

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/225272182>

Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental...

Article · June 2012

DOI: 10.1016/j.o000.2012.03.005 · Source: PubMed

CITATIONS

241

READS

329

6 authors, including:



Jeffrey Price

University of Maryland, Baltimore

3 PUBLICATIONS 279 CITATIONS

SEE PROFILE



Sotirios Tetradis

University of California, Los Angeles

133 PUBLICATIONS 2,516 CITATIONS

SEE PROFILE



Scott D. Ganz

Rutgers New Jersey Medical School

131 PUBLICATIONS 909 CITATIONS

SEE PROFILE



Charles F. Hildebolt

Washington University in St. Louis

228 PUBLICATIONS 6,412 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Clinical Applications of Digital Dental Technology [View project](#)

All content following this page was uploaded by [Scott D. Ganz](#) on 15 June 2017.

The user has requested enhancement of the downloaded file. All in-text references [underlined in blue](#) are added to the original document and are linked to publications on ResearchGate, letting you access and read them immediately.

Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography

Donald A. Tyndall, DDS, MSPH, PhD,^a Jeffery B. Price, DDS, MS,^b Sotirios Tetradis, DDS, PhD,^c Scott D. Ganz, DMD,^d Charles Hildebolt, DDS, PhD,^e and William C. Scarfe, BDS, MS^f

A Position Paper Subcommittee of the American Academy of Oral and Maxillofacial Radiology (AAOMR) reviewed the literature since the original position statement on selection criteria for radiology in dental implantology, published in 2000. All current planar modalities, including intraoral, panoramic, and cephalometric, as well as cone beam computed tomography (CBCT) are discussed, along with radiation dosimetry and anatomy considerations. We provide research-based, consensus-derived clinical guidance for practitioners on the appropriate use of specific imaging modalities in dental implant treatment planning. Specifically, the AAOMR recommends that cross-sectional imaging be used for the assessment of all dental implant sites and that CBCT is the imaging method of choice for gaining this information. This document will be periodically revised to reflect new evidence. (*Oral Surg Oral Med Oral Pathol Oral Radiol* 2012;113: 817-826)

In 2000, the American Academy of Oral and Maxillofacial Radiology (AAOMR) published a position paper on the role of imaging in dental-implant treatment planning.¹ They state, "After reviewing the current literature, the AAOMR recommends that some form of cross-sectional imaging be used for implant cases and that conventional cross-sectional tomography be the method of choice for gaining this information for most patients receiving implants." Since then, the introduction and increased use of maxillofacial cone beam computed tomography (CBCT) has had an impact on the availability of digital, cross-sectional imaging and expanded imaging clinical applications for dental-implant imaging.²⁻¹⁸

In 2008, the Executive Council (EC) of the AAOMR published an executive opinion statement on the performance and interpretation of CBCT in dentistry.¹⁹ The EC proposed guidelines and principles for CBCT

use in contemporary dental practice; these included practitioner responsibilities, the requirement for documentation, and the need for radiation-dose and quality-assurance optimization. If CBCT is used (as with any radiographic imaging technology), the benefits to the patient must outweigh the risks associated with exposure to ionizing radiation.

The purpose of developing imaging selection criteria for implant therapy is to identify the most appropriate imaging technology for each stage of patient care.¹ The development of selection criteria is based on review of treatment-decision and outcome-assessment studies. Although more than 10 years have passed since publication of the AAOMR position paper on dental implants,¹ studies of the clinical efficacy of cross-sectional imaging for implant planning decisions have been equivocal.²⁰⁻²⁵

The purpose of this document is to summarize current knowledge about maxillofacial imaging (with emphasis on CBCT) for dental, endosseous-implant therapy and to provide up-to-date radiographic selection criteria for dental implantology. The recommendations presented are not prescriptive but rather advisory and are intended to provide the dental profession with current considered opinions on the appropriate imaging for implant dentistry. The underlining goal is to maximize diagnostic efficiency while minimizing patient radiation risk.

CLINICAL CONSIDERATIONS IN SELECTION CRITERIA FOR DENTAL IMPLANTOLOGY

The diagnostic phase of dental-implant therapy and, in particular, the appropriate choice of radiographic ex-

^aDiplomate, American Board of Oral and Maxillofacial Radiology, University of North Carolina at Chapel Hill School of Dentistry, Chapel Hill, NC.

^bDiplomate, American Board of Oral and Maxillofacial Radiology, Meharry Medical College School of Dentistry, Nashville, TN.

^cDiplomate, American Board of Oral and Maxillofacial Radiology, University of California in Los Angeles School of Dentistry, Los Angeles, CA.

^dPrivate practice limited to Prosthodontics, Maxillofacial Prosthetics, and Implant Dentistry, Fort Lee, NJ.

^eMallinckrodt Institute of Radiology, Washington University in St. Louis School of Medicine, St Louis, MO.

^fDiplomate, American Board of Oral and Maxillofacial Radiology, University of Louisville School of Dentistry, Louisville, KY.

© 2012 Elsevier Inc. All rights reserved.

2212-4403/\$ - see front matter

<http://dx.doi.org/10.1016/j.o000.2012.03.005>

amination is important to the long-term success of a dental implant. Over the past decade, there has been a dramatic conceptual shift from a surgically driven to a prosthetically driven approach to dental-implant therapy.^{5,14,17,26,27} It is no longer acceptable practice to place implants in alveolar bone without a previously developed plan for prosthetic restoration. To optimize implant placement and to avoid surgical complications, the clinician must have full knowledge of oral-bone anatomy so that any osseous-topography, bone-volume excesses/deficiencies can be corrected before implant placement.²⁸⁻³¹

Several organizations, including the Faculty of General Dental Practice (UK),³² Academy of General Dentistry,³³ and Academy of Osseointegration,²⁶ dichotomize dental-implant placement difficulty as either straightforward or complex based on specific, patient-presenting characteristics. A straightforward case is one for which the “desired tooth position is clear,” the surgical procedure “involves minimal anatomical risks,” and there is no need for “significant hard or soft tissue grafting or modification of anatomical structures.” A complex case is one for which the tooth position is “not easily identifiable” with a possible need for “extensive hard and soft tissue grafting” of the residual alveolar ridge. The International Team for Implantology (ITI) recommends the SAC classification, which has 3 levels of difficulty: straightforward (S), advanced (A), and complex (C).^{27,34} This system provides general and site-specific criteria of surgical and prosthetic degrees of difficulty to define case types. Presurgical assessment guidelines underscore the need for accurate assessment of bone volume and location of adjacent anatomical structures in relation to prosthetically derived, dental-implant positioning.

