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E.A.O. Guidelines for the use of Diagnostic Imaging in Implant Dentistry

A consensus workshop organized by the European Association for Osseointegration in Trinity College Dublin.

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Introduction

Diagnostic imaging is an essential component of implant treatment planning. Until the late 1980s, conventional radiographic techniques such as intraoral, cephalometric and panoramic views have been the accepted standard.

Since then, developments in cross-sectional imaging techniques, such as spiral tomography and reformatted computerised tomograms, have become increasingly popular in the preoperative assessment and planning of implant patients. Additionally, proprietary software has become available that will allow clinicians to manipulate digital images on a PC.

The Board of the E.A.O. is concerned that the rapid adoption of these sophisticated techniques into routine practice might lead to a significant increase in the radiation burden of patients without a proper risk benefit analysis. The directive of the council of the European Communities (97/43 EURATOM, Official Journal of the European Communities. L 180, 9.7. 1997, pp 22–27) makes extensive recommendations about the responsible use of ionizing radiation in medicine. Article 3 of these directives under Justification 1. states that:

''Medical exposure ... shall show a sufficient net benefit, weighing the total potential diagnostic or therapeutic benefits it produces ... Against the individual detriment that the exposure might cause, taking into account the efficacy, benefits and risks of available alternative techniques having the same objective but involving no or less exposure to ionizing radiation.

The Board felt it would be timely to formulate guidelines that would help its members ensure a responsible and ethical application of these sophisticated techniques to implant dentistry.

A 2-day closed workshop was organised under the auspices of the E.A.O. at Trinity College Dublin, May 12th and 13th 2000.

Expert participants in the clinical and radiology fields were invited on the bases of their established scientific contributions to the field, specialist knowledge, significant clinical experience and relevant activities in their academic institutions and abilities to express themselves in English. Participants were required to reach a consensus on relevant questions and guidelines.

The aim of these guidelines is to provide recommendations in various clinical situations that will ensure essential diagnostic information is obtained with as low as reasonably achievable (ALARA principle) radiation exposure. They also draw attention to the special responsibilities and knowledge that is a prerequisite for the application of these techniques

Dr David Harris
Chairman

A. Clinical Considerations

1. What radiological information does a surgeon require when planning for implant surgery and at what stage should it be obtained?

In investigating an implant site, a surgeon requires information on bone volume and

quality, topography and the relationship to important anatomical structures, such as nerves, vessels, roots, nasal floor, and sinus cavities.

This information is obtained with a clinical examination and appropriate conventional radiographs. The decision to proceed to cross-sectional imaging must be based on clearly identified needs and the clinical requirements of the clinicians involved.

Implant failure may be related to poor bone quality at the implant site. Information about bone quality can be obtained preoperatively based on radiographic images and partly during the surgical performance (Bahat *et al*. 1993; Bassi *et al*. 1999; Ulm *et al*. 1999).

2. What type of clinical situations might potentially benefit from cross-sectional imaging?

1. When reference to such images can help minimize the risk of damage to important anatomical structures.
2. To provide more information in borderline clinical situations where there is limited bone height and/or bone width available for successful implant treatment.
3. To improve implant positioning and axial direction that will optimize biomechanical, functional and aesthetic treatment results. The diagnostic information can be enhanced by the use of appropriate radiopaque markers or restorative templates. However, this information cannot be transferred exactly to the surgical site as long as no intraoperative navigation is used (Naitoh *et al*. 2000).

3. Who should decide whether a patient requires cross-sectional imaging?

Clinicians should decide on the basis of the clinical examination and treatment requirements, and on information obtained from conventional radiographs whether or not cross-sectional imaging will be of benefit.

If the patient is to be referred then a radiologist with specialised knowledge in the field should decide on the appropriate cross-sectional imaging techniques based on the information provided by the clinician.

Circumstances may dictate that it is the clinician who must decide. Clinicians must clearly indicate the reasons for requesting the investigations and provide the radiologist with sufficient information to allow the production of accurate and relevant images of good quality. It is the duty of the clinician to understand the fundamental principles of cross-sectional imaging and to be capable of interpreting the images.

The technique chosen should provide the required diagnostic information with the least radiation exposure to the patient.

B. Radiological Considerations

1. What imaging modalities are available for investigation of potential implant sites?

Standard radiographic imaging techniques are intraoral, panoramic and profile (lateral) radiographs. In certain special indications, cross-sectional imaging [i.e. spiral tomography and multiplanar reformatted computed tomography (CT)] may be necessary.

2. What is the recommended technique performing these imaging modalities, and what is the resulting radiation dose?

Table 1 delineates the recommended technique for each imaging modality together with the resulting maximum radiation dose acceptable. It is essential that the ALARA (as low as reasonably achievable) principle is adhered at all times. This may result in significantly lower doses in certain circumstances.

