

## REPORT

# Basic principles for use of dental cone beam computed tomography: consensus guidelines of the European Academy of Dental and Maxillofacial Radiology

K Horner<sup>\*1</sup>, M Islam<sup>2</sup>, L Flygare<sup>3</sup>, K Tsiklakis<sup>4</sup> and E Whaites<sup>5</sup>

<sup>1</sup>School of Dentistry, University of Manchester, Manchester, UK; <sup>2</sup>Faculty of Medical and Human Sciences, University of Manchester, Manchester, UK; <sup>3</sup>Department of Radiology and Physiology, Sunderby Hospital, Luleå, Sweden; <sup>4</sup>Department of Oral Diagnosis and Radiology, School of Dentistry, University of Athens, Athens, Greece; <sup>5</sup>Department of Dental Radiology and Imaging, King's College London Dental Institute, London, UK

**Objectives:** To develop “basic principles” on the use of dental cone beam CT by consensus of the membership of the European Academy of Dental and Maxillofacial Radiology.

**Methods:** A guideline development panel was formed to develop a set of draft statements using existing European directives and guidelines on radiation protection. These statements were revised after an open debate of attendees at a European Academy of Dental and Maxillofacial Radiology (EADMFR) Congress in June 2008. A modified Delphi procedure was used to present the revised statements to the EADMFR membership, utilising an online survey in October/November 2008.

**Results:** Of the 339 EADMFR members, 282 had valid e-mail addresses and could be alerted to the online survey. A response rate of 71.3% of those contacted by e-mail was achieved. Consensus of EADMFR members, indicated by high level of agreement for all statements, was achieved without a need for further rounds of the Delphi process.

**Conclusions:** A set of 20 basic principles on the use of dental cone beam CT has been devised. They will act as core standards for EADMFR and, it is hoped, will be of value in national standard-setting within Europe.

*Dentomaxillofacial Radiology* (2009) **38**, 187–195. doi: 10.1259/dmfr/74941012

**Keywords:** cone-beam computed tomography; guideline; Delphi techniques; consensus

## Introduction

The introduction of cone beam CT (CBCT) represents a radical change for dental and maxillofacial radiology. The three-dimensional (3D) information appears to offer the potential of improved diagnosis for a wide range of clinical applications, and usually at lower doses than with “medical” multislice CT. Usually, however, CBCT gives increased radiation doses to patients compared with conventional dental radiographic techniques. While there is a rapidly accumulating literature on CBCT, there are no current evidence-based guidelines on its use and there is a risk of inappropriate examinations being performed. The latter is a particular concern where CBCT equipment is sited

in primary dental care without the skills of radiology specialists.

In the absence of a satisfactory volume of evidence upon which detailed guidelines can be devised, some basic principles can be based upon the fundamental tenets of X-ray use for medical purposes. Recently, an opinion statement on performing and interpreting CBCT examinations was produced by the American Academy of Oral and Maxillofacial Radiology,<sup>1</sup> which provides useful standards for the United States. In European nations that are members of the European Union,<sup>2,3</sup> guidance derives from the European Commission Directives. While European Guidelines on Radiation Protection in Dental Radiology,<sup>4</sup> developed from these Directives, were published in 2004, there was no consideration of CBCT. This deficiency was recognized by the European Commission by approving a project, SEDENTEXCT (Safety and

\*Correspondence to: Professor Keith Horner, University Dental Hospital of Manchester, Higher Cambridge Street, Manchester M15 6FH, UK; E-mail: [keith.horner@manchester.ac.uk](mailto:keith.horner@manchester.ac.uk)

Received 20 January 2009; accepted 16 February 2009 (no revision)

Efficacy of a new and emerging Dental X-ray modality<sup>5</sup> under its Seventh Framework Programme of the European Atomic Energy Community (Euratom) for nuclear research and training activities (2007–2011). The project aims to acquire key information necessary for sound and scientifically based clinical use of CBCT. As part of this aim, the project has set an objective of developing evidence-based guidelines for dental and maxillofacial use of CBCT. The project commenced on 1 January 2008, with the prospect of producing provisional guidelines early in 2009.

The European Academy of DentoMaxilloFacial Radiology (EADMFR) was formed in 2004. Its objective is to promote, advance and improve clinical practice, education and/or research specifically related to the speciality of dental and maxillofacial radiology within Europe, and to provide a forum for discussion, communication and the professional advancement of its members. As such, EADMFR represents a key stakeholder group for setting standards. Many individuals involved in the SEDENTEXCT project are also EADMFR members and co-operation between the two is seen as an important means of improving their societal impact.

