

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/258011761>

# Role of computed tomography imaging in dental implantology: An overview

Article in *Journal of Oral and Maxillofacial Radiology* · May 2013

DOI: 10.4103/2321-3841.120105

CITATIONS

6

READS

594

4 authors, including:



**Hemchand Surapaneni**

Drs Sudha and Nageswara Rao Siddhartha Institute of Dental Sciences

15 PUBLICATIONS 69 CITATIONS

[SEE PROFILE](#)



**Ravi Shankar Y**

GITAM Dental College & Hospital, Visakhapatnam

32 PUBLICATIONS 106 CITATIONS

[SEE PROFILE](#)

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



Retention of denture bases fabricated by three different processing techniques — An in vivo study [View project](#)



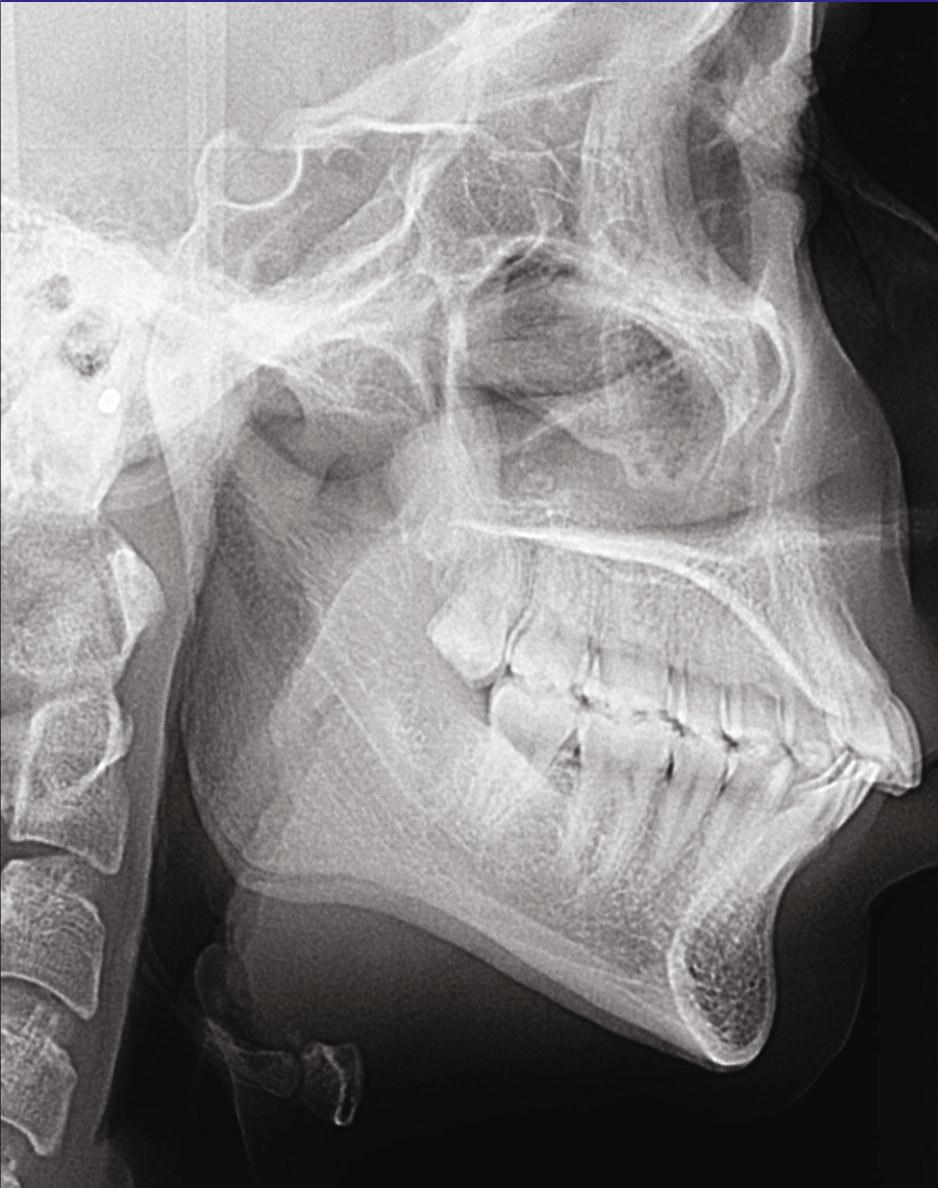
dentistry [View project](#)

