Use of Cone Beam Computed Tomography in Implant Dentistry: The International Congress of Oral Implantologists Consensus Report

Erika Benavides, DDS, PhD,* Hector F. Rios, DDS, PhD,† Scott D. Ganz, DMD,‡ Chang-Hyeon An, DDS, PhD,§ Randolph Resnik, DMD, MDS,‖ Gayle Tieszen Reardon, DDS, MS,¶ Steven J. Feldman, DDS,# James K. Mah, DDS, MSc, DMSc,** David Hatcher, DDS, MS,†† Myung-Jin Kim, DDS, MSD, PhD,‡‡ Dong-Seok Sohn, DDS, PhD,§§ Ady Palti, DMD,‖‖ Morton L. Perel, DDS, MScD,¶¶ Kenneth W. M. Judy, DDS, PhD (HC),## Carl E. Misch, DDS, MDS,*** and Hom-Lay Wang, DDS, MSD, PhD†††

It is generally accepted that partial or complete edentulism adversely affects an individual's quality of life and can negatively contribute to the maintenance of optimal health.[1–3] Structural and functional adaptations of the soft and mineralized tissues of the maxilla and mandible occur overtime after tooth extraction and can

*Clinical Assistant Professor, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI.
†Assistant Professor, Department of Periodontics and Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI.
‡Private Practice, Prosthodontics, Maxillofacial Prosthetics & Implant Dentistry, Fort Lee, NJ.
§Associate Professor, Department of Oral and Maxillofacial Radiology, School of Dentistry, Kyungpook National University, Daegu, Republic of Korea.
‖Clinical Professor, Department of Periodontology and Implantology, Temple University, Philadelphia, PA; Private Practice, Pittsburgh, PA.
¶Private Practice, Sioux Falls, SD.
#Chairman and CEO, XCPT Communication Technologies, LLC, Sarasota, FL.
**Associate Professor, University of Nevada, Las Vegas, NV; Private Practice, Advanced Dental Imaging, LLC, Las Vegas, NV.
††Clinical Professor, Roseman University of Health Sciences; Adjunct Associate Clinical Professor, University of Pacific; Private Practice, Diagnostic Digital Imaging, Sacramento, CA.
‡‡Professor, College of Dentistry, Seoul National University, Seoul, Republic of Korea.
§§Professor and Chairman, Department of Dentistry and Oral and Maxillofacial Surgery, Catholic University Hospital of Daegu, Nam-Gu, Adegu, Republic of Korea.
‖‖Private Practice, Baden-Baden, Germany; Clinical Professor, New York University, College of Dentistry, New York, NY.
¶¶Editor-in-Chief, *Implant Dentistry*.
##Clinical Professor, Department of Periodontology and Implantology, Temple University, Philadelphia, PA.
***Clinical Professor and Director of Oral Implantology, Temple University, School of Dentistry, Philadelphia, PA; Private Practice, Beverly Hills, MI, and Chicago, IL.
†††Professor and Director of Graduate Periodontics, Department of Periodontics & Oral Medicine, School of Dentistry, University of Michigan, Ann Arbor, MI.

Reprint requests to and correspondence to: Erika Benavides, DDS, PhD, University of Michigan School of Dentistry, 1011 N. University Avenue, Ann Arbor, MI 48109-1078, Tel: +1.734.936.0051, Fax: +1.734.764.6924, E-mail: benavid@umich.edu

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Purpose: *The International Congress of Oral Implantologists has supported the development of this consensus report involving the use of Cone Beam Computed Tomography (CBCT) in implant dentistry with the intent of providing scientifically based guidance to clinicians regarding its use as an adjunct to traditional imaging modalities.*

Materials and Methods: *The literature regarding CBCT and implant dentistry was systematically reviewed. A PubMed search that included studies published between January 1, 2000, and July 31, 2011, was conducted. Oral presentations, in conjunction with these studies, were given by Dr. Erika Benavides, Dr. Scott Ganz, Dr. James Mah, Dr. Myung-Jin Kim, and Dr. David Hatcher at a meeting of the International Congress of Oral Implantologists in Seoul, Korea, on October 6–8, 2011.*

