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Unjustified CT examination in young patients: a survey at Oulu University Hospital

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Introduction

Shortly after publication of the European Commission's directive 97/43/EURATOM, justification was considered to be the challenge of the decade (1). Ten years later, it has been speculated that the process of justification is sometimes weak or even nonexistent (2).

The radiation doses from computed tomography (CT) examinations are among the highest in diagnostic radiology, yet CT is being increasingly utilized. According to the referral criteria for imaging recommended by the European Commission, imaging methods without ionizing radiation, such as ultrasound (US) and magnetic resonance imaging (MRI), or methods with low-dose radiation should be considered whenever justified (3). Particular attention should be paid to young patients, since the radiation-induced lifetime risk of cancer mortality is higher at younger age until approximately 35 years of age (4).

The basic aim of our study was to determine whether previous CT examinations done at our university hospital on patients under the age of 35 years had been justified, and if not, whether other, more justifiable imaging modalities had been available, or if any modality was needed. Based on the study, a more comprehensive development project related to justification assessment was implemented.

Materials and Methods

Altogether 148,988 examinations were performed in the Department of Diagnostic Radiology of Oulu University Hospital, Oulu, Finland, in 2005. 16,975 of the examinations (11%) were done using CT, and 2,367 (14%) of the CT examinations were done on patients under the age of 35 years. The main groups of examinations were CT of the head, thorax or lungs, lumbar (and sacral) spine, abdomen or upper abdomen, trauma, cervical spine, nasal sinuses and body (thorax and abdomen) (Table 1).

The examinations analysed in this study were CTs of the head (50 patients), lumbar (and sacral) spine (30), abdomen or upper abdomen (30), trauma (30), cervical spine (30) and nasal sinuses (30) (Table 1). The final study thus included 200 examinations. Images falling in these categories were extracted from the electronic patient files of our hospital consecutively from the beginning of the year 2005. CTs of the thorax or lungs and body were excluded from the study because there is no good alternative for these examinations.

Patient files, clinicians' referrals and indications of the examinations were analysed by a specialist in radiology with good experience. Using this information and the referral criteria for imaging recommended by the European Commission (3), it was decided whether the examinations had been justified, and if not, whether some other, more justifiable imaging modalities would have been available. After that, other specialists in radiology went through the information collected and expressed their opinion; if necessary, consensus was used.

Table 1. CT examinations performed on patients under the age of 35 years in 2005 and the number of cases analysed in the study.

CT examinations	Number of CT examinations n	CT examinations analysed n
Head	1,063	50
Thorax or lungs	241	
Lumbar and sacral spine	130	30
Abdomen or upper abdomen	123	30
Trauma	117	30
Cervical spine	110	30
Nasal sinuses	100	30
Body	80	
Other	403	
Total	**2,367**	**200**

Results

About 30 per cent of all the 200 examinations evaluated were non-justified (Table 2). Twenty-three of the 30 CT examinations of the lumbar spine (77%) were considered not justified. Twenty cases could have been replaced by MRI, and three patients would not have needed any radiological examination (Table 2). Symptoms of disk syndrome, suspicion of spinal stenosis and control of spinal lymphoma in young patients may indicate MRI. Trauma and control of fixation indicate CT.

Eighteen of the 50 CT examinations of the head (36%) were not justified. All of them could have been replaced by MRI. MRI should have been performed in elective cases. CT is indicated in trauma or some other acute cases, such as suspicion of intracranial bleeding or acute stroke.

CT was not justified in 11 of the 30 CT examinations of the abdomen or upper abdomen (37%). Five of the cases could have been replaced by MRI, four by US and one by fluoroscopy. One patient would not have needed any radiological examination. Two patients had unspecific hepatic lesions at US, which should have indicated MRI instead of CT. Other patients in this group were so variable that no classification could be done; the analysis had to be done on a case-by-case basis.

Six of the 30 CT examinations of the nasal sinuses (20%) were not justified. Five of them could have been replaced by MRI, while one would not have needed any other examination but CT of the head. CT was considered to be justified especially if operation of the sinuses was being planned, since there is a need for accurate delineation of the bony structures for functional endoscopic sinus surgery (FESS). However, five of the unjustified cases also had rhinitis or sinusitis, but there was no information about operation plans in the referral.

