REPORT

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Dosimetric Evaluation in Dental Radiology

Radiological procedures performed for panoramic and volume acquisitions with the Kodak 9000 3D device

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RADIOLOGICAL PROTECTION AND HUMAN HEALTH DIVISION (DRPH)

Radiation Protection Expertise Department (SER)

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Dosimetric Evaluation in Dental Radiology

Radiological procedures performed for panoramic and volume acquisitions with the Kodak 9000 3D device

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DRPH/SER Report No. 2008-07

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SUMMARY

The purpose of this work is to study the influence of radiological parameters on the dose delivered to various organs located in the buccal environment of a child and an adult during dental radiological procedures performed using a device for panoramic and volume acquisitions (Kodak 9000 3D). The radiological procedures carried out and studied using this type of equipment are today considered to be routine.

As well as a guide to device operation and an estimate of the effective dose (E) associated with each procedure, this report also contains information regarding the doses delivered to various organs within the field of radiation and contiguous to it.

KEYWORDS

Dentistry, panoramic acquisition, volume acquisition organ dose, effective dose

CONTENTS

1. INTRODUCTION

The Kodak Company called upon the IRSN to perform a dosimetric study on a hominoid phantom during various radiological procedures using the Kodak 9000 3D device: the dental panoramic and volume radiography. The purpose of this study is to evaluate the dose to salivary glands (parotid and submandibular glands), thyroid, spinal cord, crystalline lens and the surface of the skin of a child and an adult, as well as the effective dose associated with each of the procedures.

2. DESCRIPTION OF THE "KODAK 9000-3D" MEDICAL DEVICE

This radiological equipment (see photo 1), mainly dedicated to implantology, is used to perform dental radiographic acquisitions for panoramic views as well as tomographic acquisitions of a partial volume of a mandible or maxilla, including the teeth. The radiological equipment is equipped with an x-ray generator and two digital detectors (one per acquisition mode). In 3D mode, x-ray detection is performed by a fibre optic sensor. This device allows for the rotation of x-rays beams over approximately 240° in the case of a dental panoramic and over 360° in the case of volume procedures.

In the latter mode, this device generates images in all planes reconstructed after transfer and processing of digital information acquired during rotation of the x-ray tube-detector assembly around the volume explored.

After acquisition, the digital data generated for each angular projection is transferred to a post-processing computer, and then a voxel matrix that corresponds to the explored anatomical volume is reconstructed.

It is then possible to extract images in all planes which can be used by a dentist to define a therapeutic strategy.

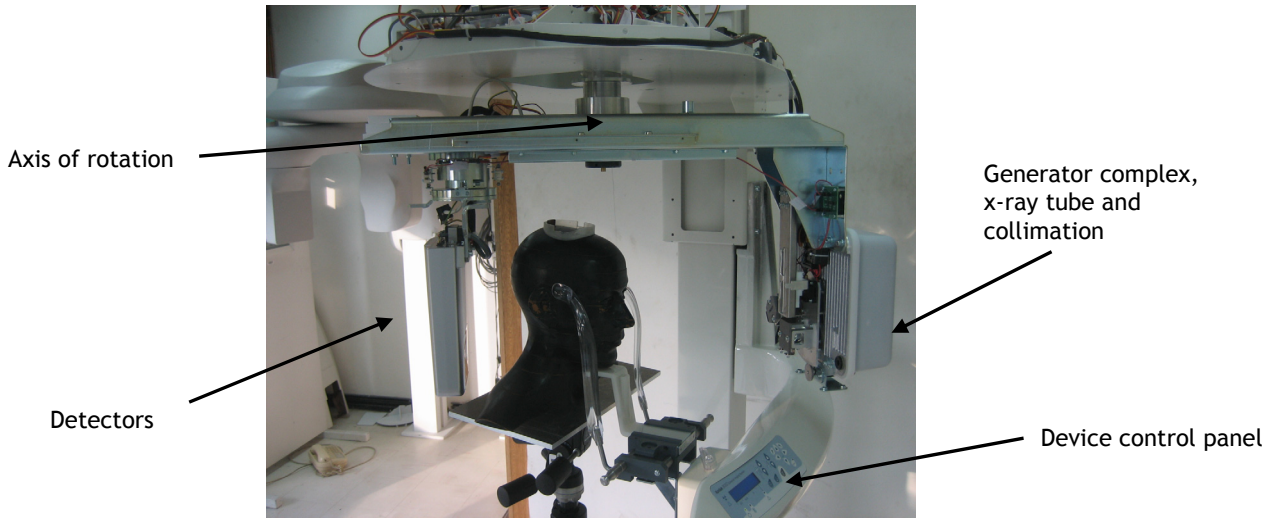


Photo 1: Main components of the Kodak 9000 3D device (housing removed)

The technical operating parameters for panoramic and volume modes are shown in Table I.

Table I: Technical parameters used in panoramic mode and in volume mode.

Parameter	Panoramic mode	Volume mode
Covered field	4mm x 126mm to 613mm from x-ray focal spot	48mm x 60mm to 690mm from x-ray focal spot
Image receiver size	CCD - 6.55mm x 129.4mm	CMOS-48mm x 60mm
Position of object	500mm: distance from incisors / from x-ray focal spot	440mm from x-ray focal spot
High voltage (kV)	from 60 to 90	from 60 to 90
Intensity (mA)	from 2 to 15	from 2 to 15
Total filtration	2.5mm eq. Al including 1.2mm of Al (glass-ware, oil) at 70kV.	2.5mm eq. Al including 1.2mm of Al (glass-ware, oil) at 70kV.
CDA	5.2mm Al at 90kV	5.2mm Al at 90kV
Exposure time	14.3 s (adult), 10.8 s (child)	30ms per acquisition. (full test = 360 acquisitions)

Figure 1 shows the implementation of a radiological procedure on the device and the principle of tomographic acquisition via a conical beam of x-rays allowing the radiography of an area of the maxillary region in a single 360° rotation.

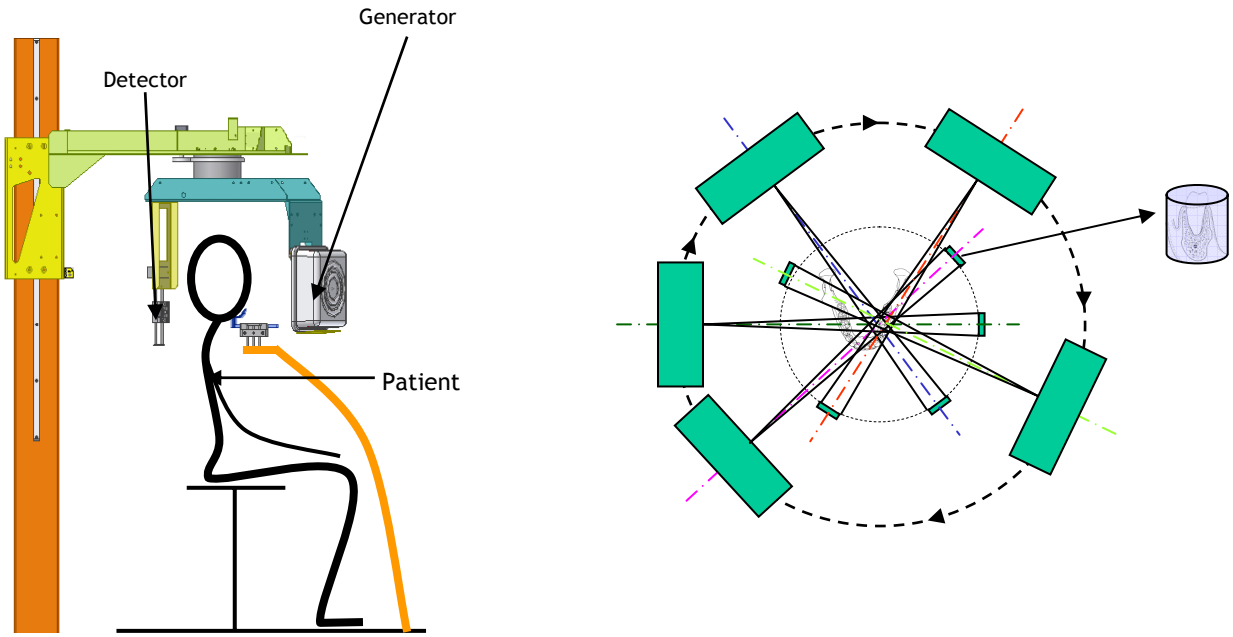


Figure 1: Representation of the implementation of a radiological procedure using the Kodak 9000 3D device, as well as the principle of image acquisition (360 images over 360°)