Results: *The studies published could be divided into four main groups: diagnostics, implant planning, surgical guidance, and postimplant evaluation.*

Conclusions: *The literature supports the use of CBCT in dental implant treatment planning particularly in regards to linear measurements, three-dimensional evaluation of alveolar ridge topography, proximity to vital anatomical structures, and fabrication of surgical guides. Areas such as CBCT-derived bone density measurements, CBCT-aided surgical navigation, and postimplant CBCT artifacts need further research.*

ICOI Recommendations: *All CBCT examinations, as all other radiographic examinations, must be justified on an individualized needs basis. The benefits to the patient for each CBCT scan must outweigh the potential risks. CBCT scans should not be taken without initially obtaining thorough medical and dental histories and performing a comprehensive clinical examination. CBCT should be considered as an imaging alternative in cases where the projected implant receptor or bone augmentation site(s) are suspect, and conventional radiography may not be able to assess the true regional three-dimensional anatomical presentation. The smallest possible field of view should be used, and the entire image volume should be interpreted. (Implant Dent 2012;21:1–000)*

Key Words: CBCT, dental implants, interactive treatment planning software, 3D implant planning, CBCT-guided surgery

Table 1. Advantages and Limitations of CBCT

Advantages of CBCT	Limitations of CBCT
Mutiplanar reconstruction	Limited soft tissue visualization
Significantly less radiation compared with other 3D advanced imaging modalities (ie, medical CT)	Some CBCT machines produce an increased radiation exposure compared with selected intraoral and panoramic radiographs
Fast, efficient, in-office modality	Limited bone density measurements
Interactive treatment planning	Artifacts created by metal subjects (eg, PFM crowns, dental implants), costly
Adequate for bone grafting assessment	Third-party software applications and 3D models are an additional expense
Computer-aided surgery	Liability, extra cost

CBCT indicates cone beam computed tomography.

directly influence the therapeutic alternatives.[4] Because mineralized tissue changes may not be clinically apparent, radiographic imaging analysis is paramount for successful diagnosis and treatment planning in dental implantology and directly contributes to the implant's long-term success.[5]

Until recently, the most common diagnostic radiographic modalities used to assist clinicians during implant treatment planning were limited to intraoral periapical and panoramic radiography.[5] These radiographic modalities only provide two-dimensional (2D) representations of three-dimensional (3D) structures. In an effort to overcome this limitation, the use of medical computed tomography (CT) for dental implant applications became available in the mid 1980s; however, this practice received some criticism due to the level of radiation exposure during image acquisition. The introduction of Cone Beam Computed Tomography (CBCT) in the late 1990s represented an unparalleled advancement in the field of dental and maxillofacial radiology because it greatly reduced the radiation exposure to patients undergoing scans.[6,7] The 3D information generated by this technique offers the potential of improved diagnosis and treatment planning for a wide range of clinical applications in implant dentistry.[8,9] The goal of this consensus report is to discuss key elements needed for the sound, scientifically based use of CBCT in the area of dental implantology.

Cone Beam Computed Tomography

CBCT is an advanced digital imaging technique that allows the operator to generate multiplanar slices of a region of interest and to reconstruct a 3D image of these structures of interest by using a cone-shaped rotating x-ray beam via a series of mathematical algorithms.[6] The advent of CBCT has made it possible to visualize the dentition, the maxillofacial skeleton, and the relationship of anatomical structures in three dimensions.[6] The use of CBCT in the dental profession is increasing exponentially due to an increase of equipment manufacturers and the growing acceptance of this imaging modality.[8]

Field of view. The size of the field of view (FOV) describes the scan volume of a particular CBCT machine and is dependent on the detector size and shape, the beam projection geometry, and the ability to collimate the beam which differs from manufacturer to manufacturer. Beam collimation limits the patient's ionizing radiation exposure to the region of interest and ensures that an appropriate FOV can be selected based on the specific case.

