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RADIATION EXPOSURE TO CHILDREN IN INTRAORAL DENTAL RADIOLOGY

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In this study, dose area product (DAP) measurements have been performed aiming at establishing diagnostic reference levels (DRLs) in paediatric intraoral dental radiology. Measurements were carried out at 52 X-ray units for all types of intraoral examinations performed in clinical routine. Not all X-ray units have pre-set child exposure settings with reduced exposure time or in some cases lower tube voltage. Child examinations are carried out using adult exposure settings at these units, which increases the DAP third quartile values by up to 50%. For example, third quartile values for periapical examination ranges from 14.4 to 40.9 mGy cm^2 for child settings and 20.6 to 48.8 mGy cm^2 when the adult settings are included. The results show that there exists a large difference between the patient exposures among different dental facilities. It was also observed that clinics working with faster film type or higher tube voltage are not always associated with lower exposure.

INTRODUCTION

According to UNSCEAR 2000 Report[1], dental radiography is one of the most frequent types of radiological procedures performed. Although the exposure associated with dental radiography is relatively low, any radiological procedure should be justified and optimised in order to keep the radiation risk as low as reasonably achievable[2]. Dose assessment is recommended to be performed on a regular basis to ensure that patient exposure is always kept within the recommended levels and to identify possible equipment malfunction or inadequate technique[3].

Compared to adults, children have been found to be more radiosensitive[4,5]. Therefore, increased attention should be paid to minimise the medical radiation exposures to children. All radiological procedures carried out on children must adapt to special radiation protection measures, which aims at recognising and implementing possible dose reduction strategies in order to eliminate unnecessary and therefore unjustified radiation exposure.

So far, no Europe-wide diagnostic reference levels (DRLs) have been promulgated for dental radiological procedures. DRLs were established for many common radiodiagnostic practices and are well accepted to assist in optimising radiological examinations in order to avoid unnecessarily high dose to patients[6]. According to the European Commission Medical Exposure Directive (97/43/EURATOM)[2], all member states shall promote the establishment and the use of DRLs for radiodiagnostic examinations and where available, the European DRLs should be used.

The use of dose area product (DAP) as the dose quantity in establishing reference levels in dental radiology was also recommended by different authors[7,8] and has proved to be a feasible approach. The aims of this study were to measure the DAP values and to determine the patient exposure resulting from paediatric intraoral dental radiography. The results could serve as a preliminary work in establishing DRLs in paediatric dental radiology.

MATERIALS AND METHODS

The measurements were performed at 52 intraoral X-ray units at 45 dentists in the Lower Saxony region, Germany, which have been carried out as part of a study 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. DAP values for the X-ray units were measured using a translucent transmission ionisation chamber connected to a DAP meter (DIAMENTOR M4, PTW Freiburg). The calibration of the device to diagnostic X-ray energies was done by the manufacturer Physikalisch-Technische Werkstätten (PTW), Freiburg, Germany. The ionisation chamber was attached to the end of the exit cone of the

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X-ray unit. To eliminate dose contribution from backscatter radiation, the exit cone was pointed towards the centre of the examination room. DAP values for all standard child exposure programmes used in daily clinical routine by different dentists were measured (periapicals: maxillary and mandibular molar, premolar, canine and incisor, bitewing and occlusal radiography). Out of 52 X-ray units, 32 units have pre-set child exposure settings with reduced exposure time or in some cases lower tube voltage compared to adult settings, whereas the others used the same exposure settings for both adult and child examinations. For units without specific child programmes, the DAP values obtained for the typical adult exposure settings were used instead. For each X-ray unit, the DAP value of one chosen programme was measured three times to check the stability of the X-ray unit. The exposure parameters such as tube voltage, tube current and exposure time were documented for each measurement. For references, the types of the X-ray units along with the manufacturers, film speed and film developer were also recorded.

Six out of the 52 X-ray units are equipped with a digital system. Five of the digital systems use storage phosphor plates and one uses a charge-coupled device sensor chip. Out of the measured X-ray units, there are 4 units operating at 50 kV, 6 units at 60 kV, 30 units at 65 kV and 12 units either operating at 70 kV or with adjustable tube voltage between 60 and 70 kV. Dental films are provided in different speed groups with D-speed films being the slowest and F-speed the fastest. Around one-third of the clinics equipped with conventional systems are still using D-speed film while the others have switched to E/F-speed film which could reduce exposure up to 50% compared to D-speed film[3].

Common statistical parameters have been calculated from the measurements. Besides the mean values, the third quartile values of the distribution have been extracted. According to European Commission Radiation Protection Document no. 109[6], the latter one may be used as an upper reference level which could be defined based on our results.