3. DOSIMETRIC EVALUATION OF VARIOUS RADIOGRAPHIC PROTOCOLS ON A HOMINOID PHANTOM

Thermoluminescence dosimetry is the only technique available for dose measurement in hominoid phantoms. It is adapted for spot measurements, low doses (≥1µGy), and when the number of measurement points is high.

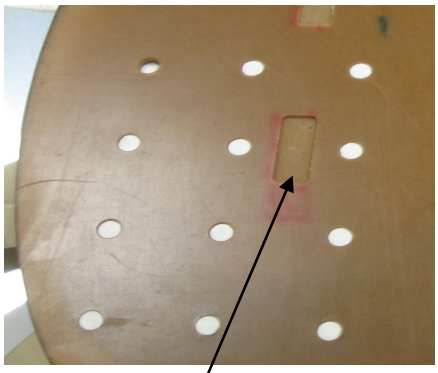
3.1. MATERIALS AND METHODS

The dosimeters used are chips with a diameter of 4.5mm and thickness of 0.8mm, placed on tabs (photo 2). These LiF dosimeters: Mg, Cu, P are made of materials equivalent to tissue. They are supplied and read by the LSDOS department of IRSN.

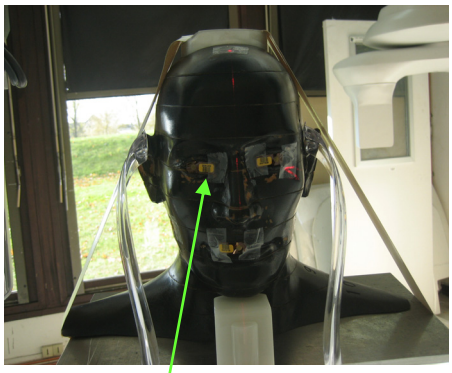
Photo 2: Thermoluminescent dosimeters on tabs

They are read using a Harshaw TLD model 8800 automatic reader from the Ariès company. The TLDs were first calibrated with Cobalt-60. They were exposed to different energies to deduce a correction coefficient linked to energy. An additional correction factor must be applied for the TLD reader. This coefficient is directly included in the final result for TLD readings.

The hominoid phantom (RANDO), with a density equivalent to that of a human body, is made up of several sections (photo 3A) with a thickness of 25mm, in which slots are included to position the tabs with the TLDs. The chips were placed on the surface and in the head of the hominoid phantom (photo 3B). For each surface measurement point, a single dosimeter was positioned per selected measurement point and for each internal measurement point, 2 to 3 TLDs were positioned in the various slots specific to selected measurement points. Note that in some cases, to obtain a better response from the TLDs, several exposures were cumulated.
The resulting dose for each measurement point is an average of the sum of the TLD dose values per measurement point divided by the number of exposures.



A) Insertion slot for TLD tab within a section of the hominoid phantom



B) RANDO phantom head and position of TLDs on surface

Photos 3 A and B: Insertion slot in a section of the hominoid phantom and thermoluminescent dosimeters on tabs positioned on its surface

For all volume acquisitions, the hominoid phantom was positioned with regard to the rotation axis of the x-ray tube/detector assembly (photo 4) and the area to be radiographed was centred around either a representation of the mandible or maxilla displayed on the control station panel (figure 2).

Figure 2: Centring of the zone to be explored on the control station panel (the axis of rotation is represented by the red cross).

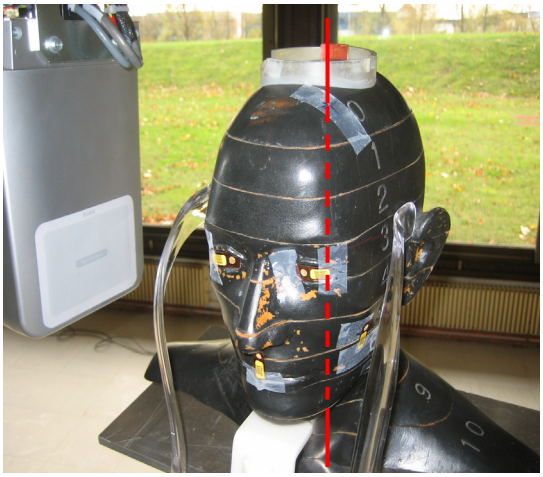


Photo 4: Positioning of the phantom with regard to the rotation axis of the tube /detector pair (red hashed line)

3.2. RESULTS

Results were obtained for panoramic acquisitions (cases 1 to 5) and volume acquisitions (cases 6 to 11) for children and adults. All tables of dose values for each acquisition are shown in Appendix 1.

3.2.1. Panoramic acquisition - Adult-70kV

Figure 3 shows the distribution of doses to organs during a panoramic procedure for an adult. The acquisition parameters are as follows: high voltage: 70kV, load: 143mAs

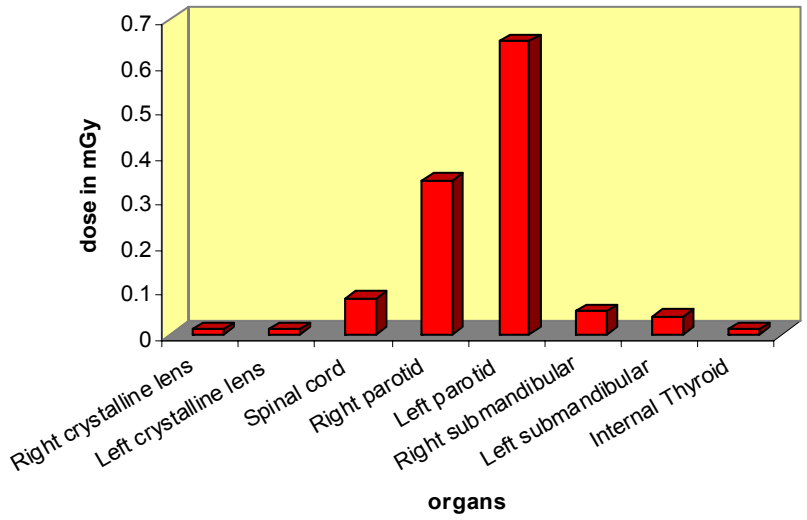


Figure 3: distribution of the organ dose during a panoramic for an adult patient (H.V.:70kV, load: 143mAs)

The organ doses are between 40µGy (internal thyroid) and 650µGy (left parotid gland). During this routine dentistry procedure, the maximum dose delivered to the submandibular salivary glands is equal to 50µGy (right submandibular gland), or a factor of 13 between the left parotid gland and the right submandibular gland. The thyroid gland, spinal cord and crystalline lenses receive 10µGy, 80µGy and 10µGy respectively. On the surface of the skin, the maximum dose is equal to 470µGy.