In general, CBCT units can be classified into small, medium, and large volume based on the size of their "FOV." Small volume CBCT machines are used to scan from a sextant or a quadrant to one jaw only. They generally offer higher image resolution because x-ray scattering (noise) is reduced as the FOV decreases. Medium volume CBCT machines are used to scan both jaws while large FOV machines allow the visualization of the entire head that is commonly used in orthodontic and orthognathic surgery treatment planning. The main limitation of large FOV CBCT units is the size of the field irradiated. Unless the smallest voxel size is selected in the larger FOV machines, there is a reduction in image resolution as compared with intraoral radiographs or small FOV CBCT machines with inherent small voxel sizes.

Limiting the scan volume should be based on the clinician's judgment for the particular situation. For most dental implant applications, small or medium FOV is sufficient to visualize the region of interest. Small volume CBCT machines are becoming more popular and provide the following advantages over larger volume CBCT:

1. Increased spatial resolution.
2. Decreased radiation exposure to the patient.
3. Smaller volume to be interpreted.
4. Less expensive machines.

Advantages and Limitations of CBCT

CBCT has made it possible for clinicians to directly visualize the dentition including the maxillofacial skeleton in 3D as opposed to "imaging" it two dimensionally (2D). The advantages of CBCT are the weaknesses of 2D intraoral periapical and panoramic radiographic representations. The ability to visualize the complete geometric shape of the area of interest and avoid superimposition or planar viewing permits accurate radiographic interpretation without assumption (Table 1). Therefore, spatial proximity of vital structures such as the inferior alveolar nerve, the incisive canal, the mental foramen, and inherent concavities can be accurately assessed and measured. However, the quality of the interpretation is based on the clinician's diagnostic ability, thoroughness, utilization of native and third-party treatment planning software, and determination of the appropriate FOV for each particular case. There are several CBCT equipment manufacturers in the dental imaging field. This has resulted in significant variability in radiation dose, scanning times, ease of use, image resolution, and software dynamics among CBCT machines.

CBCT has limitations similar to all interpretive technologies. The most significant limitations of CBCT are the lack of accurate representation of the internal structure of soft tissues such as the muscles, salivary glands, and soft-tissue lesions, the limited correlation to Hounsfield units for standardized quantification of bone density, and the various types of artifacts produced mainly by metal restorations that can interfere with the diagnostic process by masking underlying structures (Table 1). To improve visualization of the contour and thickness of the gingival soft tissues, techniques such as the use of a cotton roll or air to separate the lip from the vestibule have been described and proven successful.[9]

A large number of commercial third-party software packages are available to import and analyze CBCT data exported in a DICOM format (Digital Imaging and Communication in Medicine). The most differentiating aspects of the available software applications include their ease of navigation, cost, quantity and quality of available diagnostic tools, and their implant planning modules. Advanced software applications can significantly reduce the "scatter" effect or artifact so that an accurate diagnosis can be established, thus helping to mitigate one potential limitation of this imaging modality.

Dose Considerations

As it is well known, the main concern of exposure to dental x-rays in general is the risk of potential stochastic effects, which are those effects that can be caused regardless of how small the radiation exposure might be and include radiation-induced cancer and hereditable effects. Risks versus benefits decisions are made daily in a dental office. As with any surgical procedure, conventional dental and CBCT imaging require similar types of decisions.

This risk is age dependent, being highest for the young and least for the elderly. Published estimated risks are given for the adult patient at 30 years of age that represent averages for both genders. At all ages, risks for females are slightly higher than those for males. To calculate individual risks, these estimates should be modified using the appropriate multiplication factors derived from the International Commission on Radiologic Protection report published in 2007.[10,11] The NCRP report No. 145 published in 2003 provides guidelines to help minimize radiation risks from common dental radiographic examinations.[12]

