Low-dose CT protocol for orthodontic diagnosis

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*ABSTRACT. **Aim** This was to correlate the dosimetric evaluation with high diagnostic accuracy by suggesting a protocol that significantly reduces the dose administered by a Dentascan exam without affecting diagnostic accuracy. **Materials and methods** 17 patients were selected consecutively (7 males and 10 females) of a mean age of 11.2 (8-14 years) who sought orthodontic treatment. They needed CT control before and after treatment with RME to evaluate impacted canines. The study was performed using a multidetector 16-rows CT with two protocols that provided 2 different KV acquisition parameters: 80 KV or 120 KV. Radiation dose was evaluated in two ways: CTDI and DLP. Image quality was rated and the results were compared to identify significant differences in terms of image quality, radiation exposure and presence of artefacts. **Results** The 80 KV scanning has a significantly lower effective radiation dose compared to the 120 KV scanning ($p< 0.05$). The images of all patients were used for comparing the protocols in terms of image quality. The mean scores for the 80 KV scanning images were 4.18 +/- 0.81 and 4.41 +/- 0.80 for dose obtained by 120 KV scanning. The median image quality was 4 (good) for both protocols. The 80 KV protocol allowed, as well as the 120 KV, a careful analysis by the orthodontist and the dental surgeon that together, based on this images, can choose the best line of treatment between several available options. **Conclusion** 80 KV protocols compared with 120 KV protocols resulted in reduced total radiation dose without relevant loss of diagnostic image information and quality. The images were good enough to obtain information about the exact position of impacted teeth and to plan the best line of surgical treatment and mechanotherapy strategy.*

KEYWORDS: Diagnosis, Computed tomography, Radiation dose.

Introduction

In daily orthodontic practice it is essential the orthodontic diagnosis and the cephalometric evaluation based on bi-dimensional X-ray photographs like panoramic X-ray, posterior-anterior and latero-lateral radiographic head-plates, first approach to the stomatognatic system and the most important diagnostic tools in the past and nowadays. These methods are indeed used routinely in orthodontic practice in all phases of patient management, including treatment planning, periodic check-up, final results and follow up [Miller et al., 2004; Macchi et al., 2006; Espelid et al., 2003], but there are some clinical problems that require three-dimensional investigations to be approached in the best way.

The bi-dimensional radiographic images have shown all their limits in the observation of the complicated facial morphology because of the superimposition of different anatomical structures. This problem has become apparent especially while studying craniofacial structures like basal bone, root morphology, surrounding bone, alveolar plate thickness and the effects of an orthopaedic treatment [Matarese et al., 2006; Podesser et al., 2004].

In 1982 Timms used the Computed Tomography (CT) for the first time to study the rapid maxillary expansion [Timms et al., 1982]. The conventional radiographic images, because of the overlapping of one or more layers on the same plane, make difficult to obtain sharp images both of the midpalatal suture and of the maxillary and palatine bones. The CT allowed a real reproduction of maxillary section in any plane, showing all anatomical structures in depth, defining structures for measurements of transverse dimension in any area, as well as changes in the axial inclination of posterior teeth, quantitative evaluation of the expansion and any bone changes after treatment. By using the CT, it is possible to fully investigate the

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effects of this procedure and to compare the advantages of every appliance in order to choose the best solution for each patient [Timms et al., 1982; Garib et al., 2005; Garib et al., 2006; Sfondrini et al., 1989].

New imaging methods will replace the way we look at a variety of common diagnostic and treatment issues in daily orthodontic practice. For example tooth impaction, involving maxillary canines or incisors, supernumerary teeth or odontomes are clinical problems that can interfere with the normal occlusal development and create a variety of situations such as crowding, rotations, cystic lesions, resorption of the adjacent teeth and delayed eruption. CT allows the orthodontist to visualize the correct position of the impacted teeth, their spatial relationship with anatomical structures (sinus floor, blood vessels, nerves, contiguous teeth), the three-dimensional anatomy of the crown and the root and to evaluate root resorption due to impacted maxillary canines analyzing scan by scan along the root of adjacent maxillary incisors. Also trauma to the deciduous or permanent teeth may have various implications such as intrusion, fractures or dilacerations of the permanent teeth. Maxillary central deciduous incisors are more frequently involved than the others and often the permanent central incisors remain unerupted because they result dilacerated. The CT evaluation provides a more accurate approach to the problem: allows to determinate the exact position, the angulations of the dilacerated tooth and a careful choice between several treatments, such as removing the impacted teeth and orthodontic closure of spaces or surgical exposing and orthodontic movement toward the occlusal plane. Only by obtaining three-dimensional information it is possible to approach and move the teeth safely and efficiently [Faber et al., 2006; Agnihotri et al., 2006; Chaushu et al., 2004].