Anatomic considerations

Each location in the dental alveolus has unique morphologic characteristics owing to edentulousness and specific regional anatomic features that need to be identified and assessed in the diagnostic and treatment-planning phase of dental-implant therapy.

The maxillary anterior region (commonly referred to as the esthetic zone) often presents both surgical and prosthetic implant-assessment complexities.^{27,34} Subsequent to tooth loss, decrease in the height and/or width of the alveolar process and the development of a labial concavity often necessitate bone augmentation.^{5,16} The morphology and dimension of the nasopalatine (incisive canal)^{3,6-38} and the location of the floor of the nasal fossae may also compromise the available bone volume.

The available residual alveolar ridge in the posterior, maxillary molar region is limited superiorly by the floor

of the maxillary sinus. Assessment of the extent of this structure, including the locations of septae, is important in determining the bone volume available for implant placement and the possible need for bone-supplementation procedures, such as sinus lift and bone augmentation.³⁹ Of the various regions of the maxilla and mandible, the maxillary posterior region has the lowest bone density and the highest implant failure rate.^{40,41} Assessment of the anterior recess of the maxillary sinus is also important if markedly angled implants are considered for implant-supported edentulous prostheses.

Although the anterior mandible is a relatively safe location for implant placement, to avoid intraoperative and postoperative hemorrhage, neurosensory loss, and to increase the likelihood of osseointegration, the locations of osseous and intraosseous neurovascular structures must be identified before osteotomy and subsequent implant placement.¹⁶ Osseous structures include the lingual cortical plates,^{42,43} and neurovascular structures include the lingual foramen,⁴⁴ the terminal branch of the inferior alveolar canal, the mandibular incisive canal, the anterior loop,⁴⁵ and the mental foramen of the inferior alveolar canal.^{46,47}

In the posterior mandible, there are several anatomic structures that can compromise prosthetically driven, dental-implant placement. The lingual concavity (submandibular gland fossa, submandibular fossa) below the mylohyoid ridge and the inferior alveolar (mandibular) canal have variations that can restrict implant placement. The deficiencies of 2-dimensional imaging techniques for accurate location of the inferior alveolar canal are well documented.⁴⁸⁻⁵¹

Imaging strategies

A number of radiographic examinations are used for preoperative, dental-implant-site assessment. Clinicians commonly use 2 or more examinations. Each examination has specific indications, advantages, and disadvantages. A perfect imaging examination for dental-implant treatment planning does not exist.

Plain film radiography. This term refers to projection images obtained with a stationary x-ray source and area detector. Plain-film images represent the entire volume through which the x-ray beam is transmitted and is subject to differential magnification, geometrical distortion, and anatomic superimposition.

Intraoral radiography

Periapical intraoral radiography provides images of limited dentoalveolar regions. These images have excellent spatial and contrast resolution with minimal distortions. Images taken using film-holding devices allow regional visualizations of vertical and anteroposterior bounds of residual alveolar ridges and identifica-

tions of adjacent anatomical structures. The technique is the most widely available, inexpensive, and most common initial dental radiographic examination for implant-site assessment. The technique, however, is highly operator dependent and requires a moderate level of patient compliance to provide images with minimal geometrical distortions. Because reproducible imaging geometry is difficult to obtain in areas of extended edentulousness, images of these areas have relatively low reliabilities and accuracies. Vertical accuracy can be improved by using a radiographic marker of known dimension to calibrate image measurements.⁵² The greatest limitation of this strategy is the lack of cross-sectional information to access bone volume.

Because occlusal radiography provides information on the general shape of the residual dental arch and maximum bucco-lingual dimension of the alveolar ridge, occlusal radiography has been proposed as a supplement to periapical radiography for implant assessments. Occlusal radiography, however, provides no information in addition to that provided by dental study models, and its use is, therefore, not justified for implant-site assessments.

Cephalometric radiography

The entire maxillofacial area is contained within a lateral cephalometric radiograph, which includes 2-dimensional representations of the anteroposterior and vertical relationships of the maxillary and mandibular dental arches. Because of fixed, image-projection geometry, midline structures have constant magnifications, and this allows assessments of interarch, dentoalveolar positions and angulations. Edentulous spaces in the midline are represented as cross-sectional images that can be calibrated to provide accurate measurement of bucco-lingual as well as vertical bone dimensions of the anterior residual alveolar ridge. Equipment for lateral cephalometric radiography is readily available, and cephalometric images are relatively easy to obtain and of low cost. The use of these images is limited, however, in that they provide uniformly magnified images of midline structures only.⁵³ Although oblique, lateral cephalograms are used to image anterolateral segments,⁵⁴ the alveolar process is often obscured by the superimposition of teeth adjacent to the edentulous alveolus.