3.2.2. Panoramic acquisition - Adult-80kV

Figure 4 shows the distribution of doses to organs during a panoramic procedure for an adult. The acquisition parameters are as follows: high voltage: 80kV, load: 143mAs

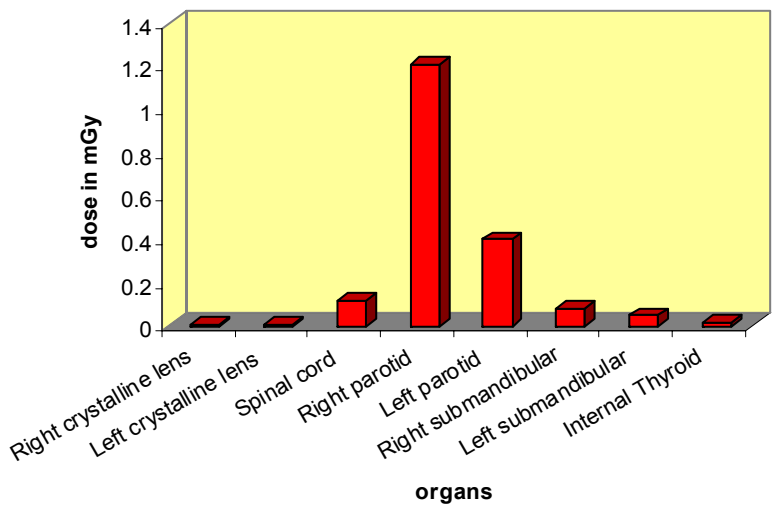


Figure 4: distribution of the organ dose during a panoramic for an adult patient (H.V.:80kV, load: 143mAs)

The organ doses are between 10µGy (right and left crystalline lenses) and 1.21mGy (right parotid gland). During this procedure, a dose approximately equal to 80µGy is delivered to the right submandibular salivary gland, or a factor of 16 between the right submandibular and parotid glands. The thyroid gland receives 20µGy and the spinal cord receives 120µGy. On the surface of the skin, the maximum dose is equal to 220µGy.

3.2.3. Panoramic acquisition - Child 60kV

Figure 5 shows the distribution of doses to organs during a panoramic procedure for a child. The acquisition parameters are as follows: high voltage: 60kV, load: 108mAs

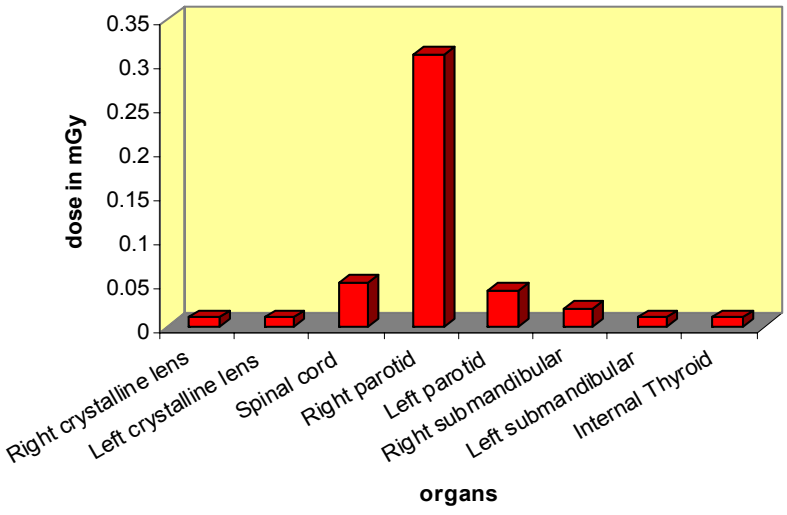


Figure 5: distribution of the organ dose during a panoramic for a child (H.V.:60kV, load: 108mAs)

The organ doses are between 10µGy (left submandibular gland) and 310µGy (right parotid gland). During this routine dentistry procedure, the maximum dose delivered to the submandibular salivary glands is equal to 20µGy (right submandibular gland), or a factor of 16 between the parotid glands and the right submandibular glands. The thyroid gland receives 10µGy and the spinal cord receives 50µGy. On the surface of the skin, the maximum dose is equal to 110µGy.

3.2.4. *Panoramic acquisition - Child 70kV*

Figure 6 shows the distribution of doses to organs during a panoramic procedure for a child. The acquisition parameters are as follows: high voltage: 70kV, load: 108mAs.

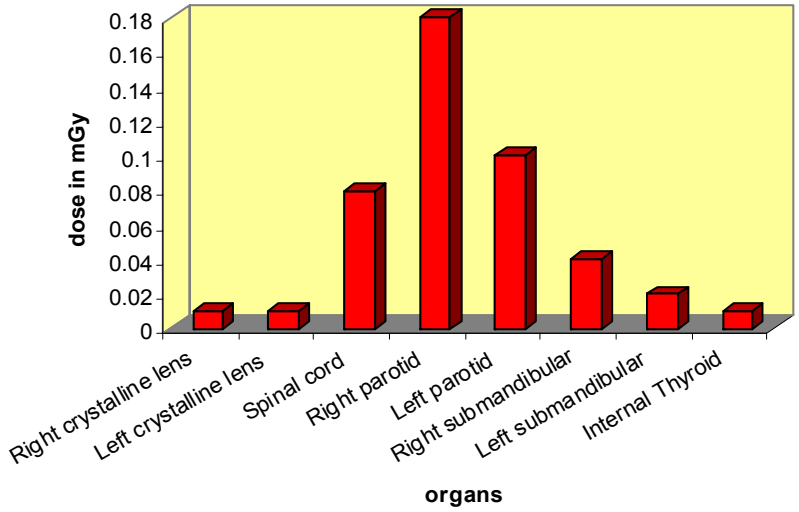


Figure 6: distribution of the organ dose during a panoramic for a child (H.V.:70kV, load: 108mAs)

The organ doses are between 10µGy (thyroid gland) and 180µGy (right parotid gland). A maximum dose approximately equal to 40µGy is delivered to the right submandibular salivary gland and a dose approximately equal to 180µGy is delivered to the right parotid gland, or a factor of 4.5 between the right submandibular gland and the right parotid gland. The thyroid gland receives 10µGy and the spinal cord receives 80µGy.

3.2.5. *Panoramic acquisition - Child - 70kV + additional collimator*

Figure 7 shows the distribution of doses to organs during a panoramic procedure for a child with an additional collimator (photo 5). The acquisition parameters are as follows: high voltage: 70kV, load: 108mAs

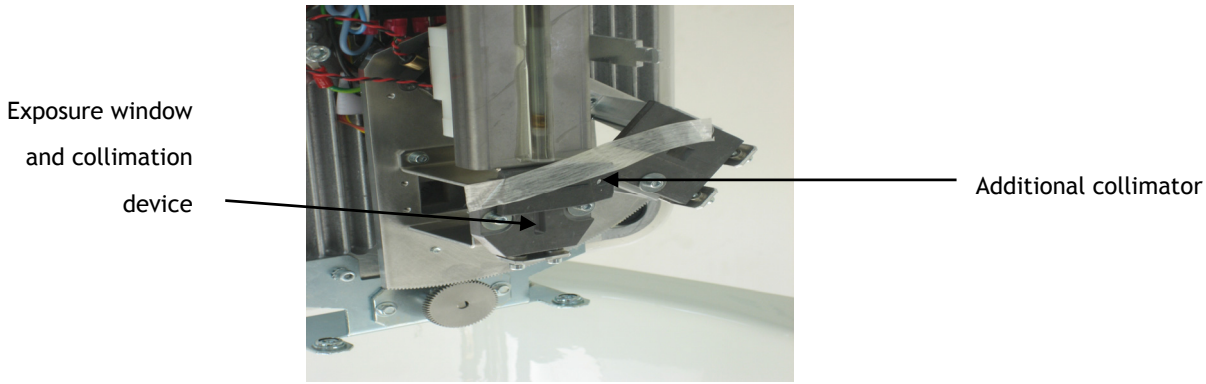


Photo 5: Additional collimator at upper section of the exposure window for the collimation device dedicated to the "dental panoramic" procedure