In view of the mutual aims of EADMFR and SEDENTEXCT, the aim of the work reported here was to develop a set of “basic principles” of dental CBCT use, using a consensus process amongst the EADMFR membership.

## Materials and methods

This study involved three stages and followed a modified Delphi method to achieve the consensus of EADMFR members on a set of basic principles of dental CBCT use.

### *Guideline development panel*

A guideline development panel was formed, consisting of the then-EADMFR President, Immediate Past-President and President-Elect (KT, EW and LF, respectively), and the Chair of the EADMFR Selection Criteria and Radiation Protection Committee (KH). KH is also co-ordinator of the SEDENTEXCT project. The EC Directive 97/43/Euratom<sup>3</sup> and the European Guidelines on Radiation Protection in Dental Radiology<sup>4</sup> were used as source material for draft guideline development. The latter document includes sections on “Justification: referral criteria”, “Equipment factors in the reduction of radiation doses to patients”, “Quality Standards and Quality Assurance” and “Staff Protection”, each containing specific recommendations relating to good clinical practice and radiation protection. These sections were hand searched and recommendations that were pertinent to CBCT, or that might be so once subjected to minor modification of the text, were extracted to form a draft set of statements on CBCT use. In addition, the panel developed a number of

additional, entirely new statements that were deemed to be consistent with EC Directive 97/43/Euratom.<sup>3</sup> 19 “basic principles” of dental CBCT use were combined into a first draft document (Table 1).

### *First consultation stage: open debate*

The 11th Congress of EADMFR was held in Budapest, Hungary, on 25–28 June 2008. On the final day of the Congress, a plenary session was held entitled “Cone beam CT debate”. The first draft document was presented to the audience as part of a PowerPoint presentation. Each of the 19 statements was presented in turn and the audience were invited to comment and participate in debate. Comments and criticisms were recorded. After this meeting, the Guideline Development Panel revised the statements in the first draft document, taking into account this feedback and suggested changes (Table 1) to provide a second draft set of statements.

### *Second consultation stage: online survey*

The membership of EADMFR was then invited to express their views on the second (revised) draft of the basic principles *via* an online (web-based) survey. At the time of carrying out this survey, there were 339 members of the Academy. The EADMFR membership database of e-mail addresses was used to contact members. Prior to the start of the survey, concerted attempts were made to update this database. EADMFR members were sent an e-mail from the then-President (LF) inviting them to take part in the survey and directing them to the webpage. The online survey (<http://www.sedentext.eu/surveyprinciples>) was available in a choice of eight languages (English, French, German, Greek, Hungarian, Italian, Polish and Turkish). Screenshots of the survey web page in English are shown in Figure 1. The online survey form was written in an XHTML 1.0 Strict markup language. The data submitted from the survey were processed by a PHP script, which is an HTML-embedded scripting language. The script checked for valid responses and formatted the data for storage in a MySQL database. Using SQL (Structured Query Language), the data were stored in the database as a flat file model. Each row contained each of the responses from the responders. Additional information such as when the survey was completed, in which language the survey was completed, the responder’s IP address, information about the web browser and the computer operating system were also recorded. All data were stored on one secure PC, following the requirements of data protection law in the United Kingdom, with one person (MI) acting as the data controller and analyst.

The modified Delphi procedure was designed to develop consensus agreement on some or all of the statements in the second draft document. Participants were invited to express their level of agreement with each of the statements using a five-point Likert scale:

- Strongly agree
- Agree
- Neither agree nor disagree

**Table 1** Draft statements on the use of cone beam CT (CBCT). The left column shows the statements as originally devised by the Guideline Development Panel. The right column shows the changes (bold), subsequent to the debate held at the 11th Congress of EADMFR in Budapest (June 2008). The second draft statements involved the splitting of the final statement to provide a 20th statement, and raising Statement 3 of the first draft to first position