There are multiple CBCT radiation dosimetry studies in the literature (Table 2). Based on these reports, it can be concluded that a significant variation in effective dose exists among CBCT machines; however, when compared to medical CT, CBCT can be recommended as a dose-reducing technique for dental implant applications.[13–17] The effective dose from CBCT examinations ranges from 13 μSv with the 3D Accuitomo CBCT machine using the 4 $\times$ 4 cm FOV to 479 μSv with the CB Mercuray CBCT machine (Table 2). For comparison, the effective dose from one panoramic radiograph is approximately 10 to 14 μSv and that of a complete series of radiographs can range from 34.9 μSv (when using PSP plates or F-speed film and the use of a rectangular collimator) to 388 μSv (when using D-speed film and a round collimator).[14] Furthermore, the exposure from a maxillomandibular medical CT ranges from 474 to 1160 μSv.[18] The average background radiation in the United States is 3000 μSv (3 mSv) per year or 8 μSv per day (Table 2).

As with any other dental imaging modality, CBCT examinations must be justified on an individual basis by demonstrating that the benefits to the patients outweigh the potential risks. CBCT examinations should potentially add significant new information to aid in the patient's management. CBCT must not be selected unless a review of the medical and dental histories and a thorough clinical examination has been performed.

It is important to understand that every effort must be made to reduce the effective radiation dose to the patient. By using the smallest possible FOV, the lowest mA setting, the shortest exposure time, and a pulsed exposure mode of acquisition, it is possible to accomplish effective dose reduction to the patient.[19] If visualization of structures beyond the region of interest for implant placement is required, imaging made with the appropriate larger FOV protocol should be selected on a case-by-case basis.

CBCT in Implant Dentistry

The use of 3D information in the areas of diagnosis and treatment planning has been greatly enhanced through the availability of CBCT. Its application in the area of implant dentistry assists the clinician in assessing individual patient anatomy in 3D. This analysis can be made through native software that initially reconstructs the CBCT data after acquisition and through advanced third-party software applications that can aid in the determination of dental implant receptor sites and related procedures. The ideal receptor site for dental implant placement can be defined as one with adequate bone quality and volume where an osteotomy can be prepared and the implant can be stabilized in a favorable position whereby the prosthetic goals can be achieved. The 3D visualization and evaluation of the structures of interest during the treatment planning phase allows for the analysis of the following parameters:

1. Determination of the available bone height, width, and relative quality.
2. Determination of the 3D topography of the alveolar ridge.
3. Identification and localization of vital anatomical structures such as the inferior alveolar nerve, mental foramen, incisive canal, maxillary sinus, ostium, and floor of the nasal cavity.
4. Identification and 3D evaluation of possible incidental pathology.
5. Fabrication of CBCT-derived implant surgical guides.