Of course the three-dimensional investigation offers the same results during the fixed orthodontic therapy to evaluate the changes that occur in alveolar bone plates as a result of teeth movement [Gunduz et al., 2004; Sarikaya et al., 2002] and in using stable intra-oral anchorage of the mini-screw [Deguchi et al., 2006]. The CT, a radiological three-dimensional technique based on computer assessment of the radiation-absorbing characteristics of the various tissues of the body, offers many advantages [Hajeer et al., 2004; Hajeer et al., 2004; Hugo et al., 1981; Redmond et al., 2005]:

- it provides true tomography images of excellent contrast resolution;
- tissue density differences of 0.5% are evident;
- all the photons that have penetrated the body are used in the formation of the images;
- X-ray beams are highly collimated into a band ranging from 2-13 mm, so that very little tissue, other than that being imaged, is irradiated.

The problems in adapting helical-CT scans for orthodontic use include high cost, long scanning time and most importantly, high radiation exposure, which is of particular concern given that the orthodontic treatment often involves young or adolescent patients [Hugo et al., 1981].

The aim of this study is to correlate the dosimetric evaluation with high diagnostic accuracy by suggesting a protocol, really useful especially when the clinical problem needs a multidisciplinary approach, that significantly reduces the dose administered by a Dentascan exam without affecting diagnostic accuracy.

Materials and methods

A groupt of 17 patients was selected consecutively (7 males and 10 females), with a mean age of 11.2 (8 - 14 years) who sought orthodontic treatment at the Department of Orthodontics, "Tor Vergata" Dental School, University of Rome. The patients presented constricted vaults, "V" form of the maxillary arch, crowding and one or both maxillary impacted canines. The exclusion criteria were:

- age above 15 years;
- metal restorations on maxillary teeth;
- previous orthodontic treatment;
- any kind of genetic diseases except for impacted maxillary canines.

Approval for the study was obtained by the Ethical Committee at Policlinico Universitario "Tor Vergata", Rome, and informed consent was obtained from the parents of all subjects, informed about the need of a three-dimensional investigation to correctly evaluate the impacted teeth.

Each patient was treated with the Hyrax Palatal Expander and the activation protocol included 2 turns per day of the screw (0.25 mm per turn) for 14 days, until obtaining the total amount of expansion of 7 mm in all subjects. Then, the screw was tied off with a ligature wire and the expander was kept on the teeth as a passive retainer for an average time of six months.

Multislices CT scans were taken before rapid palatal expansion (time T0) and after the retention period when the expander was removed (time T1).

Exams were performed at the Department of Radiology, University of Rome, "Tor Vergata", with a

FIG. 1 - *The MDCT scanner used.*

CT scanner equipped with a Dentascan reconstruction programme used to study the maxillofacial region.

Each patient was positioned by the same technician lying on the table following always the same standardised method: the Camper's plane perpendicular to the ground; the machine's perpendicular light beams were used to standardise the head position in the three planes. During the CT study, patients bit a piece of gauze to keep the maxillary and the mandibular teeth separated and to avoid the overlapping of structures.

The MDCT scanner used (Light-Speed 16, General Electric Medical System, Milwaukee, Winsconsin, USA) is equipped with 16 detector rows and has a minimal rotation time of 0.5 sec. given a collimation between 0.75 and 1.5 mm with dose calibrated (Fig. 1).

The scanning technique consisted in a preliminary scan performed in the anteroposterior (AP) and laterolateral (LL) projections, with the following acquisition parameters: 120 KV or 80 KV, with 10 mA. Every patient underwent CT examination twice, before rapid palatal expansion and after a 6-month retention period when the expander was removed, the first examination at 80 KV, the second at 120 KV. The subsequent scans were taken with a 1.25 mm slice thickness, 0.6 mm interval, 11.25 mm table speed/rotation, 100 mA, 13.7 cm FOV, 512x512 matrix and 0° gantry angle. Two kilovolt values were selected, 80 KV and 120 KV, respectively used in two corresponding imaging protocols that provided spiral mode, dose efficacy of 69.83, mean scanning time of 9.04 and 9.23. Data acquisition, planning of examinations and printing of axial images and standardised multiplanar reconstructions were performed by a technologist on a workstation (Advantage Workstation, GE). The radiologists had immediate access for visualisation and further multiplanar and 3D reformatting on the workstation.