# Journal of Oral and Maxillofacial Radiology

An official Publication of Sifa University, School of Dentistry

May-August 2013 • Issue 2 • Volume 1

[www.joomr.org](http://www.joomr.org)





# Role of computed tomography imaging in dental implantology: An overview

Hemchand Surapaneni, Pallavi Samatha Yalamanchili<sup>1</sup>, Ravi Shankar Yalavarthy<sup>2</sup>, Arunima Padmakumar Reshmarani<sup>3</sup>

Departments of Prosthodontics, and <sup>1</sup>Periodontics, Drs. Sudha & Nageswara Rao Siddhartha Institute of Dental Sciences, Chinaoutpalli, Gannavaram Mandal, Vijayawada, <sup>2</sup>Department of Prosthodontics, Gitams Dental College and Hospital, Gandhi Nagar Campus, Rushikonda, Visakhapatnam, Andhra Pradesh, <sup>3</sup>Department of Periodontics, Sree Mookambika Institute of Dental Sciences, Padanilam, Tamil Nadu, India

## ABSTRACT

Dental implants have become an accepted form of permanent tooth replacement. Advanced imaging studies can be used to determine the suitability of implant placement. Dental computed tomography (CT) has been proved to be an excellent procedure for characterizing the anatomy and dental related abnormalities of the jaws. A number of modalities such as dentascans, cone beam computed tomography (CBCT), dental CBCT software, etc., are now available. This makes the diagnostic process more interactive and increases the diagnostic potential. This article reviews the various imaging modalities available for pre-operative implant site assessment, measurement of bone density, use of radio opaque surgical guide and stimulation of implant placement using computerized application of CT.

**Key words:** Cone beam computed tomography, computed tomography, dental implants

## INTRODUCTION

According to the World Health Organization, complete or partial absence of natural teeth is a public health problem with potential poor outcomes. The development of the osseointegrated type of dental implant in the 1970s by Branemark<sup>[1, 2]</sup> was the break through that made dental rehabilitation more reliable. The advent of three-dimensional (3D) imaging and surgical planning software for implant placement has profoundly affected the science of implantology. Proper implant treatment planning remains the first priority for implant success. Dental imaging is an important tool to accomplish this task. It is now possible to plan more accurately and place dental implants more precisely. This article focuses on the role of

computed tomography (CT) in dental implant treatment planning.

## VARIOUS DIAGNOSTIC AIDS

Diagnostic imaging can play an important role in evaluating the dental implant patient.<sup>[3-5]</sup> Several intraoral and extraoral radiographic methods such as periapical, occlusal, panoramic and motion tomography and reformatted cross-sectional, panoramic and 3D imaging are commonly available for evaluation of the implant recipient site, but the information is based on bi-dimensional geometric projections.<sup>[6]</sup>

Radiographic evaluation is essential for assessing bony support for endosseous dental implants. Some of the drawbacks of these techniques include superimposition, poor visualization of other anatomic structures and distortion.<sup>[7]</sup> There might be discrepancies in measurements compared with those from volumetric methods such as multidetector CT or cone beam computed tomography (CBCT), especially if the site of interest is less than 15 mm high. Nowadays, the most accurate technique for pre-operative evaluation of dental implantation is dental CT. Dental CT demonstrates the quantity of bone in 3D, the

Access this article online	
Quick Response Code:	Website: www.joomr.org
	DOI: 10.4103/2321-3841.120105

**Address for correspondence:** Dr. Hemchand Surapaneni, Department of Prosthodontics, Drs. Sudha and Nageswara Rao Siddhartha Institute of Dental Sciences, Chinaoutpalli, Gannavaram Mandal, Vijayawada, - 521 286, Andhra Pradesh, India. E-mail: hemchand\_18@yahoo.co.in

