digital techniques are introduced into clinical practices. Furthermore, it is recommended that the manufacturer should provide accurate and sufficient technical information to the staff to help in the optimisation of image quality and dose reduction. From our results we conclude that this statement is valid for dental facilities as well. Further studies should be carried out on the E/DAP conversion factors for panoramic dental radiology. The values calculated with the conversion factors by Visser\textsuperscript{(10)} may be used as an upper limit until more detailed investigations have been performed. The results presented in this study may be used to derive DRLs for panoramic dental radiology. A similar study has been carried out for intraoral dental radiology and reported elsewhere\textsuperscript{(14,15)}\textsuperscript{4}. Other imaging techniques commonly used in dental radiology such as lateral cephalometric radiography, computed tomography as well as digital volume tomography (cone beam computed tomography) were also investigated. The results of these studies will be reported in separate works.

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REFERENCES