RESULTS

Third quartiles and mean values for each type of intraoral examinations computed separately for all the 52 X-ray units and the 32 X-ray units with child exposure settings are summarised in Table 1. The percentage increase when including adult exposure settings are presented alongside. The third quartile values and the mean values of periapical examinations increase by up to 50% when the DAP values of the adult exposure settings are included. The most evident difference is observed for incisor examinations. There is no significant increase in these values for bitewing and occlusal radiography when adult settings are included.

For periapical radiography, the highest dose was measured for maxillary molar examinations while mandibular incisor examinations require the shortest exposure time and hence lead to the lowest dose as expected. However, for the same examination, there is a large difference between the doses of different X-ray units. Figure 1 shows the measured DAP values of the 52 X-ray units for periapical examinations of the maxilla. The DAP values of the X-ray units without specific child exposure settings are shaded.

Table 1. Third quartiles and means of the DAP values for only child exposure settings and DAP values including adult exposure settings along with the percentage difference between both.

Examinations	3rd quartile[a] (mGy cm^2)	3rd quartile[b] (mGy cm^2)	Difference in 3rd quartile (%)	Mean[a] (mGy cm^2)	Mean[b] (mGy cm^2)	Difference in mean (%)
Maxillary molar	40.9	48.8	19.3	29.7	39.1	31.6
Maxillary premolar	27.7	37.6	35.7	19.7	27.1	37.6
Maxillary canine	23.6	33.6	42.4	18.3	23.6	29.0
Maxillary incisor	22.0	32.0	45.5	17.1	24.3	42.1
Mandibular molar	27.8	35.0	25.9	19.9	25.9	30.2
Mandibular premolar	18.9	24.4	29.1	14.6	19.8	35.6
Mandibular canine	18.9	24.4	29.1	14.6	19.6	34.2
Mandibular incisor	14.4	20.6	43.1	12.0	18.1	50.8
BTW: front	39.8	41.6	4.5	28.0	29.1	3.9
BTW: back	41.7	41.9	0.5	29.9	30.4	1.7
OCC: maxilla	56.9	56.9	0	51.9	47.8	−7.9
OCC: mandible	44.2	44.2	0	40.8	37.1	−9.1

[a]Only child exposure settings.
[b]Included adult exposure settings.
BTW, bitewing; OCC, occlusal.