Digital radiography might reduce the dose even further.

3. What is the biological risk from the dose incurred in each of the techniques?

The use of radiation involves a certain amount of risk. To assess the significance of this risk it is important to set it in context with other commonly encountered risk factors (NRPB 1998). A few examples are:

A: Annual risk of death in the UK

Smoking 10 cigarettes per day	1:200
Heart disease	1:300
Accident in the home	1:15,000
Accident on the road	1:17,000

B: Radiation exposure in context

The annual dose averaged over the whole European population, is about 3 mSv per person. However, 85% of this is due to natural background radiation, and only 14% from medical and dental radiation.

The International Commission on Radiological Protection (ICRP) has estimated the risk per mSv as 1 in 20000.

For younger age groups the risk is estimated to be twice as high.

Based on the above estimated values, the risk for the various imaging modalities is as follows:

Intraoral radiography	
Frontal	1:10,000,000
Premolar	1:5,000,000
Molar	1:3,000,000
Full mouth survey	1:476000
Panoramic imaging	1:667000
Cephalometric lateral skull	
With wedge form collimation	< 1:2,000,000
Computed tomography	< 1:40,000/jaw
Spiral tomography	
Maxilla	< 1:2,000,000/cut
Mandible	< 1:4,000,000/cut

4. What is the recommended imaging modality for different clinical situations

Table 2a provides an overview of the recommended standard imaging modalities to be used.

Table 2b shows the options of additional cross-sectional imaging. This applies to those cases where more information is required after appropriate clinical examination and standard radiographic techniques have been performed

The choice of techniques is based on the lowest dose giving the required diagnostic information. For example, the assessment of a single tooth gap requires approximately 25 times less radiation using one spiral cross-sectionals tomogram as compared to a CT examination.

If the suggested cross-sectional imaging modality is not available, the alternate cross-sectional modality may be used, but this may result in a higher dose and/or lower diagnostic quality.

5. What are the mechanisms of ensuring ongoing quality assurance?

Proper training of staff performing these procedures is required. In addition, they must also receive continuing education at regular intervals to maintain the quality of the images produced.

Adherence to recommended equipment-

Table 1. **Recommended techniques and associated effective doses (E)**

Modality	Recommended Technique	E (mSv)
Intraoral radiography	F-speed film	Frontal 0.002/radiograph
	Rectangular collimation	Premolar
	Paralleling technique	0.004/radiograph
	Upper jaw: palate horizontally	Molar 0.006/radiograph
	Lower jaw: occlusal plane horizontally	Full mouth survey (20 films): .04/survey
Panoramic	Proper collimation	< 0.003
imaging	Rare earth screen	
	Proper patient positioning:	
	Meato-orbital plane horizontal	
	Head symmetrical	
	Lower jaw protruding	
	Lower and upper incisors inside the image layer	
	Neck extended	
	Dorsum of tongue in contact with hard palate during exposure	
Cephalometric	Proper collimation	< 0.01
lateral skull	Rare earth screen	
	Median plane of head vertical	
Computed	KV: 120	< 0.5/jaw
tomography	mAs: < 100	
	Slice thickness: 1 mm	
	Pitch: 1–1.5	
	Suggested window: 1250; level: 250	
	Maxilla: slices parallel with hard palate from alveolar crest up to/including hard palate.	
	Mandible: slices parallel with mandibular base in region of interest.	
	Dose reduction possible by reducing number of slices, increasing pitch and/or lowering mAs.	
Conventional	Rare earth screen	*Maxilla < 0.03/cut
tomography**	As few cuts as possible.	
	Proper positioning:	*Mandible < 0.02/cut
	The tomographic plane perpendicular to the hard palate (maxilla) and the mandibular canal (mandible) and at the same time perpendicular to the tangent of the alveolar process in the region of interest.	

*14 cuts per jaw = E (mSv) 0.52/jaw

**Table 1. Information derived from the following sources: British Orthodontics Standards Working Party 1994, Dula et al. 1996, 2001; Ekestubbe et al. 1999; Price 1995; Syriopoulos et al. 2001, Velders et al. 2000, White 1992

Table 2a. **Recommended standard radiographic techniques**

	Intra-oral radiography	Panoramic imaging	**Cephalo-metric lateral skull
MAXILLA			
Single tooth	X		
Partially dentate	X	X	
Edentulous	X	X	
MANDIBLE			
Single tooth	X		
Partially dentate	X	X	
Edentulous	Axial, occlusal view*	X	X

*For Brånemark Novum cases only.

**Cephalo-metric Wedge form collimation

The Brånemark Novum Protocol for Same-Day Teeth; a global perspective.
Edited by Per-Ingvar Brånemark for Quintessence books in 2001.

maintenance policies and regular quality assurance procedures is also required to ensure the equipment produces the best possible images.