Only one of the 30 CT examinations of the cervical spine was not justified. The patient would not have needed any CT examination of the cervical spine in addition to one of the lumbar spine. Other cases were traumas and a control of fixation, which indicated CT. All the 30 CT examinations of trauma were justified because the traumas were high-energy ones.

In our study 21 out of the 200 patients were children (15 or under 15 years old) (11%). There were three unjustified cases in this group (3/21, 14%).

Table 2. The number of unjustified CT examinations out of total number of cases analysed and the possibility of other modalities to replace CT.

CT examination	Unjustified / All n (%)	Possibility of other modalities to replace CT			
		MRI n	US n	Fluoroscopy n	No examination needed n
Lumbar spine	23 / 30 (77%)	20			3
Abdomen	11 / 30 (37%)	5	4	1	1
Head	18 / 50 (36%)	18			
Nasal sinuses	6 / 30 (20%)	5			1
Cervical spine	1 / 30				1
Trauma	0 / 30				
Total	**59 / 200 (30%)**	**48**	**4**	**1**	**6**

New interventions and follow-up

As a consequence of our study, we wanted to change our practice and introduced various interventions and organized follow-up of the project. The interventions were mostly introduced in 2006-2007.

We provided education for the staff of the Department of Radiology, other personnel working with ionizing radiation in our area and the referring practitioners in our hospital. The education consisted of the risks and doses of radiation, indications of different examinations, the process of justification and legislation on radiation protection. The radiology staff in other hospitals in Northern Finland could also be reached through videoconferences. We also provided info cards containing information on radiation and justification for the referring practitioners in the Oulu area and for the people working with radiation in our hospital, and the cards will be handed out to medical students every year.

The referral criteria for imaging recommended by the European Commission were distributed into the different areas of the Department of Radiology. We also made some new recommendations for the use of CT for the referring practitioners and the radiologists at our hospital. Their content is roughly the following: 1. MRI is the primary examination of the head. CT examination is only indicated in acute cases. 2. MRI is usually the primary examination of the lumbar spine in young patients. 3. Clinicians are recommended to consult a radiologist before sending a request form for abdominal CT in the case of a young patient.

Our study revealed that most of the unjustified cases could have been replaced by MRI. Shortage of MRI capacity may partly have contributed to the poor results of justification. We addressed this by purchasing a new MR system. We have also reported about the project at conferences and in medical journals both in Finland and abroad (5).

We have followed up justification of the CT of the lumbar spine in our department. We wanted to monitor that area in particular, as it showed the poorest justification in our study. The total number of CTs of the lumbar spine has decreased and the justification has improved in patients under the age of 35 years during the years 2007-2009 when compared to the levels in 2005 (Table 3). We have also followed up the ratio of examinations with and without ionizing radiation in our department. Since 2006, the ratio also improved towards examinations without radiation until the year 2008. There was a slight opposite change again in 2009 (Table 4).

Table 3. CT examinations of the lumbar spine performed on patients under the age of 35 years in 2005 and in 2007-2009 and the number of unjustified lumbar CTs out of total number of cases analysed during the same years.

	2005	2007	2008	2009
CT of the lumbar spine (n)	130	37	38	24
Unjustified lumbar CT (n) / All (n) (%)	23/30 (77%)	2/4*/** 11/19 (58%)*/**	2/4*/** 5/20 (25%)*	1/1*/** 2/20 (10%)*

* in different units of the department; time period for the control audit varied between 9-11 months in different years
** less than 20 patients found for the control

Table 4. The ratio of examinations with and without ionizing radiation in the follow-up.

	2005 %	2006 %	2007 %	2008 %	2009
Ratio	77:23	76:24	74:26	74:26	75:25

Discussion

It is estimated that about 50% of the global collective dose of radiation is caused by CT with its relatively high doses (3). There were about 3.9 million medical x-ray examinations performed in Finland in 2005. About 7% were CT scans, and there were 30% more CT examinations in Finland in 2005 compared to 2000 (6). At Oulu

University Hospital, there were 19% more CT examinations in 2005 compared to 2000. It has been assumed that although the risk of radiological examination to a single individual is small, the exposed global population is large and increasing, which may result in significant long-term public health problems (7). It is therefore important to have good indications for CT or to utilize US or MRI or examinations with lower doses whenever possible.