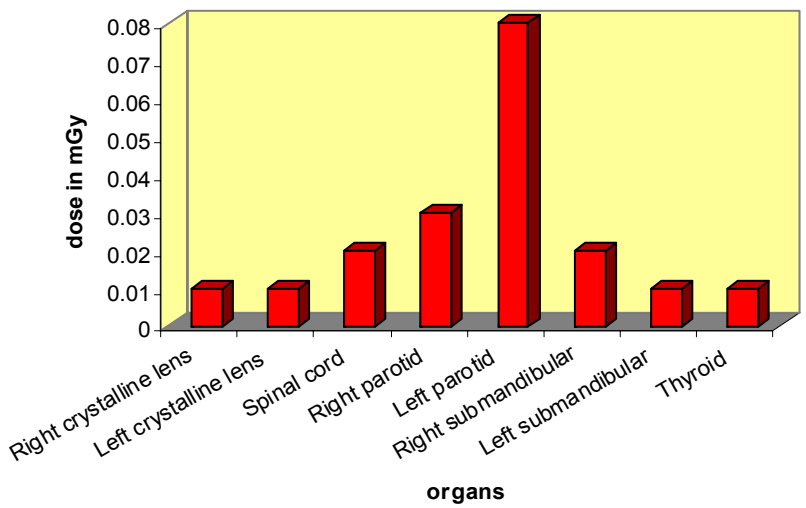


Figure 7: distribution of the organ dose during a panoramic for a child (H.V.:70kV, load: 108mAs)

The organ doses are between 10µGy (thyroid gland) and 80µGy (left parotid gland). A maximum dose approximately equal to 20µGy is delivered to the right submandibular salivary gland and a dose approximately equal to 10µGy is delivered to the left submandibular gland, or a factor of 4 between the right submandibular gland and the left parotid gland. The thyroid gland receives 10µGy and the spinal cord receives 20µGy. On the surface of the skin, the maximum dose is equal to 30µGy.

3.2.6. Volume acquisition - Adult - 70kV-incisors

Figure 8 shows the distribution of doses to organs during a procedure known as "mandibular incisor block" in 3D for an adult. The acquisition parameters are as follows: high voltage: 70kV, load: 107mAs.

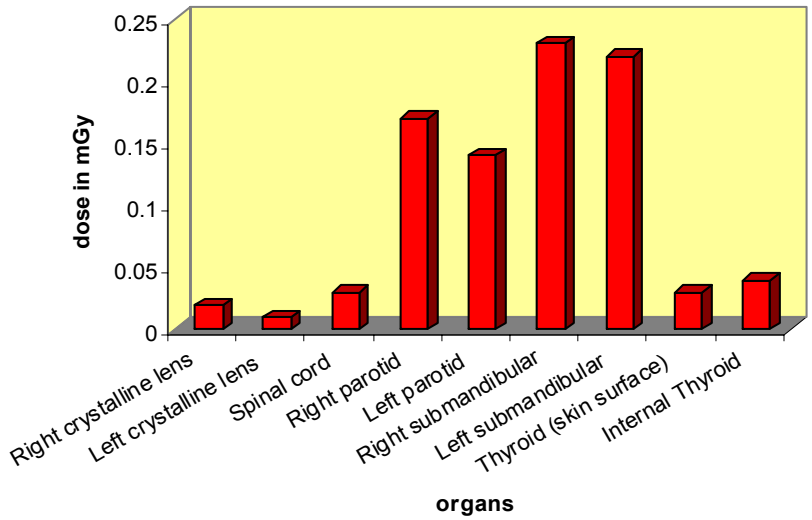


Figure 8: distribution of doses to organs during a procedure known as "mandibular incisor block" in 3D for an adult (H.V.:70kV, load: 107mAs)

The organ doses are between 30µGy (surface thyroid gland) and 230µGy (right submandibular gland). A maximum dose approximately equal to 170µGy and 140µGy is delivered to the right and left parotid glands respectively, or a factor of 1.4 between the parotid and right submandibular glands. The thyroid gland receives 40µGy and the spinal cord receives 30µGy. On the surface of the skin, the maximum dose is equal to 3.78mGy.

3.2.7. Volume acquisition - Adult - 80kV-incisors

Figure 9 shows the distribution of doses to organs during a procedure known as "mandibular incisor block" in 3D for an adult. The acquisition parameters are as follows: high voltage: 80kV, load: 107mAs.

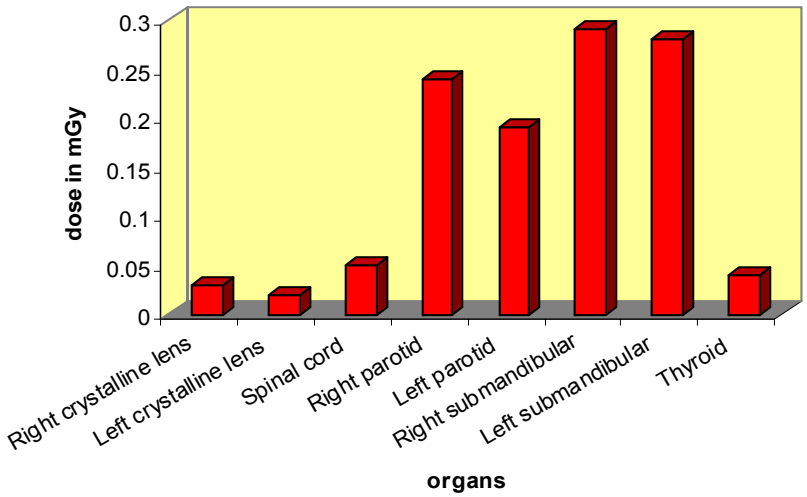


Figure 9: distribution of doses to organs during a procedure known as "mandibular incisor block" in 3D for an adult (H.V.:80kV, load: 107mAs)

The organ doses are between 40µGy (thyroid gland) and 290µGy (right submandibular gland). A maximum dose approximately equal to 240µGy and 190µGy is delivered to the right and left parotid glands respectively, or a factor of 1.2 between the parotid and right submandibular glands. The thyroid gland receives 40µGy and the spinal cord receives 50µGy. On the surface of the skin, the maximum dose is equal to 3.92mGy.

3.2.8. Volume acquisition - Child - 60kV-incisors

Figure 10 shows the distribution of doses to organs during a procedure known as "mandibular incisor block" in 3D for a child. The acquisition parameters are as follows: high voltage: 60kV, load: 107mAs.

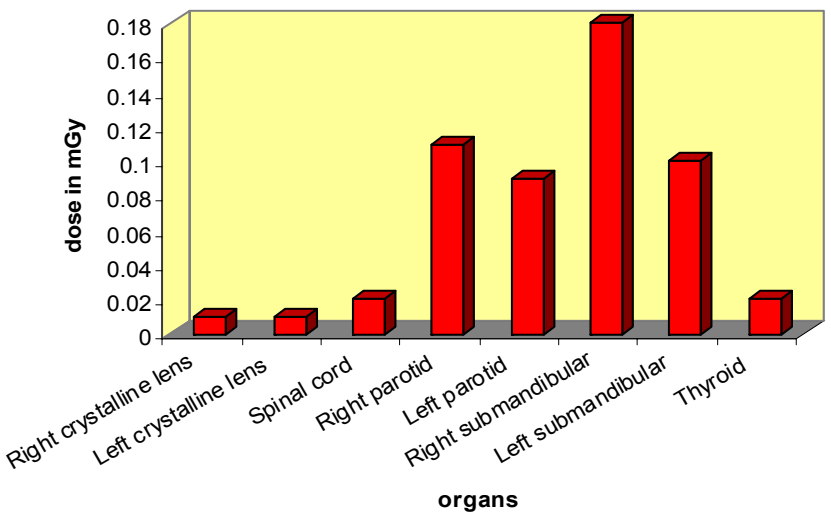


Figure 10: distribution of doses to organs during a procedure known as "mandibular incisor block" in 3D for a child (H.V.:60kV, load: 107mAs)

The organ doses are between 20µGy (thyroid gland) and 180µGy (right submandibular gland). A maximum dose approximately equal to 110µGy and 90µGy is delivered to the right and left parotid glands respectively, or a factor of 1.6 between the parotid and right submandibular glands. The thyroid gland receives 20µGy and the spinal cord receives 20µGy. On the surface of the skin, the maximum dose is equal to 2.39mGy.