An effective method of identifying weak-points in image production is film-reject analysis.

Finally, an equipment replacement policy should be in place to ensure that equipment is up to standard.

C. Diagnostic benefits

What are the potential diagnostic benefits of cross-sectional imaging?

(a) Pre-operative assessment to identify bone volume, jaw topography, bone structures, location of important anatomical landmarks, etc.

(b) Treatment planning to identify optimal locations of implant sites in relation to available anatomical conditions for best aesthetics, function and loading conditions. The techniques can also be helpful as part of the pre-operative planning for various augmentation protocols.

(c) Post-operative monitoring cross-sectional imaging is not a part of the routine protocol of post-operative examinations, unless there is a need for assessments in situations where some kind

Table 2b. **Recommended cross-sectional imaging modalities; special indications**

	Spiral tomography	Computed tomography
MAXILLA		
Single tooth		
a. incisive canal	1–2 2-mm cuts	
b. descent of maxillary sinus	1 2-mm cut	
c. clinical doubt about shape of alveolar ridge	1 2-mm cut	
Partially dentate		
a. descent of maxillary sinus	Small areas	
	(≤ 4 4-mm cuts per quadrant)	Multiple regions
b. clinical doubt about shape of alveolar ridge		
Edentulous		
a. descent of maxillary sinus	Specific sites targeted	
	(≤ 4 4-mm cuts per quadrant)	Multiple regions
b. clinical doubt about shape of alveolar ridge		
MANDIBLE		
Single tooth		
a. clinical doubt about position of mandibular canal	1 2-mm cut	
b. clinical doubt about shape of alveolar ridge		
Partially dentate		
a. clinical doubt about position of mandibular canal or mental foramen	1–4 4-mm cuts per quadrant	Multiple regions
b. clinical doubt about shape of alveolar ridge		
Edentulous		
a. severe resorption	1–2 4-mm cuts per sextant	Multiple regions
b. clinical doubt about shape of alveolar ridge		
c. clinical doubt about position of mandibular canal if posterior implants are to be placed		

of complications have occurred, such as nerve damage, postoperative infections in relation to nasal and/or sinus cavities close to implants.

D. Recommendations for the use of cross-sectional imaging in implant dentistry

Single Tooth Implant Sites

If the clinical examination indicates there is sufficient bone width and recommended standard radiographic examination reveals adequate bone height and space, no additional imaging is required.

Additional cross-sectional imaging may be required when an implant site lies in close relationship to nerve canals as occurs in the posterior mandible and the maxillary central incisors. It also may be of benefit in investigating defect sites to allow for more precise treatment planning.

Edentulous Maxilla

In many cases, clinical examination in conjunction with recommended standard radiographs will provide sufficient information on the available bone volume.

Additional cross-sectional imaging may be required to determine the adequacy of the available bone volume and the need for bone augmentation/grafting procedures.

Cross-sectional images can also help in the planning and predictability of prosthetic results that involve a fixed prosthesis and in the transfer of this information to guide the surgeon in implant positioning.

Special techniques such as zygomatic implants may also dictate the need for additional imaging.

Partially Edentulous Maxilla

Clinical examination in conjunction with recommended standard radiographs will form the basis for treatment planning and indicate if further cross-sectional imaging is required.

Assessment of bone volume and topography, the position of adjacent anatomical structures and the need for restorative planning particularly in the aesthetic zone may indicate a need for additional imaging.

Edentulous Mandible

In almost all cases, clinical examination in conjunction with recommended standard radiographs will provide sufficient information for treatment planning. In certain circumstances, involving extreme atrophy or unusual anatomy, additional imaging may be beneficial.

Partially Edentulous Mandible

Clinical examination in conjunction with recommended standard radiographs will form the basis for treatment planning and indicate if further cross-sectional imaging is required.

When implants are to be placed in proximity to the inferior alveolar nerve, cross-sectional images can provide useful additional information on the available bone volume and shape in relation to the position of the nerve canal.

Future developments

There is an urgent need enhance and improve the knowledge and skills of dentomaxillofacial radiology in undergraduate, postgraduate and continuing education programmes. Radiation protection aspects should be emphasized.

It is also of great importance that clinicians are aware of the need for communication between them and the radiologist before any radiographic examination is per-

formed and that the clinician clearly state which diagnostic information is required.

Communication among clinicians and experts for second opinion and/or interaction during planning of oral implants could also benefit from data transfer through any type of network.

Clinicians in the oral field should ideally always choose the optimal imaging technique rather than the one available in their own practice/centre.

Considering the presumed relationship between implant failure and poor bone quality, there is a clear need for developing objective assessment techniques of bone density and texture

The development within the field of radiology is moving rapidly and many new techniques are introduced. Consequently, there is a need for a continuous updating of knowledge. The potential of MRI, which does not use ionizing radiation is worth further investigation.

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