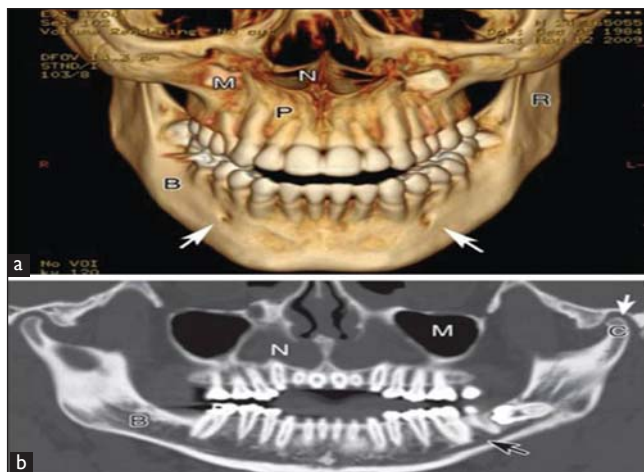
location of important adjacent anatomic structures (e.g., mandibular canal, dental inferior nerve, incisive foramen, mental foramen, maxillary sinus) and the quality of available bone with minimal geometric distortion.<sup>[7]</sup>

## COMPUTED TOMOGRAPHY

CT is a digital medical technique, which can generate 3D images of a patient's anatomy by reconstructing many axial slices. A 3D scanning allows clinicians to visualize the bony architecture, nerves, joints, sinuses and other structures much more completely than traditional flat radiographs. The newer generation of CT scans produces axial images perpendicular to the long axis of patient by rotating a radiation source, which emits fan-shaped beams 360° around. The detectors capture X-rays, which transmit the subject and the data is processed by a computer. It is unique in that it provides images of a combination of soft-tissues, bone and blood vessels.<sup>[8]</sup> CT scans can identify most inferior alveolar canals when multiple cross-sectional views are performed.<sup>[9]</sup> CT scans have been shown to be very accurate with the magnification effect, the same for both the anterior and posterior area, from a range of 0% to 6% in horizontal as well as 0-4% in the vertical dimension.<sup>[10]</sup> The technique of dental CT also known as dentascans was developed by Schwartz *et al.*<sup>[3]</sup> The dental CT can be performed with a conventional CT, a spiral CT or a multislice CT scanner [Figure 1a and b].

## WHY CT ADVANTAGEOUS OVER OTHERS?

A conventional X-ray technique, such as periapical, occlusal and panoramic radiography, is a simple, low-cost and still



**Figure 1:** (a and b) Normal anatomy of the jaws. Volume-rendered (a) and panoramic (b) computed tomography images show the nasal fossa (N), alveolar recess of the maxillary sinus (M), palate (P in a), body of the mandible (B), mental foramina (arrows in a), ramus of the mandible (R in a), condylar head (C in b), glenoid fossa (white arrow in b) and inferior alveolar canal

frequently used method, but the information provided might be insufficient. Geometric distortion occurs in about 25% of studies since the plane parallel to the beam superimposes adjacent anatomic structures. In addition, this method cannot demonstrate opacity differences of less than 10% and does not provide details about the adjacent anatomy.<sup>[6]</sup> Quantitative CT (i.e., quantitative interpretation of values derived from Hounsfield units with a suitable calibration procedure) is the modality of choice to determine bone mineral density (BMD). Quantitative CT to measure BMD by using simultaneous scanning for calibration has been extended to the jaws.<sup>[11-14]</sup>

High-resolution dental CT<sup>[3,4]</sup> can generate panoramic, cross-sectional and 3D reformatted images of the alveolar bone and adjacent structures providing accurate information about bone height and width of the alveolar ridge to determine the alternatives for dental implantation. The advantages of dental CT include elimination of superimpositions. It also allows distinction of opacity differences between two tissues (i.e., contrast resolution) and further image projections or planar reformations can be performed.<sup>[6]</sup> Dental CT can be achieved with multidetector CT or more recently with CBCT.<sup>[15-18]</sup>

## CBCT or cone beam volumetric tomography

Because of higher radiation exposure, higher cost, huge footprint and difficulty in accessibility associated with CT, a new type of CT, CBCT was developed.<sup>[19,20]</sup> CBCT scanners, newer generation machines specifically designed for the maxillofacial region, have allowed for reduction in the radiation absorbed by patient. It uses a single 360° rotation around the maxillofacial region and a cone beam, in comparison, a spiral CT, which makes several rotations and uses a fan beam. When matched up next to the conventional CT the lower cost, lower radiation exposure and in-office feasibility of CBCT render it the ideal model for oral and maxillofacial radiology. The theoretical resolution of CBCT is higher than CT. The voxel size, an indicator of resolution, can be as small as 0.1 mm for CBCT when compared with 0.5 mm for modern CT.