Dose estimated data were obtained from the console of the CT scanner:

- CTDI (Computer Tomography Dose Index) = dose measured in central and peripheral region of the subjects as a direct result of a CT section acquisition T millimetres thick;
- DLP (Dose Length Product) = total dose deposited over the length of the acquisition.

During the first reading session the two readers (BF, LR), independent and experienced orthodontists, were asked to make the diagnosis. In a second reading session, the two readers (FE, FV), independent and experienced radiologists, were asked to rate the overall image quality by considering tissue contrast, image sharpness and overall subjective impression. Images were rated according to the following scores matched by a corresponding numerical score ranging from 1 to 5: poor; moderate; satisfactory; good; excellent.

The presence of artefacts due to presence of patient's movements: no artefacts; few artefacts; moderate artefacts; severe artefacts.

Statistical analysis. Results were compared using Wilcoxon's (matched pairs) signed rank test to identify significant difference in terms of image quality, radiation exposure and presence of artefacts. The level of significance was $p<0.05$. It was used for variables that presented only 2 consecutive observations (T0-T1). Descriptive statistics included mean and standard deviation (SD) (Table 1).

	Time T0		Time T1		Change	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*P*
CTDI	6.231	1.945	13.282	4.104	-7.051	.000***
DLP	42.710	14.277	100.382	34.619	-57.672	.000***
Image quality	4.18	.81	4.41	.80	-0.23	.417

p<0.05 * Statistically significant
p<0.01 ** Statistically significant
p<0.001 *** Statistically significant
ns = Non statistically significant

TABLE 1 - *Descriptive and statistical analysis of dosimetric evaluation at time T0 and T1.*

	CTDI mGy	DLP	Image Quality
1	2.64	37.97	Satisfactory 3
2	5.44	38.08	Good 4
3	3.47	37.97	Moderate 2
4	8.13	69.49	Excellent 5
5	4.06	26.41	Good 4
6	8.07	38.03	Excellent 5
7	7.26	35.02	Excellent 5
8	8.07	42.07	Excellent 5
9	7.26	39.41	Good 4
10	5.41	37.91	Good 4
11	7.08	27.07	Good 4
12	3.47	37.97	Satisfactory 3
13	5.24	29.95	Good 4
14	6.08	33.54	Good 4
15	9.08	68.08	Excellent 5
16	7.16	69.49	Good 4
17	8.01	57.61	Good 4
Mean	6.231	42.710	4.18
Sum	105.93	726.07	69

TABLE 2 - *Dosimetric values at time T0.*

	CTDI mGy	DLP	Image Quality
1	9.5	77.45	Satisfactory 3
2	16.14	125.84	Excellent 5
3	14.52	100.6	Excellent 5
4	17.01	171.24	Excellent 5
5	12.10	91.34	Good 4
6	9.08	59.42	Excellent 5
7	19.36	146.16	Excellent 5
8	16.94	136.37	Excellent 5
9	14.52	96.94	Excellent 5
10	9.03	65.07	Satisfactory 3
11	12.10	95.91	Good 4
12	8.07	72.04	Satisfactory 3
13	10.09	61.03	Excellent 5
14	9.08	63.54	Good 4
15	10.09	86.24	Good 4
16	21.16	105.8	Excellent 5
17	17.01	151.5	Excellent 5
Mean	13.282	100.381	4.41
Sum	225.8	1706.49	75

TABLE 3 - *Dosimetric values at time T1.*

Results

Both examination protocols produce the same quality and resolution of the image. In the 80 KV scanning (T0) we obtained a mean DLP of 42.71 mGy per cm, CTDI of 6.23 mGy and a total scan time of 19 sec (Table 2). In the 120 KV scanning (T1) we obtained a mean DLP of 100.38 mGy per cm, CTDI of 13.28 mGy and a total scan time of 19 sec (Table 3).

The 80 KV scanning has a significantly lower effective radiation dose ($p< 0.05$) compared with 120 KV scanning.

No significant difference was found for image reconstruction time.