3.2.9. Volume acquisition - Child - 60kV-molars

Figure 11 shows the distribution of doses to organs during a procedure known as "maxillary molar block" in 3D for a child. The acquisition parameters are as follows: high voltage: 60kV, load: 107mAs.

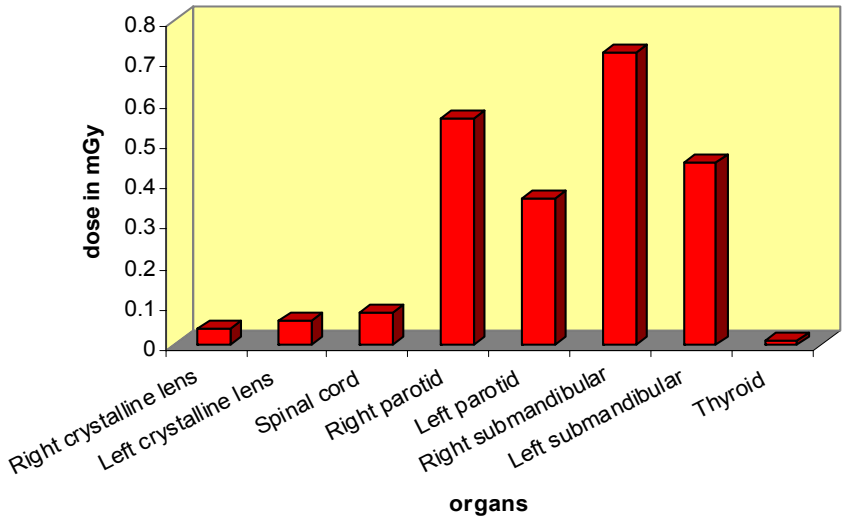


Figure 11: distribution of doses to organs during a procedure known as "maxillary molar block" in 3D for a child (H.V.:60kV, load: 107mAs)

The organ doses are between 10µGy (thyroid gland) and 720µGy (right submandibular gland). A maximum dose approximately equal to 560µGy and 360µGy is delivered to the right and left parotid glands respectively, or a factor of 1.3 between the parotid and right submandibular glands. The thyroid gland receives 10µGy and the spinal cord receives 80µGy. On the surface of the skin, the maximum dose is equal to 1.97mGy.

3.2.10. Volume acquisition - Adult - 70kV-molars

Figure 12 shows the distribution of doses to organs during a procedure known as "maxillary molar block" in 3D for an adult. The acquisition parameters are as follows: high voltage: 70kV, load: 107mAs

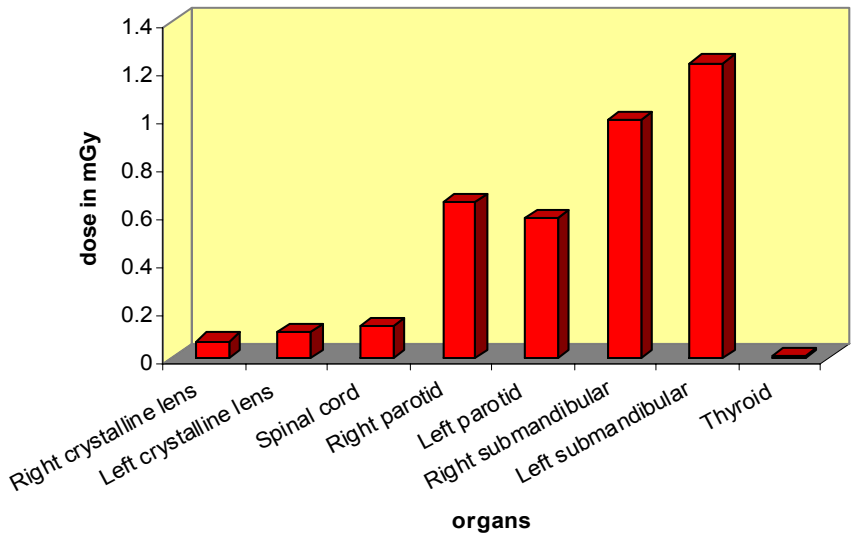


Figure 12: distribution of doses to organs during a procedure known as "maxillary molar block" in 3D for an adult (H.V.:70kV, load: 107mAs)

The organ doses are between 10µGy (thyroid gland) and 1.23mGy (left submandibular gland). A maximum dose approximately equal to 650µGy and 580µGy is delivered to the right and left parotid glands respectively, or a factor of 2.1 between the parotid and left submandibular glands. The thyroid gland receives 10µGy and the spinal cord receives 130µGy. On the surface of the skin, the maximum dose is equal to 2.78mGy.

3.2.11. Volume acquisition - Adult - 80kV-molars

Figure 13 shows the distribution of doses to organs during a procedure known as "maxillary molar block" in 3D for an adult The acquisition parameters are as follows: high voltage: 80kV, load: 107mAs.

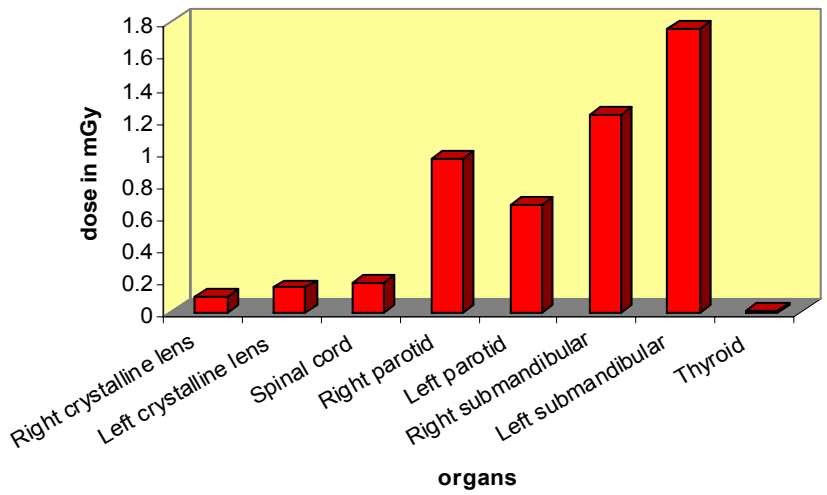


Figure 13: distribution of doses to organs during a procedure known as "maxillary molar block" in 3D for an adult (H.V.:80kV, load: 107mAs)

The organ doses are between 10µGy (thyroid gland) and 1.76mGy (left submandibular gland). A maximum dose approximately equal to 950µGy and 660µGy is delivered to the right and left parotid glands respectively, or a factor of 2.7 between the parotid and left submandibular glands. The thyroid gland receives 10µGy and the spinal cord receives 180µGy. On the surface of the skin, the maximum dose is equal to 3.97mGy.