## Indications and Contraindications

The most relevant indications for dental CT in the pre-operative evaluation of dental implant placement (listed in order of importance) are as follows:

- Assessment of height and thickness in cases of alveolar bone atrophy;<sup>[21]</sup>
- Assessment of the positions and states of the structures critical for adequate implant placement (e.g., inferior alveolar canal, location of the neurovascular bundle and the incisive and mental foramina, pneumatization

- of the maxillary sinus, floor of the maxillary sinus, nasal fossa);
- c. Diagnosis and treatment in maxillofacial surgery;
- d. Examination after placement of implants and bone grafts; and
- e. Evaluation of bone resorption and root retention, as well as lesions of the facial skeleton. The main contraindications include claustrophobia, Parkinson disease, tremors and tics and disabling conditions that might cause a patient to be uncooperative. One of the drawbacks of multidetector CT is radiation dose, which has been an issue of concern.<sup>[19,20]</sup>

## DENTAL IMPLANTS AND CT

Considering the new age tool, it blends the concept of thin layer radiography (tomography) with computer synthesis of image. It was first applied successfully in implantology in the 1980s. In CT, multiple thin axial slices at small distances are obtained through the jaws and data is reformatted with special software package to produce cross-sectional, panoramic and 3D images. As long-term dental implantation becomes more successful from both a functional and a cosmetic perspective, imaging before such implantation will become the responsibility of the implantologist. Model based treatment planning with the assistance of CT images has been developed to fulfill the purpose.<sup>[22]</sup> After a diagnostic cast and a pre-planned wax-up, diagnostic templates are fabricated or modified from existing dentures.<sup>[23]</sup> The implant position as well as direction is determined based on final restoration position using radiopaque material, such as guttapercha<sup>[24]</sup> or metalpins<sup>[25]</sup> to mark the spots. Images are then evaluated for available bone height, width and related vital anatomical structures [Figure 2a and b].

## IMAGING

Preliminary CT examination of the mandible or maxilla for implantation uses a bone algorithm to obtain contiguous 1 mm thick axial images of the mandible (excluding the

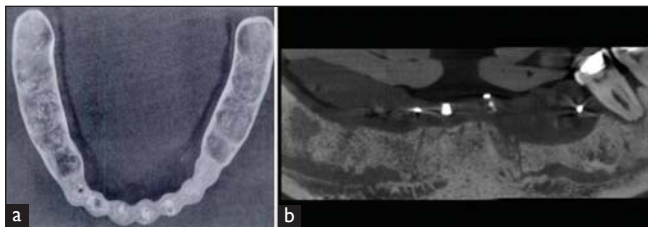
condyles) or the maxilla parallel to the alveolar ridge. A custom-designed stent may be worn by patient during CT examination.<sup>[26,27]</sup> A volume of data is acquired by CBCT, which is then reformatted and three different types of two-dimensional (2D) images are synthesized. The three types of 2D CT reconstructions are axials cans, cross-sectional reconstructions and panoramic reconstruction [Figure 3a-c].<sup>[28]</sup>

## IMAGE INTERPRETATION

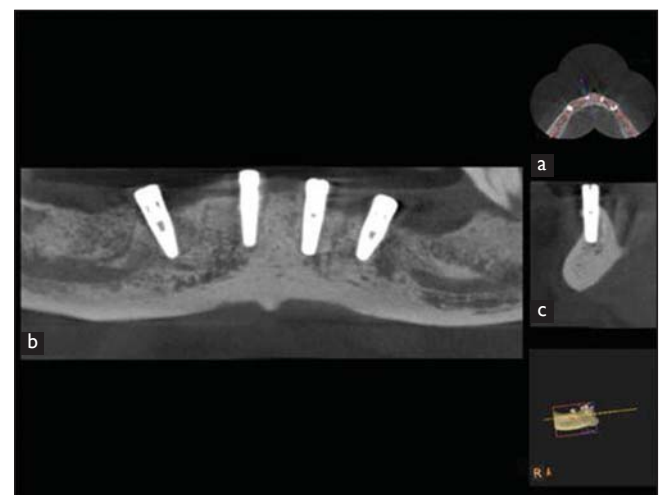
The most important information to document is the location of the indicated site, bony height and width(with the cortex included) and inclination from the vertical are noted.<sup>[26,27]</sup> Bone atrophy and remodeling of the alveolar ridge are common after tooth removal or loss; important landmarks should be noted such as the bony depth to the mandibular canal and the distance to the inferior recess of the maxillary sinus or to the floor of the nasal cavity.<sup>[27]</sup> If a stent is not used, similar data should be recorded from edentulous areas or at selective sites such as parasymphseal and premolar locations. The quality of bone directly affects the success of osseointegrated implants [Figure 4a and b].