	<i>First draft statements</i>		<i>Second draft statements</i>
1	CBCT must be justified for each patient to demonstrate that the benefits outweigh the risks	2	CBCT <b>examinations</b> must be justified for each patient to demonstrate that the benefits outweigh the risks
2	CBCT examinations should add new information to aid the patient's management	3	CBCT examinations should <b>potentially</b> add new information to aid the patient's management
3	CBCT examinations must not be carried out unless a history and clinical examination have been performed	1	No change to text
4	CBCT should not be repeated "routinely" on a patient without a new risk/benefit assessment having been performed	4	No change to text
5	When accepting referrals from other dentists for CBCT, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the Justification process	5	When accepting referrals from other dentists for CBCT <b>examinations</b> , the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the Justification process
6	CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography	6	No change to text
7	CBCT images must undergo a thorough clinical evaluation ("radiological report") of the entire image dataset	7	No change to text
8	Where it is likely that evaluation of soft tissues will be required as part of the patient's radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT	8	No change to text
9	Where CBCT equipment offers a choice of volume sizes, examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient	9	<b>CBCT equipment should offer a choice of volume sizes and</b> examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient
10	Where CBCT offers a choice of resolution, the lowest resolution compatible with adequate diagnosis should be used	10	Where CBCT offers a choice of resolution, the <b>optimal</b> resolution compatible with adequate diagnosis should be used
11	A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality control procedures	11	No change to text
12	Aids to accurate positioning (light beam markers) must always be used	12	Aids to accurate positioning (light beam markers, <b>head restraints, chin rests</b> ) must always be used
13	All new installations should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal	13	All new installations <b>of CBCT equipment</b> should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal
14	CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice/facility users and patients, has not significantly deteriorated	14	No change to text
15	For staff protection from CBCT, the guidelines detailed in Section 6 of the European Commission document <i>Radiation protection 136. European guidelines on radiation protection in dental radiology</i> should be followed	15	For staff protection from CBCT <b>equipment</b> , the guidelines detailed in Section 6 of the European Commission document <i>Radiation protection 136. European guidelines on radiation protection in dental radiology</i> should be followed
16	All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection	16	No change to text
17	Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted	17	No change to text
18	Dentists responsible for CBCT facilities who have not previously received "adequate theoretical and practical training" should undergo a period of additional theoretical and practical training that has been validated by an academic institution (University or equivalent). Where national specialist qualifications in DMFR exist, the design and delivery of CBCT training programmes should involve a DMF Radiologist	18	No change to text
19	For CBCT images that extend posterior to the third molar regions of the mandibular and maxillary bones and/or above the floor of the nose, clinical evaluation ("radiological report") should be made by a DMF Radiologist (where national specialist qualifications in DMFR exist) or by a Clinical Radiologist (Medical Radiologist)	19	<b>For dental and maxillofacial CBCT images of the teeth, their supporting structures, the mandible (including the TMJ) and the maxilla up to the floor of nose (e.g. 8 cm × 8 cm or smaller fields of view) clinical evaluation ("radiological report") should be made by an adequately trained general dental practitioner or by a specially trained DMF Radiologist</b>
		20	<b>For non-dental small fields of view (e.g. temporal bone) and all craniofacial CBCT images (fields of view larger than 8 cm × 8 cm) clinical evaluation ("radiological report") should be made by a specially trained DMF Radiologist or by a Clinical Radiologist (Medical Radiologist)</b>

home project stakeholders partners intranet

## Survey of EADMFR members on Basic Principles of Dental Cone Beam Computed Tomography

Authors: Eric Whaites, Kostas Tsiklakis, Lennart Flygare, Keith Horner

Choose your language

### SEDENTEXCT

The SEDENTEXCT project (2008–2011) is supported by the The Seventh Framework Programme of the European Atomic Energy Community (Euratom) for nuclear research and training activities (2007–2011)

**a**

**1. Basic Principles of Cone Beam CT use**

We are trying to reach a consensus on justification, optimisation and training requirements for CBCT.

Using the numerical scale below, express your agreement or disagreement with each of the 20 draft principles.