Rotational panoramic radiography. This is the most commonly used extraoral imaging modality in implant dentistry. With rotational panoramic radiography, the jaws are placed within a focal trough (a volumetric curved columnar space), and a narrow x-ray beam moves in synchrony and in opposite directions with an x-ray recep-

tor. The result is a projection image of the jaws. Panoramic radiographs provide information on the inferior alveolar canals and maxillary sinuses and may show pathologic conditions not demonstrated on complete, intraoral radiographic examinations. Panoramic radiography is commonly available, is relatively low cost, provides information on both dental arches, and is useful in the initial diagnostic phase of implant planning. By calculating the ratio between image dimensions and known dimensions of radiopaque markers on a radiographic stent, estimates of the available vertical distances between the alveolar crest and anatomic structures can be estimated at specific positions in a panoramic image. Many factors, however, limit the accuracy and reliability of this calculation. These include (1) patient-positioning errors, (2) inherent distortions related to equipment differences, (3) discrepancies between the shape of the dental arch and focal trough, and (4) beam angulation.⁵⁵ Only 17% of measurements from the crest of the residual alveolar ridge to the inferior alveolar canal have errors of ± 1 mm.⁵⁰ A major limitation of panoramic radiography is that bucco-lingual assessments cannot be made. Because of its inherent limitations, panoramic radiography is considered unsuitable as a single imaging source for dental-implant site assessment.^{7,11-13,51,56-58}

Cross-sectional imaging techniques. Cross-sectional imaging techniques produce in-focus, thin-section images. Cross-sectional images can be produced with conventional tomography, panoramic-based scanography and tomography, CBCT, and computed tomography (CT). (In this position paper, the term "computed tomography" and the abbreviation "CT" represent scanners that use multirow, detector arrays. CT scanners are most commonly used in medical radiology departments and hospitals.) Tomographic images can also be obtained with magnetic resonance (MR) imaging. Tomographic techniques produce multiple, contiguous image sections (slices) with minimal distortions, and uniform thicknesses and magnifications. In addition, images can be reconstructed such that they are perpendicular to each other. The main advantage of these images for implant dentistry is that they minimize or eliminate anatomic superimposition. Image sections perpendicular to the long axis of the region (object) of interest (e.g., the mandibular arch) are referred to as cross-sectional trans-axial images. Cross-sectional images provide optimal accuracy for visualizing the bony architecture of the jaws.^{28,59-62}

Conventional tomography

Unimodal machines capable of conventional tomography for the assessment of implant sites gained increasing popularity throughout the 1980s and 1990s.⁶³ In conventional tomography, the x-ray

source and the receptor move in synchrony and in opposite directions to each other about a fixed fulcrum, and this results in the blurring of structures outside the image plane, which is at the level of the fulcrum. For implant dentistry, this provides uniformly magnified images in 2 dimensions usually sagittal and coronal (cross-sectional). A limitation of this technique is that it produces images of limited regions (a few teeth) of a single dental arch. Only objects within the specific region of interest are in focus. Usually stents with radiopaque markers are needed to confirm positions of imaged sites. Because of blurring outside the region in focus, it is often difficult to identify structures and interpret the images.⁶⁴⁻⁶⁶ Increasing complex, synchronized, poly-directional movement patterns (e.g., circular, elliptic, hypocycloidal and tri-spiral) increase image clarity but also increase patient dose. These limitations reduce the usefulness of this technique for implant dentistry, particularly for the assessment of multiple jaw regions.

Panoramic-based tomography

Some panoramic units use x-ray beam motions and area receptors to produce planar or curved (scanogram) tomographic images. Units vary markedly in the anatomic localization methods used, the number and thickness of tomographic slices, and the resultant image magnifications. Images are often extremely wide compared with the area under study, may not cover the region of interest sufficiently, and suffer from blur, making interpretation of images difficult.⁶⁷ Although this technique can be helpful in preliminary evaluations of specific implant sites, the technique is time-consuming and multiple inter- or intra-arch implant site assessments require multiple exposures.

Computed tomography

Data acquisition in CT has evolved over the past 4 decades with 4 generations of CT scanners. The most advanced systems use fan-beam radiation and multiple detector arrays. Usually, one source of fan-beam radiation is used. The user makes selections to define the spatial resolution, field of view (FOV), and image sharpness. As the object being scanned is translated through the CT scanner, the object attenuates the x-ray beam, and the attenuated x-ray beam data are collected by detector arrays. From the volume of data that is collected, mathematical formulas are used to reconstruct volumetric and/or multiplanar images. The multiplanar reconstructions can have various image thicknesses (several mm to tenths of mm) and be in any image plane (sagittal, coronal, axial, or any plane in between). Images are undistorted, calibrated for dimen-

sional accuracy, and have high soft tissue and hard tissue contrast resolution.⁶⁸ With the use of phantoms and appropriate calibrations, small changes in radiodensities can be detected.⁶⁹ Dual-source, dual-energy CT has been developed for use in angiography and for making more accurate measurements of hard and soft tissues. New techniques are being introduced for exposure reductions with the use of CT. CT is relatively expensive and usually available in hospitals and medical imaging centers only.

Cone beam computed tomography

CBCT differs from CT in that it uses a single x-ray source that produces a cone beam of radiation (rather than a fan beam, as with CT). There is no accepted definition of when a fan beam (which is assumed to be planar) becomes a cone beam.⁷⁰ CBCT uses a single, relatively inexpensive, flat-panel or image intensifier radiation detector. CBCT imaging is performed using a rotating platform to which the x-ray source and detector are fixed. The x-ray source and detector rotate around the object being scanned and multiple, sequential, planar projection images are acquired in an arc of 180° or greater and are mathematically reconstructed into a volumetric dataset.⁷¹ Only one rotational sequence is necessary to acquire enough data for volumetric image construction because the entire FOV is irradiated simultaneously. The first CBCT unit with specific maxillofacial application (the NewTom DVT 9000; QR srl, Verona, Italy) became commercially available in Europe in 1999. The adoption of this technology in dentistry has expanded exponentially since then owing to numerous technical improvements and commercial market forces. Many CBCT devices are now multi-modal, providing panoramic and cephalometric imaging. Most have a low footprint suitable for dental office placement, are technically as easy to operate as panoramic units, allow collimation of the beam to the region of interest to reduce patient radiation exposures, and produce submillimeter resolution images of high quality. Although CBCT images have high spatial resolution, the data from which images are created contains considerable noise caused by scattered radiation. Because formulas do not exist to correct for this scattered radiation, soft tissue contrast in CBCT images is inferior to that in CT images and CBCT images are not appropriate for detecting small changes in radiodensities.