Table 2. CBCT Machines

CBCT Scanner	FOV (cm)	Effective Dose (μSv)	Digital Panoramic Equivalent (14 μSv)	No. of Days of Annual per Capita Background (3 μSv = 3000 μSv)	References
i-CAT classic	22/13 (40 s)/13 (10 s)	82/77/48	5.9/5.5/3.4	10/9.4/5.8	Loubele et al[18]
	6 min. (low resolution/ high resolution)	96.2/118.5	6.9/8.5	11.7/14.4	Hatcher[20]
	6 max. (low resolution/ high resolution)	58.9/93.3	4.2/6.6	7.2/11	Hatcher[20]
	22/13	206.2/133.9	14.7/9.6	25/16	Hatcher[20]
	13	61.1	4.4	7.4	Silva et al[21]
i-CAT next generation	23 × 17	74	5.3	9	Ludlow and Ivanovic[15]
	16 × 13 (19 mAs)	87	6.2	10.6	Ludlow and Ivanovic[15]
	16 × 13 (18.5 mAs)	83	5.9	10.2	Pauwels et al[22]
	16 × 6	45	3.2	5.5	Pauwels et al[22]
Newtom 9000	23	56.2	4	6.9	Silva et al[21]
	12 in (male/female)	93/95	6.6/6.8	11.3/11.6	Coppenrath et al[23]
Newtom 3G	19	68	4.9	8.3	Ludlow and Ivanovic[15]
	6 in/12 in	57/30	4/2.1	6.9/3.7	Loubele et al[18]
Newtom VG	15 × 10	83	5.9	10.2	Pauwels et al[22]
NewtomVGi	15 × 15	194	6.7	23.9	Pauwels et al[22]
	High resolution scan (12 × 8)	265	18.9	32.6	Pauwels et al[22]
CB MercuRay	100 kVp 19/15/10	479/402/369	34/29/26	58/49/45	Ludlow et al[14]
	120 kVp 19/15/10	761/680/603	54/49/40	93/83/73	Ludlow et al[14]
	10	510.6	36.5	62	Okano et al[16]
	19 (max./stand)/15/10	1073/569/560/407	77/41/40/20	131/69/68/50	Ludlow and Ivanovic[15]
ProMax 3D	8 × 8 (72 mAs/96 mAs)	488/652	35/47	59/79	Ludlow and Ivanovic[15]
	8 × 8 (169 mAs/19.9 mAs)	122/28	8.7/2	15/1.7	Pauwels et al[22]
Picasso-Trio	12 × 7 (127 mAs/91 mAs)	123/81	8.8/5.8	15.1/10	Pauwels et al[22]
PaX-Uni3D	5 × 5 max.	44	3.1	5.4	Pauwels et al[22]
Kodak 9000 3D	Max. ant./min. post.	19/40	1.4/2.9	2.3/4.9	Pauwels et al[22]
Kodak 9500 3D	20 × 18	92			Pauwels et al[22]
	15 × 9	136			Pauwels et al[22]
	20 × 18 (small/medium/ large adult)	76/98/166	5.4/7.0/11.9	9.3/12.1/20.4	Ludlow et al[24]
	15 × 9 (small/medium/ large adult)	93/163/260	6.6/11.6/18.6	11.4/20.1/32.0	Ludlow et al[24]
	28 mAs	84	6	10.3	Pauwels et al[22]
SCANORA 3D	14.5 × 13	68	4.9	8.4	Pauwels et al[22]
	10 × 7.5	46	3.3	5.7	Pauwels et al[22]
SkyView	17 × 17	87	6.2	10.7	Pauwels et al[22]
ILUMA	19 × 19 (20 mAs/152 mAs)	98/498	7/35.6	11.9/60.6	Ludlow and Ivanovic[15]
	20.5 × 14 (76 mAs)	368	26.3	45.3	Pauwels et al[22]

(*Continued*)

Table 2. (*Continued*)

CBCT Scanner	FOV (cm)	Effective Dose (μSv)	Digital Panoramic Equivalent (14 μSv)	No. of Days of Annual per Capita Background (3 μSv = 3000 μSv)	References
3D Accuitomo FPD	4 × 4/6 × 6	49.9/101.5	3.6/7.3	6/12.4	Okano et al[16]
	Ant. (4 × 4/6 × 6)	20/43.3	1.4/3.1	2.5/5.2	Hirsch et al[25]
	Max. ant. (4 × 4/6 × 6)	21–26/52–63	1.5–1.9/3.7–4.5	2.6–3.2/6.4–7.8	Lofthag-Hansen et al[26]
	Min. pm (4 × 4/6 × 6)	21–31/57–69	1.5–2.2/4.1–4.9	2.6–3.8/7.0–8.5	Lofthag-Hansen et al[26]
	Min. 3rd (4 × 4/6 × 6)	21–29/52–77	1.5–2.1/3.7–5.5	2.6–3.6/6.4–9.5	Lofthag-Hansen et al[26]
3D Accuitomo	4 × 3	29.6	2.1	3.6	Okano et al[16]
	Max. (ant./pm/mol)	29/44/29	2/3.2/2	3.5/5.3/3.5	Loubele et al[18]
	Min. (ant./pm/mol)	13/22/29	0.9/1.6/2	1.6/2.7/3.5	Loubele et al[18]
	Max. ant/Mn. pm/ Min. 3rd	21–25/11–25/11–27	1.5–1.8/0.8–1.8/0.8–1.9	2.6–3.1/1.4–3.1/1.4–3.3	Lofthag-Hansen et al[26]
3D Accuitomo 170	10 × 5	54	3.9	6.6	Pauwels et al[22]
	4 × 4	43	3.1	5.3	Pauwels et al[22]
Veraviewepocs 3D	Ant. (4 × 4/8 × 4/ pan + 4 × 4)	30.2/39.9/29.8	2.2/2.9/2.1	3.8/4.9/3.6	Hirsch et al[25]
	8 × 8	73	5.2	9	Pauwels et al[22]
PreXion 3D	Standard (19 s)/high resolution (37 s)	189/388	13.5/27.7	23/47	Ludlow and Ivanovic[15]