Agreement scale										
5	4	3	2	1						
Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree						
	STATEMENTS					5	4	3	2	1
1	CBCT examinations must not be carried out unless a history and clinical examination have been performed.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2	CBCT examinations must be justified for each patient to try to ensure that the benefits outweigh the risks.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3	CBCT examinations should potentially add new clinically relevant information to aid the patient's management.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4	CBCT examinations should not be repeated 'routinely' on a patient without a new risk/benefit assessment having been performed.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5	When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and clinical examination) to allow the CBCT Practitioner to perform the Justification process.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6	CBCT examinations should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) dental radiography.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7	CBCT images must undergo a thorough clinical evaluation ('radiological report') of the entire image dataset.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8	Where it is likely that evaluation of soft tissues will be required as part of the patient's radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9	CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10	Where CBCT equipment offers a choice of resolution, the optimal resolution compatible with adequate diagnosis should be used.					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11	A quality assurance programme must be established and implemented for each CBCT					<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**b**

**Figure 1** Screen shots from the online survey. (a) Title and explanatory text and (b) a section of the questionnaire

- Disagree
- Strongly disagree.

For subsequent analysis purposes, this five-point scale was allocated numerical values of 5 to 1, with 5 corresponding to “strongly agree” and 1 to “strongly disagree”. A “free text” box was also provided as part of the survey webpage in which participants were able to make specific comments on any statement and to suggest changes in the wording.

Results were analysed for each statement by median agreement score and interquartile range. Consensus agreement on each statement was predefined as a median score of 5 or 4, an interquartile range not exceeding 1 and a lower quartile score no lower than 3. Any statement for which the median score was 2 or 1 and where the upper quartile score was 3 or less was to be rejected without further consideration. Any statement for which the survey gave an intermediate result, where neither consensus agreement nor outright rejection was obtained using the above criteria, was to be reviewed by the Guideline Development Panel to determine if it should be modified and re-submitted in any subsequent round of the survey. The intention was to carry out up to three rounds of the survey.<sup>6</sup>

Specific comments of participants were extracted from the completed surveys and presented to the Guideline Development Panel for further consideration prior to final revision of the statements and establishment of these as “basic principles of CBCT use”.

## Results

### *First consultation stage: open debate*

The debate of attendees at the 11th EADMFR Congress led to several modifications to the original 19 statements devised by the Guideline Development Panel (Table 1), most of which were minor in nature. The first draft statement number 3 was highlighted as being of pre-eminent importance and was re-positioned to the first position amongst the revised draft statements. Statement 9, which deals with field sizes, provoked several comments in debate that EADMFR should unequivocally advocate the availability of a choice of field sizes in CBCT equipment as a key aspect of radiation protection. The wording of the second draft reflected this view. The other significant change related to the first draft Statement 19, for which it was argued that this might benefit from greater clarity about clinical evaluation of smaller CBCT field sizes. Consequently this statement was re-written into two separate statements (19 and 20).

### *Second consultation stage: online survey*

Of the 339 registered members of EADMFR, e-mail addresses were only available for 321 individuals on the Academy database. For 39 of these members, e-mails

consistently resulted in automated “bounced” replies. Consequently, 282 members of EADMFR (83.2% of total EADMFR membership) were assumed to have been successfully contacted and alerted to the online survey.

The survey was opened on 22 October 2008. Reminder e-mails were sent to non-responders after 2 weeks had elapsed and again after a further 1 week. The survey closed at 17.00 h (Brussels time) on 28 November 2008. At this time, valid responses had been received from 201 members – a response rate of 71.3% of those contacted by e-mail and equivalent to 59.3% of the total registered EADMFR membership.

Table 2 summarises the responses to the online survey for each of the 20 statements. In every case, the *a priori* definition of consensus agreement was satisfied and no second or further round of the survey was indicated.

Specific “free text” comments ( $n = 59$ ) were received from 46 respondents. Most of these represented suggestions for minor textual modifications or, in a few cases, expressed views that were profoundly at variance with the majority opinion. Of the 59 comments, however, 17 related specifically to statement number 19; these fell into two groups of comments. The first group expressed opposition to the interpretation of CBCT images by “adequately trained general dental practitioners”, preferring to restrict interpretation solely to radiologists. The second group felt that the definition of field size for dental and maxillofacial CBCT was imperfect and needed more precision to specify only the teeth and supporting structures. All of the free text comments were reviewed by the Guideline Development Group, commented upon and discussed. As a result, some minor changes were made and the final 20 statements (Table 3) were considered to have been adopted as EADMFR “basic principles” of the use of CBCT.