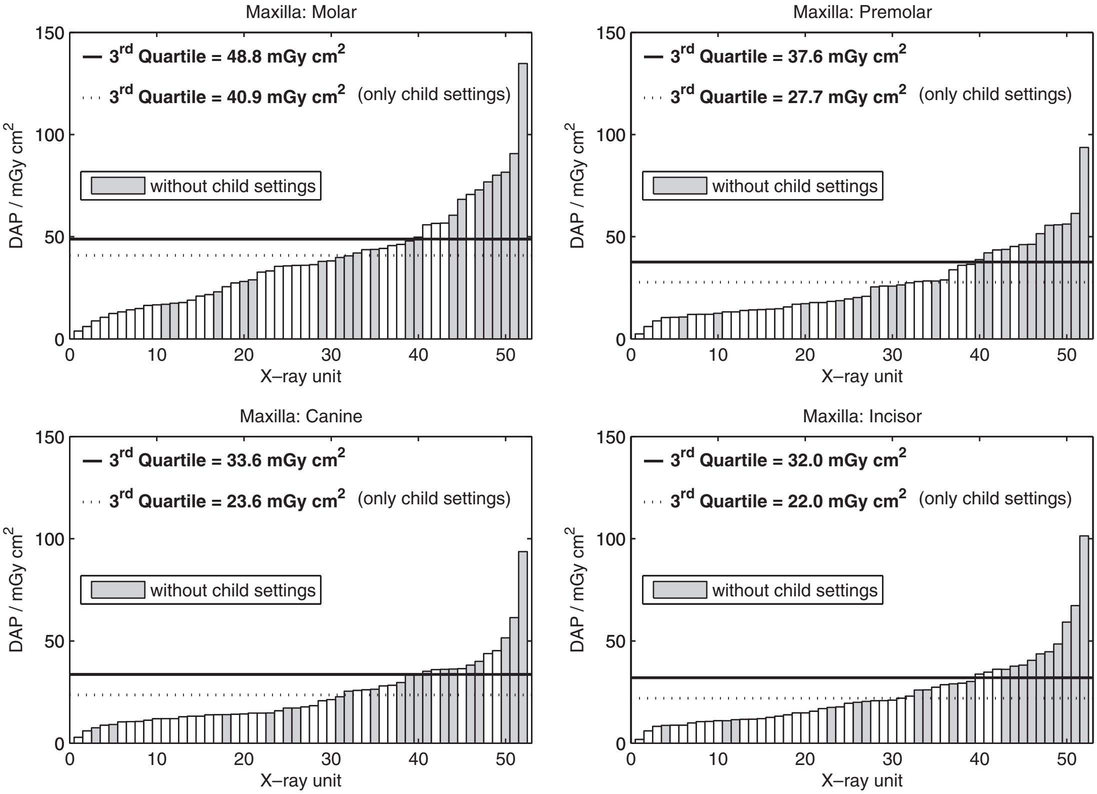

Figure 1. DAP values of periapical radiography of the maxilla. *x*-axis indicates the measured X-ray units.

The third quartile values are shown separately for all the 52 X-ray units and the 32 X-ray units with child exposure settings. The widest variation in dose range for child settings was observed for maxillary molar examinations, which yield DAP values from 3.8 to 70.6 mGy cm^2. The minimum dose measured of non-digital systems is less than one-fifth of the maximum value measured. Radiation dose from a bitewing examination is comparable to one maxillary molar examination. Among the three categories of examinations, occlusal radiography exposes the patient to the highest dose.

Nevertheless, it was observed that using a higher speed film or higher tube voltage does not always lead to dose reduction. As an example, Figure 2 shows the DAP values of maxillary molar examinations plotted according to the used image receptor. It also shows that digital system that requires less exposure than conventional film radiology exposes the least dose to patients.

DISCUSSION

The study shows that there exists a large difference between the patient exposures among different dental facilities. The disparity may arise from the different X-ray units used, exposure techniques, film speed or even inadequate exposure settings. One other cause of the diverse radiation dose observed is the fact that different dentists have their own preferred contrast for the film to be diagnostically acceptable. Image made with lower tube voltage often has better contrast which is more diagnostically favourable for most dentists. However, lower tube voltage must also be accompanied by longer exposure time to get enough radiation onto the image receptor that in turn increasing the patient exposure. Up to 50% dose reduction could be achieved by using the appropriate settings when performing examinations on children. Since children have thinner skull and tissue than adults, the use of adult exposure settings on children may often deteriorate the image quality on one side and cause unnecessarily high exposure to children on the other side.

While reference levels for children intraoral dental radiology have not been published so far, DAP values for some typical adult intraoral examinations were reported by other authors. Helmrot and Alm Carlsson[7] measured the DAP values for

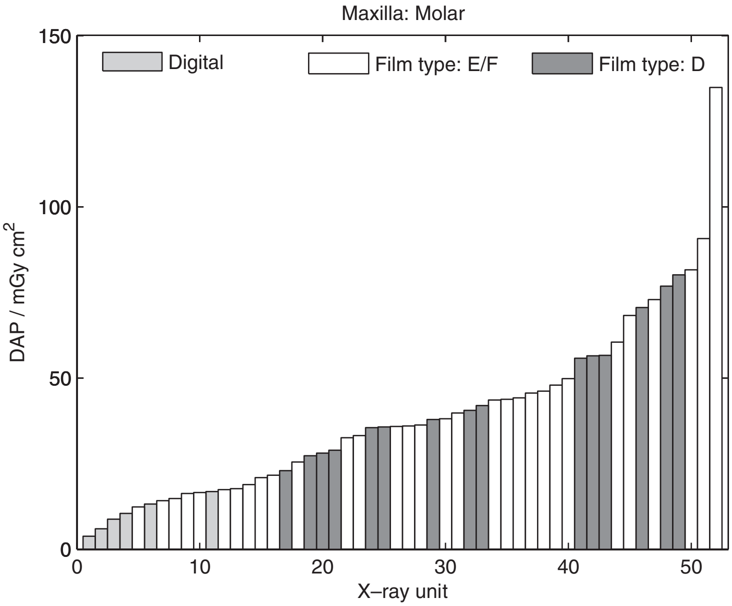

Figure 2. DAP values of periapical maxillary molar examinations with the used image receptors classified. *x*-axis indicates the measured X-ray units.

a number of common examinations at a Gendex Oralix DC X-ray unit operating at 60 kV equipped with rectangular collimator. They measured DAP values of 14–34 mGy cm^2. Tierris *et al.*[8] also carried out DAP measurements at 20 intraoral X-ray units operating at 50, 60 and 70 kV for typical adult exposure settings. Mean DAP values were found to be 80, 62 and 34 mGy cm^2 for the three different tube voltages, respectively. Our measured values for children settings which are lower than those measured by Tierris *et al*. demonstrate the difference between the radiation exposure of adult and child settings.