Both CT and CBCT volumetric datasets can be exported in DICOM (Digital Imaging and Communications in Medicine) format and imported into third-party software that is specifically designed for implant planning. With such software, various 3-dimensional and cross-sectional images can be created. It is also possible to

create virtual image-displays; simulated, implant placements^{7,15,72}; and to use the software for computer-guided surgery.^{6,8-10,60-62,73} Both CT and CBCT are used to perform multidimensional, presurgical assessments of anatomy, thereby reducing the possibilities of incorrect implant placements, which can result in untoward sequelae, such as perforations of cortical borders and invasions of adjacent structures.^{11,12,28-31,37,38,44,74-76} In comparison with conventional dental imaging, volumetric, data sets provide additional information that can be used for more sophisticated analyses and expanded, treatment-planning options that result in higher likelihoods for achieving satisfactory prosthetic results. For use in implant dentistry, a major advantage of CBCT compared with CT is that CBCT equipment is usually far less expensive than CT equipment. Another advantage is that CBCT software for use in planning implants is usually much easier to use and far more useful than is software available with CT. The primary disadvantages of both CT and CBCT are their relative higher effective radiation exposures⁷⁷ and additional costs compared with plain, panoramic and some other cross-sectional radiographic methods.

Magnetic resonance imaging

With MR imaging (which does not use ionizing radiation), cross-sectional images (suitable for dental-implant treatment planning) can be created⁷⁸⁻⁸⁰ The limitations of these images for dental-implant imaging are the increased imaging scan times, dentists' unfamiliarity with MR images, and higher costs. For dental-implant imaging, MR images are of research and educational interest only.

RADIATION DOSE CONSIDERATIONS

Understanding the radiation dose imparted to the patient is an important patient safety issue. Appropriate selection criteria must be used with the minimum radiation exposures that result in images of acceptable diagnostic qualities.^{19,81} This concept is known as ALARA (as low as reasonably achievable). Radiation effective doses are available (E_{2007})⁸² for various maxillofacial imaging modalities, including CT and CBCT.^{3,77,83-90} Although CBCT usually results in lower doses than CT, both result in substantially higher doses to patients than do other dental-implant imaging methods. With both CT and CBCT, there is wide variability in doses among different systems and among different imaging protocols (slice thickness, FOV, mAs, kVp, scan time). It is recommended that appropriate selection criteria be used along with imaging protocols that use the minimal doses that ensure acceptable diagnostic qualities.

PRINCIPLES OF IMAGING FOR DENTAL-IMPLANT ASSESSMENT

The basic principles of radiology apply to imaging for implant evaluations. Images should have appropriate diagnostic quality and not contain artifacts that compromise anatomic-structure assessments. Images should extend beyond the immediate area of interest to include areas that could be affected by implant placements. Practitioners should have appropriate training in operating radiographic equipment and competence in interpreting images from the modality used. This training and competence should be maintained through continuing dental education courses. Such training should include a thorough review of normal maxillofacial anatomy, common anatomic variants, and imaging signs of diseases and abnormalities. This is particularly important for CT and CBCT¹⁹ imaging because of the complexity of structures within the expanded FOVs.

The goal of radiographic selection criteria is to identify appropriate imaging modalities that complement the goals at each stage of implant therapy. The use of specific imaging is based on professional judgment (i.e., the clinician's professional opinion as to whether or not information from the clinical examination is inadequate and imaging is needed to formulate a diagnosis and a treatment plan, and/or for use at surgery). Professional judgment varies depending on the skill, competence, knowledge, and experience of the clinician. Specific considerations must include clinical and anatomic complexity, potential risks of complications, and esthetic outcomes. The following selection criteria recommendations provide literature-based, consensus-derived, clinical guidance for practitioners on the appropriate imaging (with particular relevance to CBCT) at each phase of dental-implant therapy.

1. Initial examination

Maxillofacial imaging interfaces with patient history, clinical examination, definitive diagnosis, treatment planning, and implant therapy. The purpose of the initial radiographic examination is to assess the overall status of the remaining dentition, to identify and characterize the location and nature of the edentulous regions, and to detect regional anatomic abnormalities and pathologies. Any of these may have important ramifications in the overall timing and sequencing of treatment phases, such as implant loading protocols and postprosthetic occlusal protection.

Recommendation 1. Panoramic radiography should be used as the imaging modality of choice in the initial evaluation of the dental implant patient.

Recommendation 2. Use intraoral periapical radiography to supplement the preliminary information from panoramic radiography.

Recommendation 3. Do not use cross-sectional imaging, including CBCT, as an initial diagnostic imaging examination.

2. Preoperative site specific imaging

Imaging for presurgical, dental-implant planning must provide information supportive of the following goals.

1. **Establish the morphologic characteristics of the residual alveolar ridge (RAR).** The morphology of the RAR includes considerations of bone volume and quality. Vertical bone height, horizontal width, and edentulous saddle length determine the amount of bone volume available for implant fixture placement. This information is necessary to match the available bone dimensions with the number and physical dimensions of the implant(s). Moderate deficiencies in horizontal and vertical bone may be corrected by augmentation procedures at the time of the osteotomies and fixture placements, whereas severe deficiencies require prior surgical procedures, such as ridge augmentations. Similarly excessive or irregular vertical alveolar bone may require preprosthetic or simultaneous alveoloplasty.

It is generally agreed that the success of dental-implant placement depends on oral bone quality. Currently, however, there is no agreed on definition for the term “bone quality” and no agreed on method for assessing bone quality. Bone quality is considered good when there is enough cortical and trabecular (cancellous) bone to hold the implant securely (which is required for osseointegration) and is considered poor when there is inadequate oral bone to hold the implant securely. Based on the abundance of published articles on assessments of osteoporosis risks, there is little doubt that oral-radiographic procedures are useful in assessing bone quality; however, few studies have been devoted to assessing oral-bone quality for implant placements. The most commonly used classification system for assessing oral-bone quality for implant placement was introduced in 1985 and uses 4 radiographic oral-bone classes that are based on visual assessments of the amounts of the cortical and trabecular bone.⁹¹ The use of dental-radiographic trabecular features for the assessment of implant sites has received little research attention other than visual assessments of dense and sparse trabeculation on radiographic images.⁹² Although several radiographic methods for assessing alveolar-bone quality have been suggested, no method has been tested in large clinical trials and no method can be recommended at this time. Better assessments of bone quality may influence surgical technique, implant selection (i.e., length, diameter, and type) and the loading protocol. Research in this area is needed.