## Discussion

CBCT undoubtedly represents a great advance in dental and maxillofacial imaging. Nonetheless, whenever ionizing radiation is used for clinical purposes, the fundamental principles of radiation protection must be applied and legal requirements recognized. There are, at the time of preparation of this manuscript, no detailed evidence-based guidelines on CBCT use, although efforts are currently being made to address this deficiency in both the United States<sup>1</sup> and in Europe.<sup>5</sup> Evidence-based guidelines (including selection criteria) require considerable time and effort to develop and, of course, an adequate volume of high-quality research evidence upon which they can be based. In the interim, however, it is possible to consider the fundamental aspects of radiation protection in the context of CBCT. The work described here represents the best efforts of the EADMFR to develop such “basic principles” that, at least, can provide “core” guidance prior to the accumulation of

**Table 2** Responses received from members of the European Academy of Dental and Maxillofacial Radiology to the online survey

Statement	n	Number of responses received for each agreement score					Median agreement score	Interquartile range	Upper quartile score	Lower quartile score
		5	4	3	2	1	5	0	5	5
1	201	191	8	1	1	0	5	0	5	5
2	201	176	16	5	2	2	5	0	5	5
3	201	163	31	6	1	0	5	0	5	5
4	201	167	9	6	5	14	5	0	5	5
5	201	162	31	5	3	0	5	0	5	5
6	201	146	43	7	4	1	5	1	5	4
7	200	163	32	3	0	2	5	0	5	5
8	201	122	65	10	3	1	5	1	5	4
9	200	160	29	9	1	1	5	0	5	5
10	201	156	40	5	0	0	5	0	5	5
11	201	165	30	4	1	1	5	0	5	5
12	201	153	38	9	0	1	5	0	5	5
13	201	181	17	2	1	0	5	0	5	5
14	201	169	27	4	1	0	5	0	5	5
15	198	161	30	7	0	0	5	0	5	5
16	201	182	17	2	0	0	5	0	5	5
17	200	164	30	4	2	0	5	0	5	5
18	199	160	26	9	2	2	5	0	5	5
19	201	155	28	6	8	4	5	0	5	5
20	201	153	31	6	4	7	5	0	5	5

n, total number of responses received

good research evidence and development of detailed guidelines. The task was considered by EADMFR to have the highest priority in view of the proliferation of

CBCT equipment in primary dental care, away from the expertise available in specialist clinics and hospitals.

**Table 3** European Academy of Dental and Maxillofacial Radiology basic principles on the use of cone beam CT (CBCT)

1	CBCT examinations must not be carried out unless a history and clinical examination have been performed
2	CBCT examinations must be justified for each patient to demonstrate that the benefits outweigh the risks
3	CBCT examinations should potentially add new information to aid the patient's management
4	CBCT should not be repeated "routinely" on a patient without a new risk/benefit assessment having been performed
5	When accepting referrals from other dentists for CBCT examinations, the referring dentist must supply sufficient clinical information (results of a history and examination) to allow the CBCT Practitioner to perform the justification process
6	CBCT should only be used when the question for which imaging is required cannot be answered adequately by lower dose conventional (traditional) radiography
7	CBCT images must undergo a thorough clinical evaluation ("radiological report") of the entire image data set
8	Where it is likely that evaluation of soft tissues will be required as part of the patient's radiological assessment, the appropriate imaging should be conventional medical CT or MR, rather than CBCT
9	CBCT equipment should offer a choice of volume sizes and examinations must use the smallest that is compatible with the clinical situation if this provides less radiation dose to the patient
10	Where CBCT equipment offers a choice of resolution, the resolution compatible with adequate diagnosis and the lowest achievable dose should be used
11	A quality assurance programme must be established and implemented for each CBCT facility, including equipment, techniques and quality control procedures
12	Aids to accurate positioning (light beam markers) must always be used
13	All new installations of CBCT equipment should undergo a critical examination and detailed acceptance tests before use to ensure that radiation protection for staff, members of the public and patient are optimal
14	CBCT equipment should undergo regular routine tests to ensure that radiation protection, for both practice/facility users and patients, has not significantly deteriorated
15	For staff protection from CBCT equipment, the guidelines detailed in Section 6 of the European Commission document <i>Radiation Protection 136. European guidelines on radiation protection in dental radiology</i> should be followed
16	All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiological practices and relevant competence in radiation protection
17	Continuing education and training after qualification are required, particularly when new CBCT equipment or techniques are adopted
18	Dentists responsible for CBCT facilities who have not previously received "adequate theoretical and practical training" should undergo a period of additional theoretical and practical training that has been validated by an academic institution (university or equivalent). Where national specialist qualifications in DMFR exist, the design and delivery of CBCT training programmes should involve a DMF Radiologist
19	For dentoalveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose ( <i>e.g.</i> 8 cm × 8 cm or smaller fields of view), clinical evaluation ("radiological report") should be made by a specially trained DMF Radiologist or, where this is impracticable, an adequately trained general dental practitioner
20	For non-dentoalveolar small fields of view ( <i>e.g.</i> temporal bone) and all craniofacial CBCT images (fields of view extending beyond the teeth, their supporting structures, the mandible, including the TMJ, and the maxilla up to the floor of the nose), clinical evaluation ("radiological report") should be made by a specially trained DMF Radiologist or by a Clinical Radiologist (Medical Radiologist)