## Interactive Implant Treatment Planning

An interactive computer program can be used for examination before dental implantation. With the aid of interactive software, another approach for the transfer of implant planning to the surgical site is to use computer-aided design/computer-aided manufacturing technique. Many software programs are currently available [Table 1]. These



**Figure 2:** (a and b) Acrylic stent with central radiopaque markers indicating the sites of proposed dental implants. Outer surface of the stent is lightly quoted with barium to facilitate stent location during computed tomography examination



**Figure 3:** (a) Panoramic computed tomography (CT) images showing implants placed in the line of arc. (b) Axial CT image shows the body and rami of the mandible and the implants osseointegrated.(c) Cross-sectional oblique CT panoramic CT images show the relationship of the implant to other structures, including contiguous implants

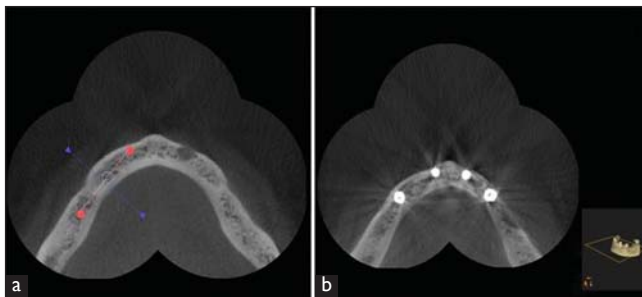
programs enable the clinician to transfer CT/CBCT findings in to the surgical area. Using one of these software programs, clinician uses CT data obtained with the same displays of axial, cross-sectional and panoramic images allowing them for pre-operative simulation of implant placement, prosthetic simulation and bone augmentation simulation that makes the software the state-of-the-art imaging tool for implants. Bony width and height and regional abnormalities are determined and measurements of bony attenuation are performed. In addition, an implantology team can manipulate graphically displayed implants to allow a more accurate selection of implant size and orientation and a better appreciation and estimation of reconstructive needs like bone-graft augmentation [Figure 5].<sup>[29]</sup>

Furthermore, the placed implant can be evaluated from several different viewpoints as well as from 3D view. It can also be rotated and tilted on any axis to adjust its position. For multiple implant placements, the parallel relationship to simplify prosthetic reconstruction can be ascertained. Moreover, once treatment planning is determined in the computer, it can be saved and applied to surgical sites by means of image-aided template production<sup>[30]</sup> or image-

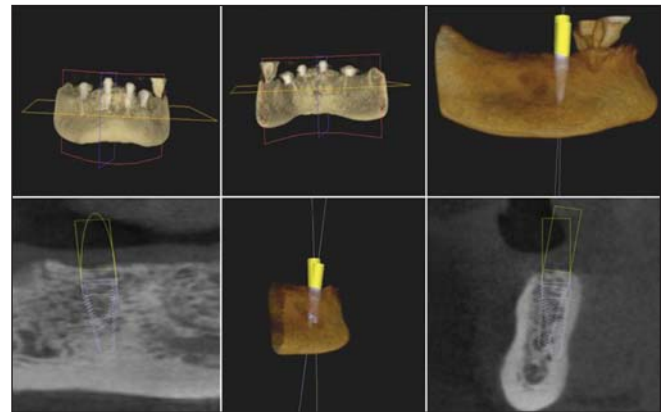
aided navigation.<sup>[31]</sup> The primary interest in the literature is the accuracy of transferring treatment plan in to the surgical field. CT based implant planning and its transfer to the surgical field through a surgical guide has resulted ~1 mm of mean linear deviation and 3° mean angulation difference. Although computer-aided-implant placement is a promising technique, the unexpected high linear deviation, which sometimes reaches 4 mm and angulation deviation 17°<sup>[32]</sup> can be a major concern. Hence, more research is needed before this approach can be widely used. With the use of interactive CT, not only is the surgical phase of treatment planned, but the prosthetic phase is planned as well.