The utilization of radiology is accepted as part of medicine, especially after careful justification. Despite the rules and recommendations defined in the legislation on medical radiation, suspicions of inappropriate use of radiological examinations and less selective use of diagnostic CT have been reported. Some paediatric radiologists have estimated that about one-third of CT examinations are unnecessary (7,8). With the help of the retrospective analysis we wanted to find out whether the number of CT examinations done on young patients could have been reduced with better justification. For the analysis, we chose CT examinations that could be replaced by other investigations, even ones not involving any radiation.

Most of the unjustified examinations, 77%, appeared to fall into the group of lumbar CT. The dose of radiation from lumbar CT is about 300 times the level of thorax PA x-ray. Most of these unjustified cases could have been replaced by MRI. Thirty-seven per cent of the cases in the group of abdominal CT were unjustified. The dose of radiation from abdominal CT examination is about 500 times that of a single thorax PA x-ray (3). Five of the unjustified cases could have been replaced by MRI, four by US and one by fluoroscopy. Thirty-six per cent of the cranial CT studies were deemed unjustified. All these 18 examinations should have been replaced by MRI. The dose of radiation from CT of the head is also about 115 times that of a thorax PA x-ray (3). There were fewer unjustified cases in the group of CT examinations of the nasal sinuses or the cervical spine, and all cases in the trauma group were justified.

To our knowledge, there are only few other studies about the justification of examinations causing radiation. In 2001, Clarke et al. reported about the possibilities of MRI to replace CT examinations. This team had more patients and subgroups than we did, and more than 70% of the CT examinations could have been replaced by MRI (9). In another report concerning CT examinations of the abdomen, pelvis and lumbar spine, the last of these was often recommended to be replaced by MRI (10). One study reports about 60% justification of CT examinations according to the request forms; in particular, US could have been useful as a preceding or alternative investigation (11). According to the Swedish national survey on justification of CT examinations approximately 20% of all examinations were not justified. The degree of justification varied strongly with the organ examined, moderately with prescriber affiliation and weakly with geographical region (12).

In our study, 21 out of the 200 patients were children. There were three unjustified cases in this group (14%). Ionizing radiation always increases the statistical risk of cancer mortality. The risk is higher at younger age because the expected lifetime is longer than at older age. Division of the cells is also fast and the organs are particularly sensitive to radiation at a younger age (4,13). There are only few published audits of justification of radiological examinations in children. The Swedish national survey on justification of CT examinations reported that the degree of justification is lower for younger patients. However, the total number of paediatric examinations was small in that study (12). There is also an audit of CT for the evaluation of mild to moderate paediatric trauma. Paediatric patients had significantly more CT scans than adults (14).

As a consequence of our study, we wanted to change our practice by introducing new interventions. It is known that awareness of radiation is often deficient and that radiation risks are frequently underestimated (15). We provided education and an info card containing information on radiation and justification for the staff of the Department of Radiology, other personnel working with ionizing radiation in our area and the referring practitioners.

The referral criteria for imaging recommended by the European Commission were distributed to different areas of the Department of Radiology. We also made some new recommendations for the use of CT for the referring practitioners and the radiologists at our hospital. Regular use of referral guidelines can also lead to a reduction in the number of request forms and ultimately to a reduction in patient exposure to ionizing radiation (3). Our study revealed that most of the unjustified cases could have been replaced by MRI. Because shortage of MRI capacity may partly have contributed to the poor results, we addressed this by purchasing a new MR system. In order to give other centres an opportunity to make use of our conclusions, we have reported about the project at different conferences and in medical journals.

The follow-up has so far mainly concentrated on the justification of CT of the lumbar spine and the results are striking. In the near future, we plan to follow up indications for CT examinations. We expect that better awareness of justification also in other areas of imaging will be reached by both the personnel working in the area of radiology and the referring practitioners. We also hope that the project will have an impact on other hospitals and health care centres in Northern Finland, other units in Finland, and other countries, too.

In conclusion, justification of CT examinations in young patients seemed to be inadequate. However, justification could be improved by interventions - education, use of referral guidelines and increased MRI capacity. The main goal of the whole project has been radiation protection of the patients, and the results have been promising.