3.2.12. Comparing dosimetric evaluations of volume acquisitions

3.2.12.1. Summary of evaluations for exploration of the mandibular incisor block

Figure 14 shows the comparison of doses delivered to organs (parotid glands, submandibular glands, thyroid and crystalline lenses) during 3D acquisitions for different voltages (60kV, 70kV and 80kV) and the same load of 107mAs.

In addition to these organ measurements, phantom skin measurements were performed in various positions for 60, 70 and 80kV. For acquisition of the mandibular incisor block, the maximum doses are 2.4mGy, 3.8mGy and 3.9mGy.

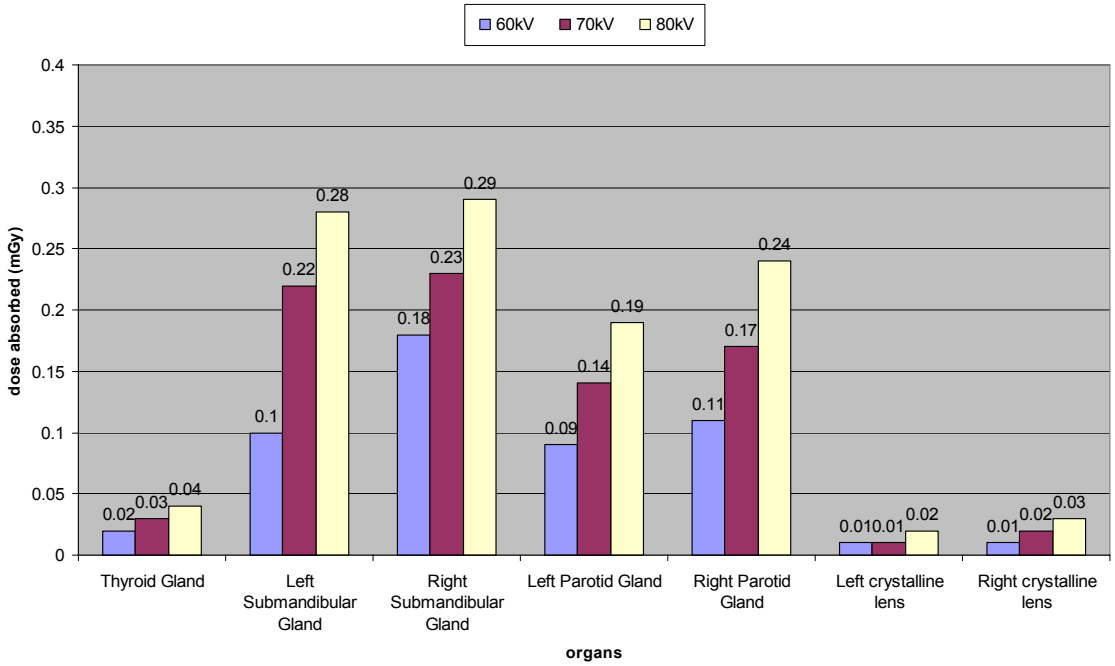


Figure 14: distribution of doses to organs during a procedure known as "mandibular incisor block" in 3D at three different voltages (60, 70 and 80kV) and a load of107mAs

3.2.12.2. Summary of evaluations for exploration of the maxillary molar block

Figure 15 shows the comparison of doses delivered to organs (parotid glands, submandibular glands, thyroid and crystalline lenses) during 3D acquisitions for different voltages (60kV, 70kV and 80kV) and the same load of 107mAs.

In addition to these organ measurements, phantom skin measurements were performed in various positions for 60, 70 and 80kV. For acquisition of the maxillary molar block, the maximum doses are respectively 2mGy, 2.8mGy and 4mGy.

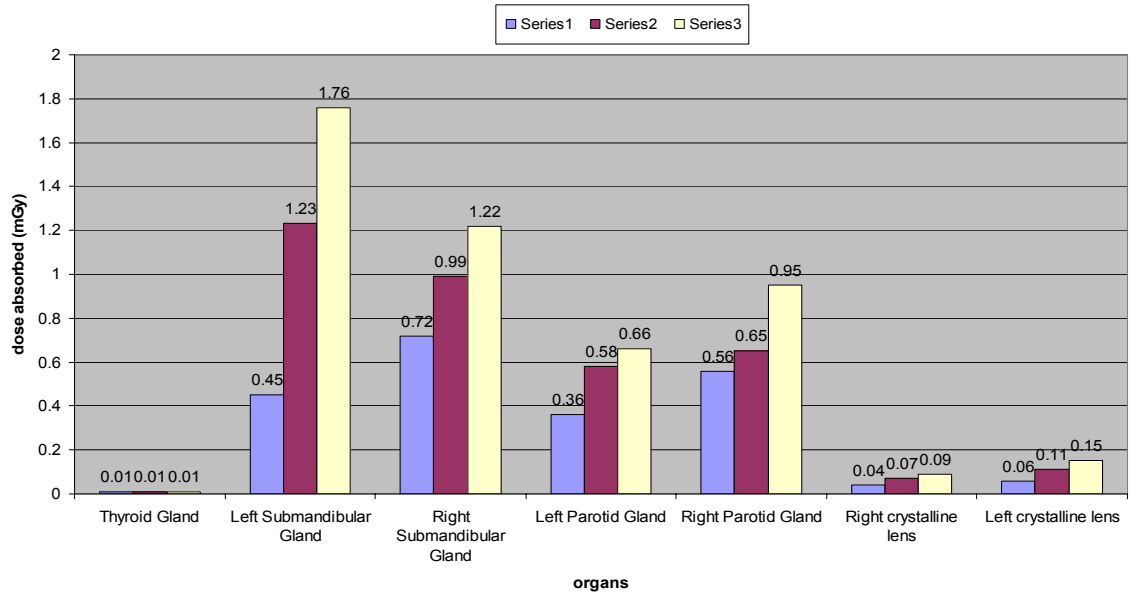


Figure 15: distribution of doses to organs during a procedure known as "maxillary molar block" in 3D at three different voltages (60, 70 and 80kV) and a load of107mAs

3.2.12.3. Discussion of volume acquisitions

Graphs 12 and 13 highlight the following points:

- Except for the thyroid gland, acquisition of the maxillary "molar" block generates the highest organ doses as compared to acquisition of the mandibular incisor block (roughly a factor of 5 for the submandibular glands, 4 for the parotid glands and 6 for the crystalline lenses). The largest doses are measured at the submandibular glands (roughly 1.8mGy for acquisition at 80kV)

- For the two types of acquisition, the doses absorbed by the crystalline lenses and the thyroid gland, which are far from the direct beam, show little significance except that they are far lower than the doses absorbed by the salivary glands.

- Regarding the dose to the skin, the measurements performed show that it is similar for the two radiological procedures.

4. CALCULATION OF THE EFFECTIVE DOSE (E)

The effective dose cannot be calculated for "child" radiological procedures without using a tissue weighting factor (W_T) for paediatrics. Currently, the International Commission on Radiological Protection (ICRP)[1] only refers to "adult" tissue weighting factors in its publications 60 and 103.

To calculate the effective dose of "adult" radiological procedures of this study, we first used the tissue weighting factors (W_T) from ICRP 103, as follows:

- W_T = 0.04 for the thyroid gland
- W_T = 0.01 for the skin
- W_T = 0.01 for the salivary glands

Since the effective dose is an estimate of risk, the various tissue weighting factors are associated with the maximum value of doses delivered to the organs in question and to the skin.

A dosimetric study on cone beam devices, similar to the volume mode of the Kodak 9000 3D, and published by J B Ludlow et al [1], specifies the percentage of tissues irradiated during dental radiological procedures. In the case of a dental panoramic, it is estimated that the exposed surface of the skin represents 2% of the total surface of a patient's body. For 3D acquisitions, this percentage will also be used. Effective dose calculations are weighted using these quotas.