2. **Determine the orientation of the RAR.** The orientation and residual topography of the alveolar-basal bone complex must be assessed to determine whether or not there are variations that could compromise the alignment of the implant fixture with the planned prosthetic restoration. This is particularly important in the mandible (e.g., submandibular gland fossa) and anterior maxilla (e.g., labial cortical bone concavity).
3. **Identify local anatomic or pathologic conditions restricting implant placement.** There are many internal anatomic features that are not easily identified or localized by clinical examination or conventional radiographic imaging that can compromise and limit implant fixture placement or risk involvement of adjacent structures. In the maxilla, these include the incisor region (nasopalatine fossa and canal, nasal fossa), the canine region (canine fossa, nasal fossa), and the premolar/molar region (floor of the maxillary sinus). In the mandible, these include the incisor region (lingual foramen), canine/premolar region (mental foramen), and molar region (submandibular gland fossa, inferior alveolar [mandibular] canal containing the neurovascular bundle).
4. **Match imaging findings to the prosthetic plan.** Successful implant treatment planning involves both surgical and prosthetic considerations. Radiographic images are not only used for prosthetic planning, but are also used to construct templates to guide surgical procedures and implant placements. The use of guided surgery for implant placement is increasing because of a number of clinical advantages, including increased practitioner confidence and reduced operating time. Guided surgery requires imaging capable of providing DICOM data (either CT or CBCT). These data are imported into software programs where interactive surgical and prosthetic tools can provide complex implant “simulations” within a virtual patient.

Most studies indicate that data from panoramic and intraoral radiography alone are inadequate to accomplish these goals (particularly no. 4) and provide insufficient information to determine treatment difficulty.

Recommendation 4. The radiographic examination of any potential implant site should include cross-sectional imaging orthogonal to the site of interest. This reaffirms the previously stated position of the AAOMR.¹

Conventional tomography provides cross-sectional information but is technique sensitive and the images are more difficult to interpret than CBCT. CBCT usually results in lower patient exposures to ionizing radiation than does CT.

Recommendation 5. CBCT should be considered as the imaging modality of choice for preoperative cross-sectional imaging of potential implant sites.

As with any type of imaging, a patient should be exposed to the least amount of ionizing radiation that is needed to produce CBCT images of acceptable diagnostic quality. This is achieved by careful selection of exposure parameters and FOV. Although the FOV should be limited to the area of interest, the FOV may extend beyond the implant site to include the maxillary sinus or opposing dental arch. CT may be considered when CBCT is unavailable; however, dose-sparing protocols must be used.

The use of CBCT before bone grafting helps define both the donor and recipient sites, allows for improved planning for surgical procedures, and reduces patient morbidities. CBCT is best for the evaluation of volumetric and topographic changes of the restored residual alveolar ridge.

Recommendation 6. CBCT should be considered when clinical conditions indicate a need for augmentation procedures or site development before placement of dental implants: (1) sinus augmentation, (2) block or particulate bone grafting, (3) ramus or symphysis grafting, (4) assessment of impacted teeth in the field of interest, and (5) evaluation of prior traumatic injury.

Recommendation 7. CBCT imaging should be considered if bone reconstruction and augmentation procedures (e.g., ridge preservation or bone grafting) have been performed to treat bone volume deficiencies before implant placement.

3. Postoperative imaging

The purpose of postoperative imaging after dental-implant placement is to confirm the location of the fixture at implant insertion. From 3 to 5 years and beyond, imaging is used to assess the bone-implant interface and marginal peri-implant bone height. Titanium implant fixtures inherently produce artifacts such as beam-hardening and streak artifacts obscuring subtle changes in marginal and peri-implant bone. In addition, the resolution of CBCT images for the detection of these findings is inferior to intraoral radiography.

Recommendation 8. In the absence of clinical signs or symptoms, use intraoral periapical radiography for the postoperative assessment of implants. Panoramic radiographs may be indicated for more extensive implant therapy cases.

Recommendation 9. Use cross-sectional imaging (particularly CBCT) immediately postoperatively only if the patient presents with implant mobility or altered sensation, especially if the fixture is in the posterior mandible.

Recommendation 10. Do not use CBCT imaging for periodic review of clinically asymptomatic implants.

Finally, implant failure, owing to either biological or mechanical causes, requires a complete assessment to characterize the existing defect, plan for surgical removal and corrective procedures, such as ridge preservation or bone augmentation, and identify the effect of surgery or the defect on adjacent structures.

Recommendation 11. Cross-sectional imaging, optimally CBCT, should be considered if implant retrieval is anticipated.

CONCLUSIONS

Initial imaging assessment is best achieved with panoramic radiography and may be supplemented with periapical radiography. For the preoperative diagnostic phase, the AAOMR reaffirms that cross-sectional imaging be used for implant site assessment. Furthermore, the AAOMR recommends CBCT imaging as the current method of choice for cross-sectional imaging in that it provides the greatest diagnostic yield at an acceptable radiation dose risk. The decision to perform a CBCT examination must be clinically justified and based on professional judgment (that is, the judgment of the clinician is that the use of CBCT will potentially provide information needed for prosthetic treatment planning, implant selection, and/or surgical placement). The CBCT imaging protocol should include the smallest FOV necessary and available and optimize exposure parameters. For periodic, postoperative implant monitoring, periapical and, in some cases, panoramic images provide adequate imaging. Finally, all CBCT volumes, regardless of clinical application, should be systematically evaluated for signs of abnormalities. This can be performed by the referring dentist or specialist (such as an oral and maxillofacial radiologist) competent in the interpretation of CBCT.