6. Communication of the diagnostic and treatment planning information to all members of the implant team.
7. Evaluation of prosthetic/restorative options through implant software applications.

In addition, the CBCT scan in combination with software modeling can be used as a virtual treatment planning platform to simulate the ideal implant placement with consideration of surgical, prosthetic, and occlusal factors.

Review of the Literature

The literature regarding CBCT and implant dentistry was systematically reviewed. A PubMed search that included studies published between January 1, 2000, and July 31, 2011, was conducted.

The use and potential of CBCT have been reported in a number of scientific papers for a number of purposes. The most commonly cited uses include the following: (1) identifying the 3D characteristics of individual patienst anatomy, (2) identifying potential risks of intrusion into vital anatomical structures including nerves, blood vessels, and impacted or supernumerary teeth, (3) ancillary bone grafting procedures including sinus augmentations, (4) assessing bone quality including facial and lingual cortical plates and intermedullary bone, (5) assessing potential dental implant receptor sites for the placement of standard, narrow-diameter, and zygomatic implants, (6) the fabrication of surgical guides/templates and prostheses, and (7) postoperative assessment of grafting procedures.

Level of evidence and other considerations. More than 40% of the published studies between 2000 and 2011 represent laboratory trials which include ex-vivo (ie, cadaver) studies and other types of models. Approximately 30% of the published studies are randomized clinical trials, and more than 20% represent case reports.

It is also important to keep in mind that published research that applies to one CBCT machine may not apply to other equipment because the image quality and resolution varies among machines and there are more than 30 CBCT machines currently available in the market.

Based on the currently available literature, the adjunctive use of CBCT in implant dentistry can be divided into four main categories:

1. Diagnostics
2. Implant planning
3. Surgical guidance
4. Postimplant and/or post grafting evaluation

CBCT and Diagnostics

CBCT is an excellent diagnostic modality in implant dentistry that should be used for the evaluation of the proposed implant site to exclude the presence of occult pathology, foreign bodies, and/or defects and to determine the suitability of the site in terms of 3D morphology and proximity to vital anatomical structures.

CBCT and Implant Planning

In dental implant treatment planning, one of the most frequently reported applications of CBCT is linear measurement of the ridge. CBCT images have been found to provide reliable bone quantity information for preoperative implant planning in different areas of the maxilla and mandible both in clinical and experimental studies.[27–31] It has been shown that magnification of CBCT-obtained linear measurements does not occur and measurements have been found to be more accurate than those obtained with medical CT.[32,33] Furthermore, dental metallic artifacts do not alter the accuracy of linear measurements obtained with CBCT.[34]

Another important advantage of CBCT in preimplant treatment planning is the ability to evaluate the ridge topography and proximity to vital anatomical structures three dimensionally to determine whether advanced grafting is necessary for appropriate implant site development. CBCT images have proven to be superior in this regard compared with other 2D imaging modalities.[35–38] CBCT can accurately assess the thickness of cortical bone such as the facial/buccal and lingual/palatal cortical plates, the floor of the nasal cavity, and the medial and lateral walls of the maxillary sinuses.