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Screening or selective imaging in paediatric dentistry: from panoramic to CBCT

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Abstract

Dental radiography is one of the most frequent forms of medical X-ray imaging. A large proportion of examinations are performed in the paediatric age group, principally for the detection of dental decay (caries) and developmental anomalies. While most dental X-ray examinations have a very low radiation dose, the introduction of Cone Beam CT (CBCT) brings a higher dose range to dental imaging. Clinical screening of children is good practice, but radiographic screening cannot be justified. Referral (selection) criteria for imaging have been developed by various authorities and organisations, but these have a variable basis upon scientific evidence and uncertain acceptance amongst dentists. Provisional evidence-based referral criteria for CBCT are available through the European SEDENTEXCT project. Considerable research is needed to refine the existing referral criteria for dental radiology and to monitor their adoption in primary dental care.

Introduction

In developed countries, it has been estimated that 20% of X-ray examinations are performed by dentists (UNSCEAR, 2000). This figure conceals considerable national variation, ranging from the highest (839 per 1000 population) in Japan to below 100 per 1000 for many countries. In the United Kingdom it was estimated in 2002 that over 9 million intraoral and over 3 million panoramic radiographs were taken annually (Hart and Wall, 2002). Although some dental practice is conducted in hospitals and community (public health service) clinics, most takes place in dental offices. It is notable, therefore, that the usual practice of dental radiography is one of self-referral, in which the dentist decides radiography is necessary, selects a particular type of X-ray examination, performs the justification process and, often, also performs the examination. In most instances, an external influence on prescription of radiographic examinations is financial, through national or private health insurance schemes.

Another important aspect of dental practice is that a large proportion of radiographic examinations are performed on younger age groups (UNSCEAR, 2000), including children, reflecting two clinical needs. First, dental caries (decay) is a particular risk soon after the eruption of teeth, both for the deciduous and permanent dentitions. Secondly, dental development in childhood is frequently complicated by eruption problems (impaction of teeth), abnormal number of teeth (hypodontia or hyperdontia), discrepancy in size between the teeth and the available space in the mouth (crowding or spacing) and aesthetic problems. These developmental disturbances may necessitate orthodontic treatment. The prevalence of these clinical problems is such that "screening" or routine X-ray examinations have been adopted by some dentists.

Traditional dental radiographic techniques are limited in scope, being intraoral, panoramic and cephalometric techniques. Relative to most medical X-ray examinations, each of these is associated with a low radiation dose (European Commission, 2004; Ludlow et al 2008). Recently, however, Cone Beam CT (CBCT) has become available to dentists, at an equipment cost that makes it affordable. CBCT is associated with a higher radiation dose than is seen with traditional radiographic techniques, raising important challenges in justification and optimisation (SEDENTEXCT, 2009).

Radiographic screening in paediatric dentistry

Screening can be defined as "the testing of a symptomless population in order to detect cases of a disease at an early stage" (Bandolier, 2004). The basic principles of screening are:

- The condition is common and disabling, the natural history is known and that there is a recognisable latent or pre-symptomatic phase.
- The screening test is reliable, valid and repeatable, is acceptable and easy to perform, is sensitive and specific and low cost.
- Treatment should be effective and available, and that there is an agreed policy on who to treat.

How do these criteria fit with paediatric dentistry? As detailed above, there are two broad categories of "common or disabling" conditions for which a dentist (or public health dental service) might choose to screen: dental caries and its sequelae and anomalies of growth and development of the dentition requiring orthodontic management

Dental caries is a common disease in some populations, being associated with low socio-economic status, inadequate fluoride exposure, poor oral hygiene, poor diet and numerous other less frequent risk factors (Faculty of General Dental Practitioners UK, 1998; Pendlebury et al, 2004). In low caries risk populations, however, caries has become a rare condition in children. Nonetheless, the natural history of dental caries is well understood and the disease has a long pre-symptomatic phase and therefore might be seen to comply with the first criterion of a screening programme. Similarly, treatments and care pathways for dental caries are readily available and have well established efficacies, whether these relate to remineralisation of early, non-cavitated, lesions or restoration of carious cavities in teeth.