Secondly, for comparison, the effective dose will be calculated with tissue weighting factors (W_T) from ICRP publication 60 (W_T = 0.05 for the thyroid gland and 0.01 for the skin).

[1] ICRP: International Commission on Radiological Protection

Finally, bear in mind that the effective dose can be calculated from the dose–area product (DAP). E. Helmrot [2, 3] believes that, in the case of a dental panoramic, the factor for conversion of DAP to (E) is equal to 0.08 mSv/Gy.cm^2. The conversion factors are calculated from the measured doses of various organs (thyroid, salivary glands and skin) and DAPs communicated by the developer.

Table II shows a comparison of the effective doses calculated for various "adult" radiological procedures.

Tableau II: Summary of ICRP 60/ICRP 103 effective doses (E) for various adult procedures

Procedure	E (ICRP 60) µSv	E (ICRP 103) µSv	Ratio between E (ICRP 60) and E (ICRP 103)
Panoramic (70kV, 143mAs)	**0.6**	**7**	**11.7**
Panoramic (80kV, 143mAs)	**1**	**12.9**	**12.9**
Mandibular incisor block (70kV, 107mAs)	**2.8**	**4.7**	**1.7**
Mandibular incisor block (80kV, 107mAs)	**2.8**	**5.3**	**1.9**
Maxillary molar block (70kV, 107mAs)	**1.1**	**13.3**	**12.1**
Maxillary molar block (80kV, 107mAs)	**1.3**	**18.8**	**14.5**

Between E (ICRP 60) and E (ICRP 103), we observe an increase by a factor of between 1.7 and 14.5 depending on the radiological procedures. This difference is due to taking account of $W_{T\ factor}$ = 0.01 (ICRP 103) for the salivary glands.

- "Dental Panoramic" procedures:

The value of (E) increases by a factor of 11.7 and 12.9 between the effective doses calculated with factors from ICRP 60 and ICRP 103, for respective voltages of 70kV and 80kV. Recall that the voltage used for standard-type patients is equal to 70kV.

- 3D Procedures:

For the same reasons as discussed above, the values of E (ICRP 103) are larger than those of E (ICRP 60). The value of E (ICRP 103) is between 4.7 and 18.8 µSv. It is roughly 4 times larger for "molar block" acquisitions as compared to those for "molar block". This difference is explained by the larger dose contribution of submandibular glands for "molar block" procedures, since the salivary glands are within the acquisition volume during "molar block" radiological procedures. During the "incisor block" procedure, the entire salivary glands are within the scattered radiation and the value of (E) is approximately equal to 5.3 µSv.

Table III specifies the effective doses, DAPs (Kodak) and conversion factors (E) for the various adult procedures of this study.

Tableau III: Summary of effective doses, DAPs (Kodak) and conversion factors (E) for the various adult procedures of this study

Procedure	E (ICRP 103) µSv	DAPmGyxcm²	Conversion factor DAP/(E) mSv/Gyxcm²
Panoramic (70kV, 143mAs)	**7**	**70**	**0.10**
Panoramic (80kV, 143mAs)	**12.9**	**93**	**0.14**
Mandibular incisor block (70kV, 107mAs)	**4.7**	**188**	**0.026**
Mandibular incisor block (80kV, 107mAs)	**5.3**	**228**	**0.023**
Maxillary molar block (70kV, 107mAs)	**13.3**	**188**	**0.07**
Maxillary molar block (80kV, 107mAs)	**18.8**	**228**	**0.08**

In the case of a dental panoramic, the factor for conversion of DAP to (E) calculated by E. Helmrot [2, 3] is equal to 0.08 mSv/Gy.cm²; in the case of this study it is equal to 0.1 mSv/Gy.cm². This factor changes significantly according to voltage, at equivalent load.

5. DISCUSSION AND CONCLUSION

5.1. DENTAL PANORAMIC ACQUISITION

Table IV compares the measured organ doses using the "panoramic" mode of the Kodak 9000 3D installation (digital detection by CCD camera) to data detected during various IRSN studies [1-2] on panoramic radiography installations using detection systems (screen/film combination, digital by CCD camera and photostimulable plates).

During studies performed previously by IRSN, the doses measured at the level of parotid glands were comparable, although doses were 3 to 4 times higher on a digitized installation than on a conventional installation in which detection is performed by screen/film combination. These differences are mainly explained by the higher loads used on digital installations.

Table IV: Doses absorbed by organs (mGy) for installations with various detection systems

Organ	*Dose (mGy)*			
	This study	*IRSN studies [1-2]*		
	CCD sensor	*Photostimulable plates*	*Screen/film combination*	*CCD sensor*
Thyroid	0.01	0.1	0.06	0.07
Crystalline lenses	0.01	0.03	0.02	0.02
Parotid glands	0.5	1.15	0.31	1.19
Submandibular glands	0.05	Not measured	0.32	0.54
Voltage (kV)	70	75	75	75
Load (mAs)	143	208	120	208.5

Except for the dose to parotid glands, measured on a conventional installation with a screen/film combination, organ doses measured on the Kodak 9000 3D installation are lower than those obtained during previous studies using digital detectors. The decrease is by a factor of 2.3 for the parotid glands, 10 for the submandibular glands, 7 for the thyroid and 2 for crystalline lenses. This is explained by the use of a 31%-lower load and a slightly lower voltage (5kV).

Finally, during the evaluation, additional collimation was installed to limit the field of exposure in its upper section. Its relevance was evaluated dosimetrically. The dose decreases by a factor of 6 at the right parotid and a factor of 2 for all other organs. This technical modification which results in a dose decrease holds great interest for the paediatric population considering that dental panoramic exams are iterative procedures in orthodontics.

5.2. 3D ACQUISITIONS

Table V shows the doses absorbed by organs for volume acquisition centred on the left lower molars, as well as the doses obtained during a previous IRSN study with the purpose of dosimetric evaluation of scanographic procedures on various anatomical regions (maxillary region and "optimized" full skull) but for which the indications may be identical (implants).

Table V: Doses absorbed (mGy) by organs for volume acquisition centred on the lower molars and for procedures measured on a multisection scanner

Organ	*Dose (mGy)*		
	Kodak 9000 3D	*Scanner*	
	Maxillary region	*Maxillary region*	*Optimised full skull*
Thyroid	0.1	0.7	0.6
Crystalline lens (L)	0.1	0.4	2.1
Crystalline lens (R)	0.15*	0.4	2.1
Parotid gland (L)	0.66	9.0	2.1
Parotid gland (R)	0.95	9.0	2.1
Submandibular gland (L)	1.76	1.3	2.0
Submandibular gland (R)	1.22	1.3	2.0

5.2.1. Comments on the Kodak 9000 3D device

The largest doses are measured for organs located in or near the acquisition volume. In particular, the left submandibular gland (1.8mGy): this is explained by the region of interest found in the axis of these salivary glands. Other organs far from the acquisition volume but exposed during beam rotation absorb a significant dose (0.95mGy at the right parotid gland). The average dose absorbed at the crystalline lenses is equal to 0.1mGy.

5.2.2. Comparison between 3D acquisitions from the Kodak 9000 3D device and scanner procedures

It is important to note the limits of a comparison between these two types of radiological procedures since the Kodak 9000 3D only allows for very localized acquisition in contrast to a scanner, which can be used for imaging of the entire maxillo-facial region in a single acquisition over variable lengths (7 cm for maxillary and mandibular procedures; 20 cm for the entire skull). **Thus, the comments in this paragraph are only valid for localized diagnostics.**

Overall, the Kodak 9000 3D is a medical device which allows for the delivery of low doses within the framework of 3D acquisition. In fact, standard scanner procedures localized in the maxillary region involve higher exposure to salivary glands (factors 10 to 14). For the thyroid, the dose absorbed is up to 7 times lower with the Kodak 9000 3D. The "full skull" procedure, for which the acquisition parameters have been optimized, does not reduce the doses to a level equivalent to those evaluated using the Kodak 9000 3D.

