REVIEW ARTICLE

Dental Implant Imaging and Its Current Update: A Review

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Abstract

People who have severe dental issues and were unable to keep their natural teeth have seen an improvement in their quality of life thanks to dental implants. They have gained a lot of traction since they can replace damaged tooth structures permanently and give restorative benefits for a modern lifestyle without affecting the patient's self-esteem or oral or speaking skills. Since the advent of newer imaging modalities, choosing a suitable implant imaging technique has become a difficult task, and several of these are employed for implant imaging. The imaging modality should provide dimensional accuracy in addition to accounting for the anatomy. Due to the need of placing implants in the exact planned position in both mandible and maxilla, radiography has grown to serve a major part in dental implantology diagnosis and treatment planning. Since there are so many imaging modalities available, treatment planning for implant placement can be difficult. Therefore, all associated benefits and drawbacks should be taken into account when choosing the type of imaging technique for pre and postoperative assessment of dental implants, which will be comprehensively reviewed in this study.

Keywords: Advanced imaging, Dental implants, Implant software, Radiography.

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Introduction

People who have severe dental issues and were unable to keep their natural teeth have seen an improvement in their quality of life thanks to dental implants. They have gained a lot of attraction since they can replace damaged tooth structures permanently and give restorative benefits for a modern lifestyle without affecting the patient's self-esteem or oral or speaking skills. Due to the need of placing implants in the exact planned position in both the mandible and maxilla, radiography has grown to serve a major part in dental implantology diagnosis and treatment planning. Conventional radiographic techniques like periapical radiographs, occlusal radiographs, and panoramic pictures were the conventional imaging modalities of implant diagnosis and treatment planning until the late 1980s. These radiography modalities represent three-dimensional (3D) structures in two dimensions (2D). Cephalometrics, computed tomography (CT), magnetic resonance imaging (MRI), and cone-beam CT (CBCT) are just a few of the modern radiographic imaging modalities that are becoming increasingly relevant for effective implant placement. Imaging is used to determine the best course of treatment Imaging is used to determine the best course of treatment and locate the inferior alveolar nerve and maxillary sinus for the patients, measure the quantity of bone, height, buccolingual width, and angulation of the alveolar process, look for any potential pathological conditions and determine the length and width of the implant to be placed. Imaging also plays a significant role to detect any abnormalities after implant placement. As a result, selecting the right imaging modality for implant treatment planning could be challenging.

Description of Different Imaging Modalities

Tow-dimensional Implant Imaging Techniques

Periapical radiographs are regularly employed to study areas of interest that require better image detail since they outperform panoramic radiographs in this regard. Periapical radiographs, which exceed panoramic radiographs in this sense, are frequently used to explore areas of interest that require more image information. Periapical radiographs provide exact measurements, the location of nearby tooth roots, and the assessment of the recipient alveolar bone's quality based on the trabecular pattern (Fig. 1). Periapical radiography exposes patients to less radiation and can be used in any clinical setting.[1]

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Digital Imaging

Film-based radiography has been replaced with direct digital intraoral imaging. Its benefits include efficient image capturing, storage, retrieval, and transmission to remote locations. Direct height and width measurements are possible. Teleradiography allows these radiographs to be conveniently transferred to different operator sites.[1]

Occlusal Radiography

Intraoral occlusal radiographs can be utilized to determine buccolingual width and contour, especially in the edentulous mandible. High-resolution planar pictures of the mandible or maxilla are produced *via* occlusal radiography. Structures including the maxillary sinus, nasal cavity, and nasopalatine canal can all be assessed with occlusal radiography. A mandibular occlusal

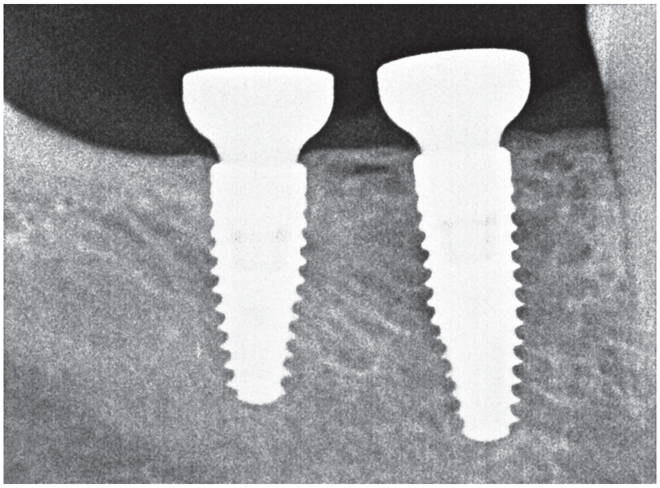

Fig 1: The intraoral periapical imaging-guided implant

radiograph's projection is less distorted than a maxillary occlusal radiograph's[1,2]