Evaluation of bone density has also been an area of increasing interest. Because of the volumetric data acquisition and reconstruction of CBCT data, linear attenuation coefficients and true Hounsfield units which originated from medical CT scans are challenging to calculate from CBCT scans. To date, it has been possible to obtain only relative bone quality information. However, several research studies have been done to assess the reliability of bone density measurements obtained with CBCT in an effort to overcome this limitation and provide a method to standardize imaging variables to better estimate true tissue density.[39] Some studies have found that CBCT might hold potential with regard to the structural analysis of trabecular bone and that bone quality evaluated by CBCT shows a high correlation with the primary stability of dental implants.[40–43] Furthermore, the use of the quantitative CBCT (QCBCT) method holds promise as an alternative diagnostic tool for preoperative bone density evaluation.[44]

In addition to implant planning, the use of CBCT has been found to be effective in locating blood vessels in the lateral wall of the maxillary sinus – which should be appreciated before sinus augmentation procedures. Significant vessels also reside in the mandibular symphysis region that can cause life-threatening events if perforated during implant surgery. CBCT can aid clinicians in identifying these important anatomical features to avoid potential serious complications.

CBCT and Surgical Guidance

CBCT-aided implant surgery can be divided into the following: passive, semi-active, and active.

1. Passive CBCT-aided implant surgery refers to the use of CBCT information such as linear measurements, relative bone quality, 3D evaluation of ridge topography, and proximity to vital anatomical structures to help in the implant treatment planning process. Passive CBCT-aided implant surgery can be accomplished with or without third-party interactive treatment planning software.
2. Semi-active CBCT-aided implant surgery includes the use of CBCT data imported into third-party interactive treatment planning software where virtual implants are simulated as a precursor to the fabrication of surgical guides that will be used at the time of implant placement.Depending on the software application's protocol to relate implant position to the underlying bone and restorative needs of the patient, a scanning template may need to be fabricated before the scan acquisition. The scanning template can be made with a radiopaque material (barium sulfate), contain gutta-percha markers, or other specific fiduciary markers that aid in the fabrication of the surgical guide. The scanning template is positioned intraorally, and the CBCT scan is acquired. The data from the scan are then imported into the interactive treatment planning software for implant planning. Surgical guides can be fabricated by several different methods, based on the particular software application and are not all equally accurate. The use of stereolithography or rapid prototyping has been successful in the ability to reconstruct the patient's bony anatomy, and facilitates the fabrication of CBCT-derived surgical guides. This process can be completed with or without a scanning appliance worn during the CBCT scan acquisition. Other methods involve laboratory-drilled templates that require registration of the scanning template to the CBCT data. Each type of template contains metal cylinders that correspond to the diameter of the osteotomy drills specific to the implants to be placed. The registration of 3D surface data has been found to be reliable and sufficiently accurate for dental implant planning. Thereby, in certain situations and with certain software applications, barium-sulfate scanning templates can be avoided and dental implant planning can be accomplished fully virtual.[45] The process to perform virtual implant treatment planning involves the use of third-party software to decide the most appropriate location and orientation of the proposed implant.[27,46] Moreover, the use of surgical guides facilitates flapless implant placement.[47,48] The use of CBCT-derived surgical guides has been enhanced to allow for implants to be placed directly through the surgical template with manufacturer specific hardware to control depth and rotation of the implants. Therefore, extra equipment and cost is associated with these protocols. CBCT-generated surgical guides and the integration of CAD/CAM and CBCT to determine the appropriate restorative modality have been found to be precise[27,49,50] and will continue to evolve as a link between the treatment planning and the restorative processes.
3. Active CBCT-aided implant surgery refers to the use CBCT data and surgical navigation systems to perform fully computer-guided im-

plant placement. The accuracy of navigation systems has been tested in some studies; however, more research is need in this area.[51]

CBCT and Postimplant/ Postgrafting Evaluation

The usefulness of CBCT for postimplant evaluation has also been studied. One of the main concerns of postimplant evaluation with CBCT is the presence of beam hardening and partial volume artifacts around implants which in some cases prevent the visualization of the bone-implant interface. However, scattering artifacts caused by metal are significantly less with CBCT as compared with medical CT. Naitoh *et al*[52] 2010 evaluated the rate of bone-to-implant contact in a clinical study and reported that the bone configuration surrounding anterior dental implants with and without bone grafting can be adequately assessed using CBCT. Similar findings have also been obtained in human skulls.[31] However, controversial results are also found in the literature using other animal models where the evaluation of periimplant bone defect regeneration by means of CBCT was not accurate for sites providing bone width of <0.5 mm. Research to reduce artifacts caused by titanium implants in CBCT images is being done.[53]