5.3. EFFECTIVE DOSE

There is a difference by a factor of 2 to 15 between the effective doses calculated using the W_T coefficients from publications 60 and 103 of the ICRP. This difference is due to taking account of W_T factor = 0.01 (ICRP 103) for the salivary glands.

J B Ludlow et al [1], for the tissue weighting factors of ICRP 103, published effective doses between 6.3 and 13.3 µSv for dental panoramics. In our study, the effective dose calculated for the same procedure was between 7 and 12.9 µSv. These doses are equivalent.

Effective doses have been calculated using DAPs for various 3D acquisitions (see reference [3]). For the molar region, these doses are between 11 and 69 µSv. In our study, we estimated an effective dose for equivalent procedures of between 13 and 19 µSv. These effective doses are close to the minimum dose value calculated by S Lofthag - Hansen et al.

6. BIBLIOGRAPHY

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7. APPENDIX 1

Summary of organ doses for all radiographic procedures (mGy)

ADULT PANORAMIC Parameters: 70kV/143mAs	
RIGHT CRYSTALLINE LENS	0.01
LEFT CRYSTALLINE LENS	0.01
SPINAL CORD T5	0.08
RIGHT PAROTID	0.34
LEFT PAROTID	0.65
SKIN FROM RIGHT	0.47
SKIN (occipital)	0.18
SKIN FROM LEFT	0.46
RIGHT SUBMANDIBULAR	0.05
LEFT SUBMANDIBULAR	0.04
INTERNAL THYROID	0.01

MANDIBULAR INCISOR BLOCK Adult Parameters: 70kV/107mAs	
RIGHT CRYSTALLINE LENS	0.02
LEFT CRYSTALLINE LENS	0.01
SPINAL CORD	0.03
RIGHT PAROTID	0.17
LEFT PAROTID	0.14
SKIN FROM MOUTH	3.78
SKIN FROM RIGHT	0.35
SKIN (occipital)	0.10
SKIN FROM LEFT	1.02
RIGHT SUBMANDIBULAR	0.23
LEFT SUBMANDIBULAR	0.22
THYROID (surface of the skin)	0.03
INTERNAL THYROID	0.04

MAXILLARY MOLAR BLOCK Adult Parameters: 70kV/107mAs	
RIGHT CRYSTALLINE LENS	0.07
LEFT CRYSTALLINE LENS	0.11
SPINAL CORD	0.13
RIGHT PAROTID	0.65
LEFT PAROTID	0.58
NASAL SKIN T5	1.74
SKIN FROM RIGHT	1.00
SKIN (occipital)	0.66
SKIN FROM LEFT	2.78
RIGHT SUBMANDIBULAR	0.99
LEFT SUBMANDIBULAR	1.23
THYROID	0.01

ADULT PANORAMIC Parameters: 80kV/143mAs	
RIGHT CRYSTALLINE LENS	0.01
LEFT CRYSTALLINE LENS	0.01
SPINAL CORD	0.12
RIGHT PAROTID	1.21
LEFT PAROTID	0.40
SKIN FROM RIGHT	0.08
SKIN (occipital)	0.22
SKIN FROM LEFT	0.06
RIGHT SUBMANDIBULAR	0.08
LEFT SUBMANDIBULAR	0.05
INTERNAL THYROID	0.02

MANDIBULAR INCISOR BLOCK Adult Parameters: 80kV/107mAs	
RIGHT CRYSTALLINE LENS	0.03
LEFT CRYSTALLINE LENS	0.02
SPINAL CORD	0.05
RIGHT PAROTID	0.24
LEFT PAROTID	0.19
SKIN FROM MOUTH	3.92
SKIN FROM RIGHT	0.54
SKIN (occipital)	0.12
SKIN FROM LEFT	1.29
RIGHT SUBMANDIBULAR	0.29
LEFT SUBMANDIBULAR	0.28
THYROID T10	0.04

MAXILLARY MOLAR BLOCK Adult Parameters: 80kV/107mAs	
RIGHT CRYSTALLINE LENS	0.09
LEFT CRYSTALLINE LENS	0.15
SPINAL CORD	0.18
RIGHT PAROTID	0.95
LEFT PAROTID	0.66
SKIN FROM MOUTH	2.00
SKIN FROM RIGHT	1.20
SKIN (occipital)	0.80
SKIN FROM LEFT	3.97
RIGHT SUBMANDIBULAR	1.22
LEFT SUBMANDIBULAR	1.76
THYROID	0.01

CHILD PANORAMIC Parameters: 60kV/108mAs	
RIGHT CRYSTALLINE LENS	0.01
LEFT CRYSTALLINE LENS	0.01
SPINAL CORD T5	0.05
RIGHT PAROTID	0.31
LEFT PAROTID	0.04
SKIN FROM RIGHT	0.01
SKIN (occipital)	0.11
SKIN FROM LEFT	0.01
RIGHT SUBMANDIBULAR	0.02
LEFT SUBMANDIBULAR	0.01
INTERNAL THYROID	0.01

MANDIBULAR INCISOR BLOCK Child Parameters: 60kV/107mAs	
RIGHT CRYSTALLINE LENS	0.01
LEFT CRYSTALLINE LENS	0.01
SPINAL CORD	0.02
RIGHT PAROTID	0.11
LEFT PAROTID	0.09
SKIN FROM MOUTH	2.39
SKIN FROM RIGHT	0.22
SKIN (occipital)	0.07
SKIN FROM LEFT	0.50
RIGHT SUBMANDIBULAR	0.18
LEFT SUBMANDIBULAR	0.10
THYROID	0.02

MAXILLARY MOLAR BLOCK Child Parameters: 60kV/107mAs	
RIGHT CRYSTALLINE LENS	0.04
LEFT CRYSTALLINE LENS	0.06
SPINAL CORD	0.08
RIGHT PAROTID	0.56
LEFT PAROTID	0.36
SKIN FROM MOUTH	1.31
SKIN FROM RIGHT	0.71
SKIN (occipital)	0.57
SKIN FROM LEFT	1.97
RIGHT SUBMANDIBULAR	0.72
LEFT SUBMANDIBULAR	0.45
THYROID	0.01

CHILD PANORAMIC **Parameters: 70kV/108mAs**	
RIGHT CRYSTALLINE LENS	0.01
LEFT CRYSTALLINE LENS	0.01
SPINAL CORD	0.08
RIGHT PAROTID	0.18
LEFT PAROTID	0.10
SKIN FROM RIGHT	0.01
SKIN (occipital)	0.02
SKIN FROM LEFT	0.01
RIGHT SUBMANDIBULAR	0.04
LEFT SUBMANDIBULAR	0.02
INTERNAL THYROID	0.01

CHILD PANO WITH COLLIMATOR **Parameters: 70kV/108mAs**	
RIGHT CRYSTALLINE LENS	0.01
LEFT CRYSTALLINE LENS	0.01
SPINAL CORD	0.02
RIGHT PAROTID	0.03
LEFT PAROTID	0.08
SKIN FROM MOUTH T5	0.01
SKIN FROM MOUTH T6	0.01
SKIN FROM RIGHT T5	0.01
SKIN FROM RIGHT T6	0.02
SKIN (occipital)	0.01
SKIN FROM LEFT T5	0.01
SKIN FROM LEFT T6	0.03
RIGHT SUBMANDIBULAR	0.02
LEFT SUBMANDIBULAR	0.01
THYROID	0.01