## SUMMARY AND CONCLUSION

Dental CT enables analysis of the state, quality and quantity of bone, jaw tomography and important anatomical landmarks. However, because of its higher



**Figure 4:** Transverse pre-operative (a) and post-operative (b) scans of mandible, with regions of interest indicating implant positions. Because of blurring, implants appear larger on the postoperative scan than they actually are



**Figure 5:** Three-dimensional scans of mandible obtained from pre-operative (rendered with gradient shading) and post-operative data sets. Implant positions were depicted with summed-voxel rendering. Transparent gradient-shaded rendering of the pre-operative data set, with superimposed implant positions

**Table 1: Software programs for implant treatment planning**

Comparison of some of commonly used software programs for implant planning			
Software	Company	Features	Website
Simplant	Materialize, Belgium	Compatible with SLA technique	www.materialisedental.com
ProCera	Noble Biocare, Sweden	Compatible with SLA technique dual-scan technique: The patient scanned with the guide and the guide itself alone	www.nobelbiocare.com
VIP	Implant logic Cedarhurst, NY	Compatible with five-axis milling technique Copu-Guide (pilot and the complete Compu-Guide)	www.implantlogic.com
Scan 2 Guide	iDent, Israel	Compatible with SLA technique Have license to make guides in the United States Dual-S scan technique	www.ident-surgical.com
In vivo dental	Anatomage, CA	Volumetric superimposition function 3D stitching plugin create-model (compatible with SLA)	www.anatomage.com
Facilitate	Astra Tech, Sweden	Based on the Simplant software	www.astratech.nl
Easy guide	Keystone Dental, MI	Xmmarker: Allow for surgical guide manufacturing process	www.keystonedental.com
Dolphin3D	Patterson Dental, St. Paul, MN	Volume-to-volume superimposition 3D nerve marking	www.dolphinimaging.com
Accu dental	Medical Modeling Co.	Compatible with SLA technique	www.medicalmodeling.com

SLA: Stereolithography

radiation exposure and cost associated with CT, CBCT was introduced to overcome these shortfalls. With images acquired from CBCT and the assistance of software programs, has greatly enhanced the dental implant team's ability to plan, place and restore implants accurately, with a level of precision that was unattainable a few years ago. CBCT permits more than diagnosis; it facilitates image-guided surgery fulfilling esthetic, functional and biologic demands of both the surgical and prosthetic phases in dental implants.