A significant proportion of children in developed countries may seek orthodontic treatment (Pendlebury et al, 2004; Isaacson et al, 2008). Because of this, clinical screening of children at around 8-10 years has become accepted practice. The addition of radiographic examinations to the clinical screening procedure has, however, become common. The aim of the dentist or orthodontist is to ensure the development of a functional and aesthetic dentition. It is important to remember that an impacted or missing tooth does not necessarily prevent this. The subjectivity of dental aesthetics means that some patients may find entirely acceptable anomalies for which others may demand treatment. On the other hand, the natural history of anomalous dental development and the pre-symptomatic phase are compatible with the first screening criterion. Treatments are effective and available and criteria for treatment have been developed based on clinical findings, notably the DAI (Dental Aesthetic Index; Cons et al, 1986) and IOTN (Index of Orthodontic Treatment Need; Brook & Shaw, 1989). Such indices typically identify that up to about half of children are in need of orthodontic treatment (Chestnutt et al, 2006; Manzanera et al, 2010).

From the above, therefore, it can be seen that a reasonable person might argue that radiographic screening of children is justifiable because the conditions and diseases of greatest prevalence in this age group are of significance and amenable to effective treatment. The question that remains relates to the screening methods that are used. In dental practice, the primary method of diagnosis is always clinical, after which special tests can be selected. The most widely used special test in dentistry remains imaging using X-rays.

Diagnostic tests for dental caries

While clinical examination of clean dry teeth, with good lighting, can reveal dental caries lesions, several high quality reviews indicate that posterior bitewing radiographs are an essential adjunct (Hanlon PM, 1985; Kidd & Pitts, 1990; Henderson & Crawford 1995; Weerheijm 1997; Pitts 1996). Bitewing radiographs (Fig. 1) reveal significantly greater proportions of caries lesions than clinical examination alone in both high and moderate caries risk populations (Faculty of General Dental Practitioners UK, 1998; Pendlebury et al, 2004). The diagnostic accuracy of bitewing radiographs for caries diagnosis has been subject to a systematic review by Bader et al (2001). They reported mean sensitivities ranging from 30-66% (depending on lesion size and site) and specificities of 76-95%. For low caries risk populations the evidence for screening using bitewing radiographs is less convincing (Hintze & Wenzel, 1994).

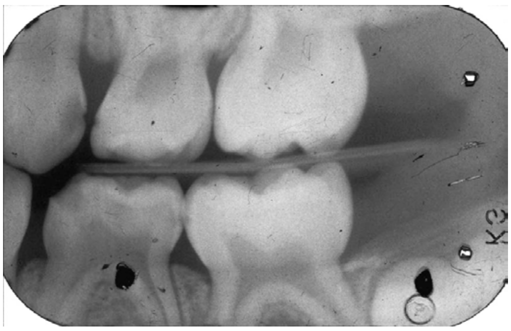

Fig. 1. A bitewing radiograph from a 6 year-old patient in the deciduous dentition.

While there is a well understood body of evidence surrounding the use of bitewing radiographs for dental caries diagnosis, there is less evidence for the role of panoramic radiographs in this respect. The reason for the limited volume of research in this field is, in part, because of the inferior imaging characteristics of panoramic radiography for detection of the small demineralisations of tooth enamel that represent caries lesions. As such, there is not a great pressure to perform research comparing an inferior (panoramic) with a superior (bitewing) technique. Panoramic radiographs have lower resolution and often show overlap between teeth that obscure lesions. Thus, caries diagnosis accuracy is lower than for bitewing radiographs (Scarfe et al, 1994; Rushton & Horner, 1996; Akkaya et al, 2006). Overlying this, image quality is often compromised by poor technique in primary dental care facilities (Rushton et al, 1999). Nonetheless, while emphasising the need for individualised prescription of radiographs, US guidelines still recommend "posterior bitewings with panoramic exam" as appropriate at all paediatric ages subsequent to the eruption of the first permanent molar at around 6 years of age (American Academy on Pediatric Dentistry, 2008).