REFERENCES

1. Tyndall DA, Brooks SL. Selection criteria for dental implant site imaging: a position paper of the American Academy of Oral and Maxillofacial Radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000;89:630-7.
2. Tetradis S, White SC. A decade of cone beam computed tomography. *J Calif Dent Assoc* 2010;38:24-6.
3. Ganz SD. Cone beam computed tomography-assisted treatment planning concepts. *Dent Clin North Am* 2011;55:515-36.
4. Angelopoulos C, Aghaloo T. Imaging technology in implant diagnosis. *Dent Clin North Am* 2011;55:141-58.
5. Misch CE. *Contemporary implant dentistry*. 3rd ed. St. Louis: Mosby Elsevier; 2008.
6. Tardieu PB, Rosenfeld AL, editors. *The art of computer-guided implantology*. Chicago, IL: Quintessence Publishing; 2009.
7. Ganz S. CT scan technology—an evolving tool for predictable implant placement and restoration. *Int Mag Oral Implantol* 2001;1:6-13.
8. Ganz SD. Presurgical planning with CT-derived fabrication of surgical guides. *J Oral Maxillofac Surg* 2005;63:59-71.

9. Ganz SD. Advanced case planning with SimPlant. In: Tardieu PB, Rosenfeld AL, editors. *The art of computer-guided implantology*. Chicago: Quintessence Publishing; 2009. p. 193-210.
10. Ganz SD. Computer-aided design/computer-aided manufacturing applications using CT and cone beam CT scanning technology. *Dent Clin North Am* 2008;52:777-808.
11. Hatcher DC, Dial C, Mayorga C. Cone beam CT for pre-surgical assessment of implant sites. *J Calif Dent Assoc* 2003;31:825-34.
12. Kraut RA. Interactive CT diagnostics, planning and preparation for dental implants. *Implant Dent* 1998;7:19-25.
13. Mupparapu M, Singer SR. Implant imaging for the dentist. *J Can Dent Assoc* 2004;70:32a-g.
14. Sethi A, Kaus T. Practical implant dentistry: diagnostic, surgical, restorative and technical aspects of aesthetic and functional Harmony. Chicago: Quintessence Publishing; 2005. p. 288.
15. Spector L. Computer-aided dental implant planning. *Dent Clin North Am* 2008;52:761-75, vi.
16. Babbush CA, Hahn JA, Krauser JT, Rosenlicht JL. Dental implants: the art and science. Philadelphia: W. B. Saunders; 2010. p. 544.
17. Rosenfeld AL, Mandelaris GA, Tardieu PB. Prosthetically directed implant placement using computer software to ensure precise placement and predictable prosthetic outcomes. Part 1: diagnostics, imaging, and collaborative accountability. *Int J Periodontics Restorative Dent* 2006;26:215-21.
18. Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging for preoperative planning of implant placement. *Clin Oral Investig* 2006;10:1-7.
19. 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;106:561-2.
20. Jacobs R, Adriansens A, Naert I, Quirynen M, Hermans R, Van Steenberghe D. Predictability of reformatted computed tomography for pre-operative planning of endosseous implants. *Dentomaxillofac Radiol* 1999;28:37-41.
21. Schropp L, Wenzel A, Kostopoulos L. Impact of conventional tomography on prediction of the appropriate implant size. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001;92:458-63.
22. Diniz AF, Mendonça EF, Leles CR, Guilherme AS, Cavalcante MP, Silva MA. Changes in the pre-surgical treatment planning using conventional spiral tomography. *Clin Oral Implants Res* 2008;19:249-53.
23. Frei C, Buser D, Dula K. Study on the necessity for cross-section imaging of the posterior mandible for treatment planning of standard cases in implant dentistry. *Clin Oral Implants Res* 2004;15:490-7.
24. Vazquez L, Saulacic N, Belser U, Bernard JP. Efficacy of panoramic radiographs in the preoperative planning of posterior mandibular implants: a prospective clinical study of 1527 consecutively treated patients. *Clin Oral Implants Res* 2008;19:81-5.
25. Schropp L, Stavropoulos A, Gotfredsen E, Wenzel A. Comparison of panoramic and conventional cross-sectional tomography for preoperative selection of implant size. *Clin Oral Implants Res* 2011;22:424-9.
26. Norton MR, Ganeles J, Ganz SD, Stumpel LJ, Schmidt JM. Guidelines of the academy of osseointegration for the provision of dental implants and associated patient care. *Int J Oral Maxillofac Implants* 2010;2010:620-7.
27. Dawson A, Chen S, Buser D, Cordaro L, Martin W, Belser U. The SAC classification in implant dentistry. Berlin: Quintessence Publishing; 2009.
28. Misch K, Wang HL. Implant surgery complications: etiology and treatment. *Implant Dent* 2008;17:159-68.
29. Greenstein G, Cavallaro J, Romanos G, Tarnow D. Clinical recommendations for avoiding and managing surgical complications associated with implant dentistry: a review. *J Periodontol* 2008;79:1317-29.
30. Ganz SD. Implant complications associated with two- and three-dimensional diagnostic imaging technologies. In: Froum S, editor. *Dental implant complications*. Hoboken, NJ: Wiley-Blackwell; 2010. p. 71-99.
31. Ardekanian L, Dodson TB. Complications associated with the placement of dental implants. *Oral Maxillofac Surg Clin North Am* 2003;15:243-50.
32. The Faculty of General Dental Practice (UK), the Royal College of Surgeons of England. Training standards in implant dentistry for general dental practitioners. Available at: http://www.fgdp.org.uk/pdf/training_stds_imp_dent_guide_2008.pdf. Accessed January 23, 2012.
33. Academy of General Dentistry. Educational objectives for the provision of dental implant therapy by dentists Chicago, IL. p. 1-4. Available at: <http://www.agd.org/files/education/pace/educationalobjectives.pdf>. Accessed January 23, 2012.
34. Buser D, Belser UC, Wismeijer D, editors. *Implant therapy in the esthetic zone: single-tooth replacements*. Berlin: Quintessence Publishing; 2007.
35. Dreiseidler T, Mischkowski RA, Neugebauer J, Ritter L, Zöller JE. Comparison of cone-beam imaging with orthopantomography and computerized tomography for assessment in presurgical implant dentistry. *Int J Oral Maxillofac Implants* 2009;24:216-25.
36. Mraiwa N, Jacobs R, Van Cleynenbreugel J, Sanderink G, Schutyser F, Suetens P, et al. The nasopalatine canal revisited using 2D and 3D CT imaging. *Dentomaxillofac Radiol* 2004;33:396-402.
37. Romanos GE, Greenstein G. The incisive canal. Considerations during implant placement: case report and literature review. *Int J Oral Maxillofac Implants* 2009;24:740-5.
38. Asaumi R, Kawai T, Sato I, Yoshida S, Yosue T. Three-dimensional observations of the incisive canal and the surrounding bone using cone-beam computed tomography. *Oral Radiol* 2010;26:20-8.
39. Neugebauer J, Ritter L, Mischkowski RA, Dreiseidler T, Scherer P, Ketterle M, et al. Evaluation of maxillary sinus anatomy by cone-beam CT prior to sinus floor elevation. *Int J Oral Maxillofac Implants* 2010;25:258-65.
40. Misch CE. Density of bone: effect on surgical approach, and healing. In: Misch CE, editor. *Contemporary implant dentistry*. St Louis: Mosby; 1999. p. 371-84.
41. Ekfeldt A, Christiansson U, Eriksson T, Lindén U, Lundqvist S, Rundcrantz T, et al. A retrospective analysis of factors associated with multiple implant failures in maxillae. *Clin Oral Implants Res* 2001;12:462-7.
42. Tagaya A, Matsuda Y, Nakajima K, Seki K, Okano T. Assessment of the blood supply to the lingual surface of the mandible for reduction of bleeding during implant surgery. *Clin Oral Implants Res* 2009;20:351-5.
43. Rosano G, Taschieri S, Gaudy JF, Testori T, Del Fabbro M, Galeazzi V. Anatomic assessment of the anterior mandible and relative hemorrhage risk in implant dentistry: a cadaveric study. *Clin Oral Implants Res* 2009;20:791-5.
44. Katakami K, Mishima A, Kuribayashi A, Shimoda S, Hamada Y, Kobayashi K. Anatomical characteristics of the mandibular lingual foramina observed on limited cone-beam CT images. *Clin Oral Implants Res* 2009;20:386-90.
45. Kuzmanovic DV, Payne AG, Kieser JA, Dias GJ. Anterior loop of the mental nerve: a morphological and radiographic study. *Clin Oral Implants Res* 2003;14:464-71.
46. Tepper G, Hofschneider UB, Gahleitner A, Ulm C. Computed tomographic diagnosis and localization of bone canals in the mandibular interforaminal region for prevention of bleeding