Although radiation exposure arising from dental radiology is considered to be low, a child may undergo repeated dental radiological procedures during childhood and adolescence. Therefore, the accumulated effect of the radiation exposure should be taken into consideration. Salivary gland and the thyroid gland are among the organs at risk in dental radiology. Salivary gland, which often lies within the primary beam in intraoral radiographic projections has been shown to receive dose from 0.02 mGy up to ~0.1 mGy per examination by Lecomber *et al.*[9]. Preston-Martin *et al.*[10] found that cumulative exposure of the salivary gland is associated with increase in risk of malignant tumours. Another study has shown that ~15% of parotid gland cancers were attributed to prior exposure from diagnostic radiology[11]. However, one should not over interpret this result. A rough estimation of the risk due to exposure to salivary gland can be performed based on ICRP recommendation. When using a risk factor of 15% Sv^{-1} for children and a tissue weighting factor of 2.5%, which is probably an overestimation because the salivary gland is not a remainder organ and the highest dose of 0.1 mGy per examination, the resulting risk would be $<4 \times 10^{-7}$, which is a comparable small risk.

Dose received by the thyroid gland, mainly due to scattered radiation, is comparably less than those received by the salivary glands. On the other hand, the thyroid gland is one of the most radiosensitive organs for children and dose imparted on the thyroid gland should be minimised whenever possible.

Even if the relative risk in dental radiology is smaller when comparing with other radiological investigation techniques, our study still shows that with adequate techniques the dose to children can be reduced further.

The technologist should be given adequate information on the possibilities of reducing dose to children in the situation where there is no pre-set child exposure setting available for the X-ray unit. One simple option would be using adult canine exposure settings for child molar examinations, which reduces the irradiation time. X-ray units operating at different tube voltages did not show significant distinctive behaviour in our results; however, it should be noted that 2 out of the 3 highest DAP values for periapical radiography were measured on X-ray units operating at 50 kV.

The transition to faster film types should always be accompanied by reduction of exposure time, which was not always the case in our study. Technologists should be informed about the necessity of reducing exposure time when working with faster films.

CONCLUSION

The study shows that there is a large dose variation between different X-ray units used for the same radiographic projection. When performing radiological examinations on children, a reduced child exposure programme shall be used. Clinics working with faster film type or higher tube voltage are not always associated with lower exposure. Many precaution measures could be taken at no cost to reduce the patient exposure by choosing the appropriate exposure parameters. Operators of X-ray units shall pay special attention to ensure that the right radiological equipment and techniques are used when performing radiological procedures on children. The results of this study could be used in establishing DRLs in paediatric intraoral dental radiology.

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REFERENCES

1. United Nations Scientific Committee on the Effects of Atomic Radiation. *Sources and effect of ionizing radiation*. Report Vol. 1 UNSCEAR publications (2000).
2. European Union. *Council Directive 97/43 Euratom, on health protection of individuals against the dangers of ionizing radiation in relation to medical exposures, and repealing Directive 84/466 Euratom*. Off. J. Eur. Commun. **L180**, 22 (1997).
3. Radiation protection 136. European Guidelines on radiation protection in dental radiology: The safe use of radiographs in dental radiology. European Commission publications.
4. Almén, A. and Mattsson, S. *On the calculation of effective dose to children and adolescents*. J. Radiol. Prot. **16**(2), 81–89 (1996).
5. International Comission on Radiological Protection. *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60. (Oxford: Pergamon Press) (1991).
6. Radiation protection 109. Guidance on diagnostic reference levels (DRLs) for medical exposures. European Commission publications.
7. Helmrot, E. and Alm Carlsson, G. *Measurement of radiation dose in dental radiology*. Radiat. Prot. Dosim. **114**(1–3), 168–171 (2005).
8. Tierris, C. E., Yakoumakis, E. N., Bramis, G. N. and Georgiou, E. *Dose area product reference levels in dental panoramic radiology*. Radiat. Prot. Dosim. **111**(3), 283–287 (2004).
9. Lecomber, A. R. and Faulkner, K. *Organ absorbed doses in intraoral dental radiography*. Br. J. Radiol. **66**(791), 1035–1041 (1993).
10. Preston-Martin, S., Thomas, D. C., White, S. C. and Cohen, D. *Prior exposure to medical and dental x-rays related to tumors of the parotid gland*. J. Natl Cancer. Inst. **80**(12), 943–949 (1988).
11. Preston-Martin, S. and White, S. C. *Brain and salivary gland tumors related to prior dental radiography: implications for current practice*. J. Am. Dent. Assoc. **120**(2), 151–158 (1990).