## REFERENCES

- Brånemark PI, Hansson BO, Adell R, Breine U, Lindström J, Hallén O, *et al.* Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl* 1977;16:1-132.
- Block MS, Kent JN, Guerra LR. *Implants in Dentistry*. Philadelphia: Saunders;1997. p. 17-45.
- Schwarz MS, Rothman SL, Rhodes ML, Chafetz N. Computed tomography: Part I. Preoperative assessment of the mandible for endosseous implant surgery. *Int J Oral Maxillofac Implants* 1987;2:137-41.
- Schwarz MS, Rothman SL, Rhodes ML, Chafetz N. Computed tomography: Part II. Preoperative assessment of the maxilla for endosseous implant surgery. *Int J Oral Maxillofac Implants* 1987;2:143-8.
- James RA, Lozada JL, Truitt HP. Computer tomography (CT) applications in implant dentistry. *J Oral Implantol* 1991;17:10-5.
- Lam EW, Ruprecht A, Yang J. Comparison of two-dimensional orthoradially reformatted computed tomography and panoramic radiography for dental implant treatment planning. *J Prosthet Dent* 1995;74:42-6.
- Matteson SR, Deahl ST, Alder ME, Nummikoski PV. Advanced imaging methods. *Crit Rev Oral Biol Med* 1996;7:346-95.
- Worthington P, Rubenstein J, Hatcher DC. The role of cone-beam computed tomography in the planning and placement of implants. *J Am Dent Assoc* 2010;141Suppl 3:19S-24.
- Todd AD, Gher ME, Quintero G, Richardson AC. Interpretation of linear and computed tomograms in the assessment of implant recipient sites. *J Periodontol* 1993;64:1243-9.
- Reddy MS, Mayfield-Donahoo T, Vandervan FJ, Jeffcoat MK. A comparison of the diagnostic advantages of panoramic radiography and computed tomography scanning for placement of root form dental implants. *Clin Oral Implants Res* 1994;5:229-38.
- Lindh C, Nilsson M, Klinge B, Petersson A. Quantitative computed tomography of trabecular bone in the mandible. *Dentomaxillofac Radiol* 1996;25:146-50.
- Maki K, Okano T, Morohashi T, Yamada S, Shibasaki Y. The application of three-dimensional quantitative computed tomography to the maxillofacial skeleton. *Dentomaxillofac Radiol* 1997;26:39-44.
- Maki K, Miller A, Okano T, Shibasaki Y. Changes in cortical bone mineralization in the developing mandible: A three-dimensional quantitative computed tomography study. *J Bone Miner Res* 2000;15:700-9.
- Iwashita Y. Basic study of the measurement of bone mineral content of cortical and cancellous bone of the mandible by computed tomography. *Dentomaxillofac Radiol* 2000;29:209-15.
- Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. *J Can Dent Assoc* 2006;72:75-80.
- Miles DA. Clinical experience with cone-beam volumetric imaging: Report of findings in 381 cases. *US Dent* 2006;1:39-41.
- 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.
- Almog DM, LaMar J, LaMar FR, LaMar F. Conebeam computerized tomography-based dental imaging for implant planning and surgical guidance, Part 1: Single implant in the mandibular molar region. *J Oral Implantol* 2006;32:77-81.
- Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. *Dentomaxillofac Radiol* 1999;28:245-8.
- Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: Preliminary results. *Eur Radiol* 1998;8:1558-64.
- Kohavi D, Bar-Ziv J, Marmary Y. Effect of axial plane deviation on cross-sectional height in reformatted computed tomography of the mandible. *Dentomaxillofac Radiol* 1997;26:189-91.
- 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.
- Israelson H, Plemons JM, Watkins P, Sory C. Barium-coated surgical stents and computer-assisted tomography in the preoperative assessment of dental implant patients. *Int J Periodontics Restorative Dent* 1992;12:52-61.
- Klein M, Cranin AN, Sirakian A. A computerized tomography (CT) scan appliance for optimal presurgical and preprosthetic planning of the implant patient. *Pract Periodontics Aesthet Dent* 1993;5:33-9.
- Peck JN, Conte GJ. Radiologic techniques using CBCT and 3-D treatment planning for implant placement. *J Calif Dent Assoc* 2008;36:287-90, 292.
- Weinberg LA. CT scan as a radiologic data base for optimum implant orientation. *J Prosthet Dent* 1993;69:381-5.
- DelBalso AM, Greiner FG, Licata M. Role of diagnostic imaging in evaluation of the dental implant patient. *Radiographics* 1994;14:699-719.
- Bellaiche N. Imaging in oral implantology. In: Scortecchi GM, Misch CE, Benner KU, editors. *Implants and Restorative Dentistry*. 1<sup>st</sup>ed. London: Martin Dunitz Publication; 2001. p. 178-96.
- 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.
- Verstreken K, Van Cleynebreugel J, Marchal G, Naert I, Suetens P, van Steenberghe D. Computer-assisted planning of oral implant surgery: A three-dimensional approach. *Int J Oral Maxillofac Implants* 1996;11:806-10.
- Siessegger M, Schneider BT, Mischkowski RA, Lazar F, Krug B, Klesper B, *et al.* Use of an image-guided navigation system in dental implant surgery in anatomically complex operation sites. *J Craniomaxillofac Surg* 2001;29:276-81.
- 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.

**Cite this article as:** Surapaneni H, Yalamanchili PS, Yalavarthy RS, Reshmarani AP. Role of computed tomography imaging in dental implantology: An overview. *J Oral Maxillofac Radiol* 2013;1:43-7.

**Source of Support:** Nil. **Conflict of Interest:** None declared.