In the retro-analysis, the images of all patients were used for comparing the protocols in terms of image quality. The mean score for 80 KV scanning images was 4.18 +/- 0.81 and 4.41 +/- 0.80 for dose obtained by 120 KV scanning. The median image quality was 4 (good) for both protocols. The 80 KV protocol, as well as the 120 KV protocol, allowed a careful analysis by the orthodontist and the dental surgeon that together on this images can choose the best line of treatment between several available options (Fig. 2).

Multiplanar reformatting and Dentascan reformatting was routinely performed after examination. Three-dimensional reconstruction was often performed in bone imaging.

All relevant lesions were diagnosed. Some artefacts were present in both protocols because of patient's movements.

FIG. 2 - *Image obtained with the low dose protocol of 80 KV. In this kind of image the anatomy, the exact position, the spatial relationship and the orientation of the impacted tooth are perfectly clear.*

Discussion

The use of a small sample in this study was justified by ethical considerations, which limit radiation exposure for research purposes. The Italian law, Article 2 of Legislative Decree 230/95, regulates all activities carrying a risk of ionising radiation. Therefore, our study continues this line of research by modifying the acquisition parameters in order to reduce the absorbed X-ray [Dula et al., 1996; Ziegler et al., 2002].

CT images are not part of routine orthodontics records, but the craniofacial complex cannot be correctly investigated by traditional X-ray techniques due to superimposition of the bone structures [Sfondrini et al., 1989]. For this reason the demand for Dentascan exams and the use of this technique on children is increased constantly from 1982, when the use of spiral CT was proposed by Timms in orthodontic treatment. The risk factors associated with being exposed to ionised radiation must be considered and more attention should be paid to this diagnostic tool to optimise the technique and reduce the dose to the lowest possible level. The data obtained indicate that the parotid glands, the thyroid and the mouth are the anatomical structures most exposed to radiation during Dentascan CT examinations, both of the upper and low jaw bone, in line with what has been reported in previous studies [Bianchi et al., 1996].

At the Department of Radiology of the University of Rome "Tor Vergata" the standard setting of the equipment typically used in Dentascan examinations that provides 120 KV was modified [Matarese et al., 2006; Garib et al., 2005; Garib et al., 2006; Gunduz et al., 2004; Sarikaya et al., 2002; Deguchi et al., 2006]. The choice of the lower dose of 80 KV was made as a necessary compromise to reach a good diagnostic accuracy and the images obtained with the 80 KV protocol were good enough for orthodontic diagnosis. When milliamperes are kept constant, the radiation dose delivered by a X-ray tube increases, as the X-ray energy, that is the kilovoltage, increases. This effect is largely exploited in diagnostic imaging performed on babies or children, where a low radiation dose is required. As X-ray energy (kilovoltage) decreases, the contrast between the structures crossed by the X-ray beam increases [Jurik et al., 1997; Scheck et al., 2002]. Further, the anatomical structures investigated in orthodontics are tissues with a high concentration of calcium and thus with a high power of X-ray adsorption. This concept proved to be useful in our experience, as it enabled a marked reduction of the administered dose without affecting image quality.

The dose values obtained are significantly lower than the minimum values reported in the literature that contains numerous studies on dosimetry in dental radiology, often with comparisons between conventional CT, CBCT and orthopantomography [Lecomber et al., 2001; Villari et al., 1999].

Even when compared with the doses reported for CBCT, with the obvious approximations linked to the different dosimetric techniques, our results were comparable, and the absorbed dose measured in our study was even lower in some anatomical sites [Ludlow et al., 2003; Huda and Sandison, 1984; Fanucci et al., 2006].

Image quality with the lower kilovoltage remains acceptable both regarding quantitative measurements and evaluation of bone quality. In orthodontics we are just beginning to establish the potential diagnostic and therapeutic applications of three-dimensional images. Evolution of the technology and software will allow further studies to demonstrate that valuable diagnostic results may be obtained with even lower kilovoltage and tube current. Future technical developments, such as further increases in axial resolution combined with intelligent dose modulation protocols, may help strengthen the role of CT in orthodontic use.

Conclusion

Three-dimensional investigations are necessary in orthodontic daily practice every time conventional X-ray techniques are not enough, such as impacted maxillary canines or incisors, supernumeraries teeth, odontomes, trauma and orthopaedic treatment.

80 KV protocols compared with 120 KV protocols resulted in reduced total radiation dose without relevant loss of contrast and resolution of images.

80 KV protocols allow good quality of images for orthodontics diagnosis and treatment.

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