- complications during implant surgery. *Int J Oral Maxillofac Implants* 2001;16:68-72.
47. Quirynen M, Mraiwa N, van Steenberghe D, Jacobs R. Morphology and dimensions of the mandibular jaw bone in the interforaminal region in patients requiring implants in the distal areas. *Clin Oral Implants Res* 2003;14:280-5.
 48. Angelopoulos C, Thomas SL, Hechler S, Parisis N, Hlavacek M. Comparison between digital panoramic radiography and cone-beam computed tomography for the identification of the mandibular canal as part of presurgical dental implant assessment. *J Oral Maxillofac Surg* 2008;66:2130-5.
 49. Bolin A, Eliasson S, von Beetzen M, Jansson L. Radiographic evaluation of mandibular posterior implant sites; correlation between panoramic and tomographic determinations. *Clin Oral Implants Res* 1996;7:354-9.
 50. Klinge B, Petersson A, Maly P. Location of the mandibular canal: comparison of macroscopic findings, conventional radiography, and computed tomography. *Int J Oral Maxillofac Implants* 1989;4:327-32.
 51. Sonick M, Abrahams J, Faiella R. A comparison of the accuracy of periapical, panoramic, and computerized tomographic radiographs in locating the mandibular canal. *Int J Oral Maxillofac Implants* 1994;9:455-60.
 52. Wakoh M, Harada T, Otonari T, Otonari-Yamamoto M, Ohkubo M, Kousuge Y, et al. Reliability of linear distance measurement for dental implant length with standardized periapical radiographs. *Bull Tokyo Dent Coll* 2006;47:105-15.
 53. Jacobs R, van Steenberghe D. Imaging procedures for pre-operative assessment. In: *Radiographic planning and assessment of endosseous oral implants*. 1st ed. Berlin.; Springer-Verlag; 1998. p. 7-20.
 54. Verhoeven JW, Cune MS. Oblique lateral cephalometric radiographs of the mandible in implantology: usefulness and accuracy of the technique in height measurements of mandibular bone in vivo. *Clin Oral Implants Res* 2000;11:39-43.
 55. Langland OE, Langlais RP, McDavid WD, DelBalso AM. Panoramic radiology. 2nd ed. Philadelphia: Lea & Febiger; 1989.
 56. Benson BW, Shetty V. Dental implants. In: White SC, Pharoah MJ, editors. *Oral radiology: principles and interpretation*. St. Louis: Mosby Elsevier; 2009. p. 597-612.
 57. Frederiksen NL. Diagnostic imaging in dental implantology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1995;80:540-54.
 58. Benson B. Presurgical radiographic planning for dental implants. *Oral Maxillofac Surg Clin North Am* 2001;13:751-62.
 59. Loubele M, Guerrero ME, Jacobs R, Suetens P, van Steenberghe D. A comparison of jaw dimensional and quality assessments of bone characteristics with cone-beam CT, spiral tomography, and multi-slice spiral CT. *Int J Oral Maxillofac Implants* 2007;22:446-54.
 60. Nickenig HJ, Eitner S. Reliability of implant placement after virtual planning of implant positions using cone beam CT data and surgical (guide) templates. *J Craniomaxillofac Surg* 2007;35:207-11.
 61. Vercruyssen M, Jacobs R, Van Assche N, van Steenberghe D. The use of CT scan based planning for oral rehabilitation by means of implants and its transfer to the surgical field: a critical review on accuracy. *J Oral Rehabil* 2008;35:454-74.
 62. Sarment DP, Sukovic P, Clinthorne N. Accuracy of implant placement with a stereolithographic surgical guide. *Int J Oral Maxillofac Implants* 2003;18:571-7.
 63. Ekstubbbe A, Gröndahl K, Gröndahl HG. The use of tomography for dental implant planning. *Dentomaxillofac Radiol* 1997;26:206-13.
 64. Perez LA, Brooks SL, Wang HL, Eber RM. Comparison of linear tomography and direct ridge mapping for the determination of edentulous ridge dimensions in human cadavers. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2005;99:748-54.
 65. Peker I, Alkurt MT, Michcioglu T. The use of 3 different imaging methods for the localization of the mandibular canal in dental implant planning. *Int J Oral Maxillofac Implants* 2008;23:463-70.
 66. Kassebaum DK, Nummikoski PV, Triplett RG, Langlais RP. Cross-sectional radiography for implant site assessment. *Oral Surg Oral Med Oral Pathol* 1990;70:674-8.
 67. Scarfe WC. A common sense approach to TMJ and implant imaging. *Ann R Australas Coll Dent Surg* 1998;14:48-61.
 68. Seeram E. *Computed tomography: physical principles, clinical applications, and quality control*. 3rd ed. St. Louis: Saunders Elsevier; 2009.
 69. Commean PK, Kennedy JA, Bahow KA, Hildebolt CF, Liu L, Smith KE, et al. Volumetric quantitative computed tomography measurement precision for volumes and densities of tarsal and metatarsal bones. *J Clin Densitom* 2011;14:313-20.
 70. Kalender WA. *Computed tomography: fundamentals, system technology, image quality, applications* 2nd ed. Erlangen: Publicis Corporate Publishing; 2005. p. 69.
 71. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? *Dent Clin North Am* 2008;52:707-30.
 72. Fortin T, Bosson JL, Coudert JL, Isidori M. Reliability of pre-operative planning of an image-guided system for oral implant placement based on 3-dimensional images: an in vivo study. *Int J Oral Maxillofac Implants* 2003;18:886-93.
 73. Balshi S, Wolfinger G, Balshi T. Surgical planning and prosthesis construction using computed tomography, CAD/CAM technology, and the Internet for immediate loading of dental implants. *J Esthet Restor Dent* 2006;18:312-25.
 74. Chaushu G, Taicher S, Halamish-Shani T, Givol N. Medicolegal aspects of altered sensation following implant placement in the mandible. *Int J Oral Maxillofac Implants* 2002;17:413-5.
 75. Curley A, Hatcher DC. Cone beam CT—anatomic assessment and legal issues: the new standards of care. *J Calif Dent Assoc* 2009;37:653-62.
 76. Givol N, Taicher S, Halamish-Shani T, Chaushu G. Risk management aspects of implant dentistry. *Int J Oral Maxillofac Implants* 2002;17:258-62.
 77. Chau AC, Fung K. Comparison of radiation dose for implant imaging using conventional spiral tomography, computed tomography, and cone-beam computed tomography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;107:559-65.
 78. Gray CF, Redpath TW, Smith FW. Low-field magnetic resonance imaging for implant dentistry. *Dentomaxillofac Radiol* 1998;27:225-9.
 79. Gray CF, Redpath TW, Smith FW, Staff RT. *Advanced imaging: magnetic resonance imaging in implant dentistry: a review*. *Clin Oral Implants Res* 2003;14:18-27.
 80. Aguiar MF, Marques AP, Carvalho AC, Cavalcanti MG. Accuracy of magnetic resonance imaging compared with computed tomography for implant planning. *Clin Oral Implants Res* 2008;19:362-5.
 81. Horner K, Islam M, Flygare L, Tsiklakis K, Whaites E. Basic principles for use of dental cone beam computed tomography: consensus guidelines of the European Academy of Dental and Maxillofacial Radiology. *Dentomaxillofac Radiol* 2009;38:187-95.
 82. Valentin J. The 2007 recommendations of the international commission on radiological protection. Publication 103. *Ann ICRP* 2007;37:1-332.
 83. Ludlow JB, Davies-Ludlow LE, Brooks SL. Dosimetry of two