The methodology followed here can be defined as a modified Delphi technique. This is a method of soliciting information about a subject from a group of experts and, by successive rounds of the procedure, is designed to yield consensus. In the current context, the membership of the EADMFR was considered as the “expert group”. The technique was modified by the use of a Guideline Development Group to select items for inclusion in the consultation process. While this probably restricted the scope of the content, it was felt that this was likely to avoid numerous rounds of consultation. Furthermore, the content was strongly based upon existing European Directives<sup>2,3</sup> and existing, evidence-based, guidelines<sup>4</sup> and so limited the influence of the personal opinions of the Guideline Development Group members. This type of modification has previously been recommended.<sup>7</sup> The first-stage consultation, using a debate at an EADMFR Congress, afforded an opportunity to identify any significant problems with the first draft document. It also primed the membership with the information that the second stage consultation (the online survey) was planned, perhaps improving the eventual response rate and providing assurance to the membership that its views were of real influence.

While the first consultation in a debate was useful, such a format risked the dominance of more confident individuals and those fluent in English. The second stage consultation, by online survey, reduced the risk of bias through group interaction and, by ensuring anonymity, encouraged the expression of minority/atypical views. Furthermore, by presenting the survey in a choice of languages, the likely reluctance to become involved for those who lack good English (the primary language of EADMFR for documentation and communication) was probably reduced. The languages used here were selected to represent the membership profile of EADMFR. While the Scandinavian nations contribute a significant proportion of the Academy’s membership, it was judged that the almost-universal fluency in English in these countries did not justify translation.

The response rate to the survey (71.3% of those successfully contacted by e-mail) was considered acceptable. Sumsion<sup>8</sup> suggested that a 70% response was necessary to ensure satisfactory rigour of the Delphi method. It was not possible to contact all EADMFR members, but every reasonable effort was made to locate individuals with either an incorrect or no e-mail address before and during the survey period. E-mail addresses are requested when individuals join EADMFR, but there is inevitably some loss of accuracy as members change internet service providers and/or employment. Non-response bias to any survey must also be considered. Only two of the non-responders contacted us to say that they did not feel it appropriate to complete the survey (one a long-retired radiologist and the other a non-clinical scientist). In view of the requirements of data protection for the survey it was not possible to approach all the non-

responders directly to investigate their reasons. The membership of any organization, however, is always likely to include some non-active individuals or those for whom the subject of a consultation seems irrelevant. The strength of the consensus achieved amongst responders helps to overcome any concerns over any non-response bias.

There is no generally accepted definition of “consensus” in Delphi procedures. McKenna<sup>9</sup> recommended 51% agreement as sufficient, while others have suggested up to 80% agreement as the definition.<sup>6</sup> Regardless of the lack of a universal standard for consensus, the results presented in Table 2 exceed any recommended agreement threshold. This strength of agreement led us not to pursue any subsequent iteration of the process, along with the fear of “sample fatigue”.<sup>10</sup> It could be argued that the minor textual changes made to the second draft statements to establish them as “basic principles” should have warranted a second Delphi round, but comparison between the two versions (Tables 1 and 3) shows that these were related to improving clarity of language. The only significant change was made to statement number 10, where some specific comments received *via* the survey “free text” facility persuaded the Guideline Development Panel that radiation dose should be included in the wording.