The advent of CBCT to dentistry raises the potential of its use for the full range of diagnostic applications, including caries diagnosis. The current evidence suggests that limited (small field-of-view) CBCT has a similar diagnostic accuracy to conventional radiography for the detection of caries in posterior teeth *in vitro*, but that the representation of caries depth may be superior (Akdeniz et al, 2006; Haiter-Neto et al 2008; Tsuchida et al 2007; Qu et al, 2010). It should be emphasised, however, that the CBCT systems available to dentists vary enormously in their imaging characteristics, including resolution and field-of-view. In clinical practice, an important additional problem of using CBCT is the presence of artefacts from high atomic number dental restorations that will substantially reduce specificity. Because of these findings, the only currently available evidence-based guidelines on dental CBCT state that "CBCT should not be used as a routine method of caries detection and diagnosis" (SEDENTEXCT, 2009).

Diagnostic tests for anomalies of dental development

The usual radiographic examination performed for the assessment of the developing dentition is the panoramic radiograph (Fig.2). It is an effective method of identifying most dental developmental anomalies, as demonstrated by several surveys of unselected populations (Bergstrom, 1977; Locht, 1980; Ignelzi at al, 1989). The panoramic radiograph may be supplemented by selected intraoral radiographs and, where orthodontic treatment is planned, by a lateral cephalogram. Beyond initial diagnosis, patients who go on to orthodontic treatment may receive repeated X-ray exposures (Hujoel et al, 2006).

The evidence that panoramic radiography can identify dental anomalies should not be seen as a justification for imaging. Many anomalies are of purely documentary interest and the important aspect is whether the radiological findings influence management. Research suggests that in a large proportion of cases the radiographic evidence makes no contribution to diagnostic thinking (Atchinson et al 1991; Han et al 1991). While understandable emphasis has been placed here on the use of screening panoramic radiographs, the role of cephalometric radiographs in management of orthodontic patients has also recently been questioned (Nijkamp et al, 2008). Research performed 20 years ago provided compelling evidence that panoramic radiographic screening for the purpose of assessing malocclusion and timing of treatment was ineffective. In their key paper, Hintze et al (1990) demonstrated that a 2-3 minute clinical examination of an unselected 11-12 year old population, followed by selected panoramic radiographic examination, could identify all children except one in need of immediate orthodontic treatment (a nosological sensitivity of 97%) while excluding 94% of "healthy" children. In a further study in a larger population, Hintze & Wenzel

(1990) reported that screening panoramic radiography resulted in 67% of children being exposed for no benefit.

Fig. 2. A panoramic radiograph from a 9 year-old patient in the mixed (deciduous and permanent) dentition.

It is clear that, for some years, the research evidence has been against the concept of screening panoramic radiography of children for development of the dentition and orthodontic assessment, but in favour of *clinical* screening supplemented by radiographs when indicated. Nonetheless, the practice of radiographic screening and “routine” radiography persists amongst some dentists, particularly in the United States, possibly driven by fears of litigation if “something is missed”.

Orthodontics involves the bodily movement of teeth through bone, using appliances that exert a steady force upon the former. This is therefore “three-dimensional” treatment. As such, the arrival of CBCT into dental practice has been greeted enthusiastically by orthodontists as offering an opportunity to have accurate three-dimensional knowledge of tooth position before, during and after orthodontic treatment. For assessment of facial bone shape, position and inter-relationships, there must be a high accuracy of measurements made with CBCT. Several studies have addressed this, reviewed by the SEDENTEXCT Guideline Development Panel (SEDENTEXCT, 2009), usually using direct calliper measurement of dried skulls as a reference standard. Differences between CBCT-derived measurements and the reference standard appear to be small and are unlikely to be clinically significant. Studies are not, however, available for all CBCT machines on the market. In considering the use of CBCT in orthodontics, a clear distinction must be made between localised CBCT (using a restricted field-of-view for a specific purpose) and large volume CBCT in which the facial bones are viewed in their entirety.

For localisation of unerupted teeth, CBCT can be reasonably assumed to have high accuracy. Teeth are relatively large objects, having good contrast with the surrounding bone. It is obvious that a three-dimensional imaging technique with acceptable measurement accuracy and little distortion will identify position of teeth with high diagnostic accuracy. As such, it is not surprising that no formal study has been performed that compares diagnosis of unerupted tooth position using CBCT and conventional radiographs. As conventional (“medical”) CT is used in some centres for localisation of unerupted maxillary canine teeth (Alqerban et al, 2009), the dose advantage seen with CBCT means that CBCT may be preferred (SEDENTEXCT, 2009). Fig. 3 shows an image from a localised CBCT examination. A similar argument can be made in favour of CBCT in the assessment of cleft palate, for which conventional CT is the usual examination.