Interpretation of CBCT Scans

Clinicians ordering CBCT scans are responsible for interpreting the entire image volume because incidental findings that may be significant to the health of the patient could be present. These incidental findings may include, but are not limited to, osseous or sinus pathology, intracranial or vascular calcifications, and airway asymmetry. The likelihood of seeing these types of findings increases with a larger FOV where a larger head volume is included in the scan. There is no informed consent process or signature of waiver that allows the clinician to interpret only a specific area of an image volume. Therefore, the clinician may be considered liable for a missed diagnosis, even if it is outside of his/her area of practice.[54] If questions regarding image data interpretation occur, prompt referral to a specialist in oral and maxillofacial or medical radiology is recommended. If incidental findings are considered clinically significant, appropriate referral for medical consultation should follow.

RECOMMENDATIONS

The decision to order a CBCT scan must be based on the patient's history and clinical examination, and justified on an individualized needs basis that demonstrates that the benefits to the patient outweigh the potential risks of the patient's exposure to ionizing radiation, especially in the case of children or young adults and large FOV scans. Because the 3D information obtained with CBCT cannot be obtained with other 2D imaging modalities, it is virtually impossible to predict which treatment cases would not benefit from having this additional information before obtaining it.

Based on the available evidence and the type of information acquired with 3D imaging modalities, the consensus panel suggests that use of CBCT should be considered as an imaging alternative before cases where the proposed implant receptor or bone augmentation site(s) are suspect, and conventional radiography may not be able to assess the true regional 3D anatomical presentation as indicated below:

- Computer-aided implant planning and placement including flapless techniques (eg, interactive treatment planning software applications, surgical guides, and navigation systems)
- Implant placement in a highly esthetic zone or where concavities, ridge inclination, inadequate bone volume or quality, undeterminable proximity to vital structures, and insufficient inter-radicular spacing is suspected
- Pre- and postadvanced bone grafting evaluation (eg, sinus lift, ridge splitting, block grafting)
- History or suspected trauma to the jaws, foreign bodies, maxillofacial lesions, and/or developmental defects
- Evaluation of postimplant complications (eg, postoperative neurosensory impairment, osteomyelitis, acute rhinosinusitis)

It is important to keep in mind that the smallest possible FOV should be used and the entire image volume should be interpreted.

Additional recommendations

Education. The use of CBCT requires a specific skill set, that until recently has not been taught in dental schools at either the undergraduate or postgraduate levels. Therefore, it is also recommended that clinicians who are providing dental implant procedures for their patients become knowledgeable in 3D diagnosis and treatment planning concepts, and become familiar with interactive treatment planning software applications.

Protocols. 3D imaging technology does not supersede sound surgical and restorative/prosthetic fundamentals. Clinicians should understand that the scan process often starts before the scan itself. Diagnostic wax-ups, mounted articulated study casts, and the use of scanning templates helps to improve the diagnostic accuracy of the CBCT data as it relates to the desired implant placement or ancillary grafting procedure. The use of scanning and surgical templates helps to improve surgical accuracy, reduce postoperative morbidity, and aid in the restorative phase of treatment.

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Addendum

The American Association of Physicists in Medicine whose members continually strive to improve medical imaging by lowering radiation levels and maximizing benefits of imaging procedures involving ionizing radiation, issued a Position Statement on radiation risks from medical imaging procedures on December 13, 2011. In part, it reads "predictions of hypothetical cancer incidents and deaths in patient populations exposed to such low doses are highly speculative and should be discouraged. These predictions are harmful because they lead to sensationalistic articles in the public media …." Readers are urged to go to the website of the American Association of Physicists in Medicine to read this statement in its entirety.

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