In the final “basic principles” (Table 3), one can see that the first eight statements relate principally to justification of CBCT examinations, while the first four of these implicitly condemn “routine” examinations. Statement 6, that “CBCT should only be used when the question for which imaging is required cannot be answered adequately by conventional (traditional) radiography”, gives a clear guideline that simple, lower dose techniques should be preferred where they can answer the question for which imaging is required. This also reflects cost-efficacy, a subject that has received little or no attention in the CBCT literature or, indeed, in diagnostic imaging generally. Principle number 6 does not, however, veto the “first choice” use of CBCT so long as there is good evidence of superior diagnostic performance over conventional techniques. Principle number 7, emphasising the need for a clinical evaluation of the entire image dataset, agrees with the clear statements made in the recent American Academy of Oral and Maxillofacial Radiology opinion statement.<sup>1</sup>

While the “basic principles” steer clear of specific selection criteria, Statement 8 comes close to this in recommending that CBCT not be used where soft tissue assessment is a significant aspect of the need for imaging. With current CBCT systems, the soft tissue differentiation is poor compared with conventional CT or MR images and the intention behind this principle is the prevention of multiple examinations being performed. Looking ahead, it is possible that developments in CBCT may mean that this statement would require revision, but only on the basis of convincing research evidence.

Statements 9–15 (inclusive) deal, broadly, with optimisation and dose limitation. Statement 9 is of particular importance. Several CBCT systems currently marketed offer no choice of field size. Those that offer a single “craniofacial” field are of particular concern as, unless the clinician only uses this in carefully selected cases where the entire craniofacial region must be imaged, there is a potential for exposure of anatomical areas that are irrelevant to the clinical problem. Such a practice is contrary to the drive towards field size limitation that is intrinsic to dose limitation. It is hoped that this statement will act as a driver to manufacturers to offer a choice of field sizes. Similarly, Statement 10 addresses the issue of choice of resolution; while capturing high-resolution images may improve image quality both subjectively and objectively, it may also lead to higher radiation doses. Such high-resolution images may not be needed for all clinical applications of CBCT and there is an obvious risk of unnecessary radiation exposure.

The final statements (16–20, inclusive) deal with training and competence issues. In some countries of the European Union, CBCT equipment can be purchased, installed and used by a dentist with no requirement for additional training. These “basic principles” are aimed primarily at addressing this deficiency. There remains, however, the question of

what constitutes “adequate theoretical and practical training”. While the latter is likely to be determined nationally rather than at a European level, EADMFR is currently preparing a curriculum for such training, while the SEDENTEXCT project has an aim at developing a training and information website.<sup>5</sup> As an interim measure, the Guideline Development Panel has endorsed a draft core curriculum which provides a basic structure and content for “adequate theoretical and practical training” (Table 4). This curriculum should be viewed as an Appendix to the “basic principles”. The Guideline Development Panel recognizes the large national variation in Europe in the clinical services provided by dentists in primary care. Thus, the detailed content of “adequate training” for radiological interpretation should reflect this so that competence is assured.

It was notable that the part of the survey that provoked the greatest number of comments from responders was statement number 19. Several responders opined that only a specialist dental and maxillofacial radiologist should interpret CBCT images, regardless of the field of view. While this may be the ideal situation, the wording of the basic principles needed to recognize the current situation, where dentists without training are using CBCT and where several EU countries have no recognized specialism in dental and maxillofacial radiology (a comment made by

**Table 4** Appendix to the European Academy of Dental and Maxillofacial Radiology basic principles on the use of cone beam CT (CBCT), outlining “adequate theoretical and practical training” for dentists using CBCT

<i>Role</i>	<i>Training content</i>
<i>Dentist referring a patient for CBCT and receiving images for clinical use</i>	<p><b>Theoretical instruction</b></p> <ul style="list-style-type: none"> <li>• Radiation physics in relation to CBCT equipment</li> <li>• Radiation doses and risks with CBCT</li> <li>• Radiation protection in relation to CBCT equipment, including justification (referral/ selection criteria) and relevant aspects of optimization of exposures</li> <li>• CBCT equipment and apparatus</li> </ul> <p><b>Radiological interpretation</b></p> <ul style="list-style-type: none"> <li>• Principles and practice of interpretation of dentoalveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (<i>e.g.</i> 8 cm × 8 cm or smaller fields of view)</li> <li>• Normal radiological anatomy on CBCT images</li> <li>• Radiological interpretation of disease affecting the teeth and jaws on CBCT images</li> <li>• Artefacts on CBCT images</li> </ul>
<i>Dentist responsible for performing CBCT examinations</i>	<p><b>Theoretical instruction</b></p> <ul style="list-style-type: none"> <li>• Radiation physics in relation to CBCT equipment</li> <li>• Radiation doses and risks with CBCT</li> <li>• Radiation protection in relation to CBCT equipment, including justification (referral/ selection criteria), optimisation of exposures and staff protection</li> <li>• CBCT equipment and apparatus</li> <li>• CBCT image acquisition and processing</li> </ul> <p><b>Practical instruction</b></p> <ul style="list-style-type: none"> <li>• Principles of CBCT imaging</li> <li>• CBCT equipment</li> <li>• CBCT imaging techniques</li> <li>• Quality assurance for CBCT</li> <li>• Care of patients undergoing CBCT</li> </ul> <p><b>Radiological interpretation</b></p> <ul style="list-style-type: none"> <li>• Principles and practice of interpretation of dentoalveolar CBCT images of the teeth, their supporting structures, the mandible and the maxilla up to the floor of the nose (<i>e.g.</i> 8 cm × 8 cm or smaller fields of view)</li> <li>• Normal radiological anatomy on CBCT images</li> <li>• Radiological interpretation of disease affecting the teeth and jaws on CBCT images</li> <li>• Artefacts on CBCT images</li> </ul>