Fig. 3. Images from a localised CBCT examination for the localisation of an unerupted permanent canine tooth in the maxilla (upper jaw).

In contrast to this positive assessment of CBCT, the use of large volume (craniofacial) CBCT as a routine means of assessing growth and development of the dentition and the face in orthodontics causes concern. Compared with a "conventional" examination, using a panoramic and a lateral cephalometric examination, large volume CBCT gives a higher radiation dose, sometimes considerably so. The SEDENTEXCT Guideline document, based on systematic review, described the literature on this subject as "strong on hyperbole and short on evidence of significant clinical impact" (SEDENTEXCT, 2009), with case reports and non-systematic reviews claiming improvements in diagnosis and treatment in orthodontics for CBCT without any objective justification (e.g. Kau et al, 2005; Cattaneo & Melsen, 2008) . The concerns over the spreading use of CBCT as a treatment standard in orthodontics is compounded by anecdotal evidence of large volume CBCT datasets being used solely for the purposes of reformatting into panoramic and cephalometric images, a practice condemned in a recent Health Protection Agency Guideline document in the United Kingdom (Holroyd & Gulson, 2009).

Referral criteria instead of screening

Probably the first set of guidelines dealing with justification of radiology in dentistry, including paediatric uses, were those produced in the United States in 1987 (Dental Radiographic Patient Selection Criteria Panel & Joseph, 1987). These "expert panel" guidelines emphasised that individualized radiographic examinations should be prescribed based upon the patient's signs, symptoms, and history using selection [referral] criteria that increase the likelihood that the patient will benefit from the radiographic examination.

In Europe, most recommendations relating to Justification seem to be general guidance that imaging should be selected on an individual patient basis after a history and examination have been performed, relying on individual dentists' judgements rather than a set of specific referral criteria (European Commission, 2004; Martínez-Beneyto et al, 2007; Peltola et al, 2009). More detailed guidelines have appeared sporadically from European and national dental organisations, notably in the UK (Faculty of General Dental Practitioners UK, 1998) and France (Haute Autorité de Santé, 2006). Apart from national initiatives, guidelines on imaging have also appeared from national (American Academy on Pediatric Dentistry, 2008; Isaacson et al, 2008) and international (Espelid et al, 2003) specialist organisations. On close examination, however, many of these sets of referral criteria are expert panel based, rather than developed using a structured method of literature review. This no doubt explains why different sets of referral criteria may disagree.

In the UK, the Faculty of General Dental Practice (UK) produced evidence-based referral criteria for dental radiography in 1998 (Faculty of General Dental Practitioners UK, 1998.), revised them in 2004 (Pendlebury et al, 2004) and is now working on its 3rd edition. Unlike the US and previous European guidelines, these were very clearly "evidence-based", following a specific methodology which, at best, included systematic review. These guidelines acted as the model for the development of the European Guidelines on Radiation Protection in Dental Radiology (European Commission, 2004). Unfortunately, such is the rapidity with which CBCT has developed and proliferated in dentistry that those guidelines did not address it in any way. This provided the reason for the initiation of the SEDENTEXCT project under the European Atomic Energy Community's Seventh Framework Programme, which has recently developed evidence-based guidelines on CBCT use in dentistry, including referral criteria (SEDENTEXCT, 2009).

Conclusions

The nature of clinical dentistry, based largely in independent practice, increases the chances of inappropriate use of X-ray-based imaging. Conventional radiography has a low dose when appropriately optimised, although the increasingly available CBCT has significantly higher radiation doses. While clinical screening of children for the most common dental disease (caries) and developmental conditions requiring orthodontic intervention is appropriate, radiographic screening of children is unjustifiable on the basis of the research evidence. Instead, referral (selection) criteria have been developed by various organisations to encourage rational prescription of imaging that promotes improved treatment outcomes. Many of these guidelines have a low evidence base, however, and considerable research is needed to refine the existing guidance and to monitor their adoption in primary dental care.

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