- extraoral direct digital imaging devices: NewTom cone beam CT and Orthophos plus DS panoramic unit. *Dentomaxillofac Radiol* 2003;32:229-34.
84. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. *Dentomaxillofac Radiol* 2006;35:219-26.
85. Ludlow JB, Davies-Ludlow LE, White SC. Patient risk related to common dental radiographic examinations: the impact of 2007 International Commission on Radiological Protection recommendations regarding dose calculation. *J Am Dent Assoc* 2008;139:1237-43.
86. Loubele M, Bogaerts R, Van Dijck E, Pauwels R, Vanheusden S, Suetens P, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. *Eur J Radiol* 2009;71:461-8.
87. Cohnen M, Kemper J, Möbes O, Pawelzik J, Mödder U. Radiation dose in dental radiology. *Eur Radiol* 2002;12:634-7.
88. Roberts JA, Drage NA, Davies J, Thomas DW. Effective dose from cone beam CT examinations in dentistry. *Br J Radiol* 2009;82:35-40.
89. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;106:106-14.
90. Pauwels R, Beinsberger J, Collaert B, Theodorakou C, Rogers J, Walker A, et al. Effective dose range for dental cone beam computed tomography scanners. *Eur J Radiol* 2012;81:267-71ed.
91. Lekholm U, Zarb GA. Patient selection and preparation. In: Branemark PI, Zarb G, Albrektsson T, editors. *Tissue integrated prostheses. Osteointegration in clinical dentistry*. 3rd ed. Chicago: Quintessence Publishing; 1985. p. 199-209.
92. Ribeiro-Rotta RF, Lindh C, Rohlin M. Efficacy of clinical methods to assess jawbone tissue prior to and during endosseous dental implant placement: a systematic literature review. *Int J Oral Maxillofac Implants* 2007;22:289-300.