several responders). The final “basic principles” (Statements 19 and 20) maintain the view that, with adequate training, it is reasonable to expect dentists to perform clinical evaluation of images in the familiar area of teeth and their supporting structures, while advocating a specialist evaluation for other anatomical areas.

In conclusion, the potential impact of these basic principles remains to be seen, but it is hoped that the positions of the EADMFR membership, as key stakeholders in CBCT use and development, will improve their dissemination and impact. The basic principles may be of particular value to colleagues in countries with less well-developed systems for national standard setting. Over and above this, the development of the basic principles sees the EADMFR fulfilling one aspect of its mission: “to promote, advance and

improve clinical practice... related to the specialty of dental and maxillofacial radiology”.

#### Acknowledgments

The research leading to these results has received funding from the European Atomic Energy Community’s Seventh Framework programme FP7/2007-2011 under grant agreement number 212246.

Enormous thanks are due to the following EADMFR members who gave up their time to translate the draft statements for the online survey: Norbert Bellaiche, Robert Cavézian, Silvio Diego Bianchi, Csaba Dob-Nagy, François Gabioud, Georges Georgakopoulos, Kaan Orhan, Dirk Schulze, Harry Stamatakis and Krystyna Thun-Szretter. We also thank all those members of EADMFR who responded to the online survey or who contributed in other ways.

#### References

1. Carter L, Farman AG, Geist J, Scarfe WC, Angelopoulos C, Nair MK, et al. American Academy of Oral and Maxillofacial Radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008; **106**: 561–562.
2. The Council of the European Union. Council Directive 96/29/Euratom of 13 May 1996: laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation. *Official Journal of the European Communities* No. L 159:[29 pp]. Available from: [http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/9629\\_en.pdf](http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/9629_en.pdf)
3. The Council of the European Union. Council Directive 97/43/Euratom of 30 June 1997: on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure, and repealing Directive 84/466/Euratom. 1997. Available from: [http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/9743\\_en.pdf](http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/9743_en.pdf)
4. European Commission. *Radiation protection 136. European guidelines on radiation protection in dental radiology*. Luxembourg: Office for Official Publications of the European Communities, 2004. Available from: [http://ec.europa.eu/energy/nuclear/radioprotection/publication/doc/136\\_en.pdf](http://ec.europa.eu/energy/nuclear/radioprotection/publication/doc/136_en.pdf)
5. Sedentext.eu [homepage on the Internet]. University of Manchester; 2008 [cited 13 Jan 2009]. Available from: <http://www.sedentext.eu/>
6. Hasson F, Keeney S, McKenna H. Research guidelines for the Delphi survey. *J Adv Nurs* 2000; **32**: 1008–1015.
7. Custer RL, Scarcella JA, Stewart BR. The modified Delphi technique – a rotational modification. *J Vocat Tech Educ* 1999; **15**: 50–58.
8. Sumsion T. The Delphi technique: an adaptive research tool. *Br J Occup Ther* 1998; **61**: 153–156.
9. McKenna HP. The Delphi technique: a worthwhile approach for nursing? *J Adv Nurs* 1994; **19**: 1221–1225.
10. Schmidt RC. Managing Delphi surveys using nonparametric statistical techniques. *Decis Sci J* 1997; **28**: 763–774.