Panoramic Radiography

The imaging method should be able to evaluate probable prosthetic placements, provide practicable surgical insertion courses, help with postoperative evaluations, and provide diagnostic and therapeutic documentation in addition to being able to analyze normal anatomic features from all angles. Panoramic radiography is one of the imaging modalities that can aid a practitioner in achieving these goals.[2] A panoramic radiograph is useful in determining the relationship of anatomic features such as maxillary sinuses, mandibular canals, and maxillary and mandibular foramen to the implant site, as well as diagnosing extensive etiology inside the jaws. Panorama radiography has a number of drawbacks, the most significant of which is image distortion and low reproducibility.

Zonography

Zonography is a cross-sectional image of the jaws created by modifying a panoramic X-ray machine. The thickness of the tomographic layer is roughly 5 mm. Zonography can be used to understand the spatial relationship between significant structures and the implant site.[1,2]

Cephalometric Radiography

For the examination of the anterior maxilla and mandible for implant placement, cephalometric radiographs, specifically those of the lateral aspect, have been recommended. Using a combination of lateral and posteroanterior cephalograms, it is possible to accurately measure the height and width of the residual bone at the mandibular and maxillary anterior midlines. The lateral cephalograms can also be used to view the residual ridge connection, as well as to determine and develop new occlusal schemes.[3]

Three-dimensional Implant Imaging Techniques

Dental radiography has been the main source of diagnostic data in the oral and maxillofacial complex since the discovery of X-rays 120 years ago. However, complex 3D anatomical features and associated diseases cannot be represented using two-dimensional (2D) imaging approaches.

As 2D has several drawbacks, such as superimpositions and distortions, it was necessary to develop new imaging modalities in order to meet the expectations of advanced implant dental treatment.

Computed Tomography

For implant site assessment, CT has been generally recommended, especially in the mandibular and maxillary posterior regions and in complicated situation. The CT is a computerized representation of a tissue slice that is calculated from the attenuation of numerous exposures of an X-ray beam at various angles through a tissue slice. Axially oriented slices, or slices that are normally at right angles to the patient's body's long axis, are exposed by the CT unit when it is set up for implant imaging applications.[4]

For the examination of implant sites, particularly in the posterior regions of the maxilla and mandible, and in complicated situations, CT has been strongly recommended (Fig. 2). The CT is a digital image of a tissue slice generated mathematically from the measurement of the attenuation of multiple exposures of an X-ray beam at various angles through a tissue slice. For implant imaging applications, the CT unit is aligned to expose tissue slices that are roughly at right angles to the patient's body's long axis and are referred to as axially oriented slices. Computed tomography can provide you with a numerical number (in Hounsfield units) for the linear attenuation coefficient of a bone location, which can help you figure out how dense your bones are. The use of a calcium hydroxide standard in quantitative computed tomography (QCT) may provide a more accurate method of assessing bone density[4,5] Computed tomography has faster examination time and produces sharper images with less distortion and higher X-ray efficiency however CT is more expensive and causes more radiation exposure to the patients.

Interactive Computed Tomography

It took a long time for computerized tomography to be adopted in dentistry, despite the fact that it is significantly superior to previous radiography procedures. When it comes to implant instances, the absence of distortion allows for more predictability. The primary benefit of ICT is that it allows clinicians to do "electronic surgery." This allows the clinician and the patient to visualize before having implant surgery, the treatment plan can be visualized and merged with the patient's anatomy.[6] In 1993, the SIMPLANT® 3D dental software package for Windows was released, allowing practitioners to plan implant cases interactively on their own computers. The SIMPLANT® program has several advantages, including the capacity to detect bone density, identify and measure the implant's proximity to important structures, and estimate the volume required for a sinus graft.

Tuned Aperture Computed Tomography

For dentoalveolar imaging, film-based tomography and CT are alternatives to tuned aperture computed tomography (TACT), a method based on optical aperture theory. TACT offers a number of benefits, including the ability to identify projection geometry following individual exposures, a decrease in patient movement difficulties, and fewer radiation doses.[7] The TACT imaging can locate crestal deficiencies near implant components and healthy teeth, as well as detect minor or recurrent decay.

The TACT imaging has been demonstrated in studies to be effective in locating crestal abnormalities around dental implants

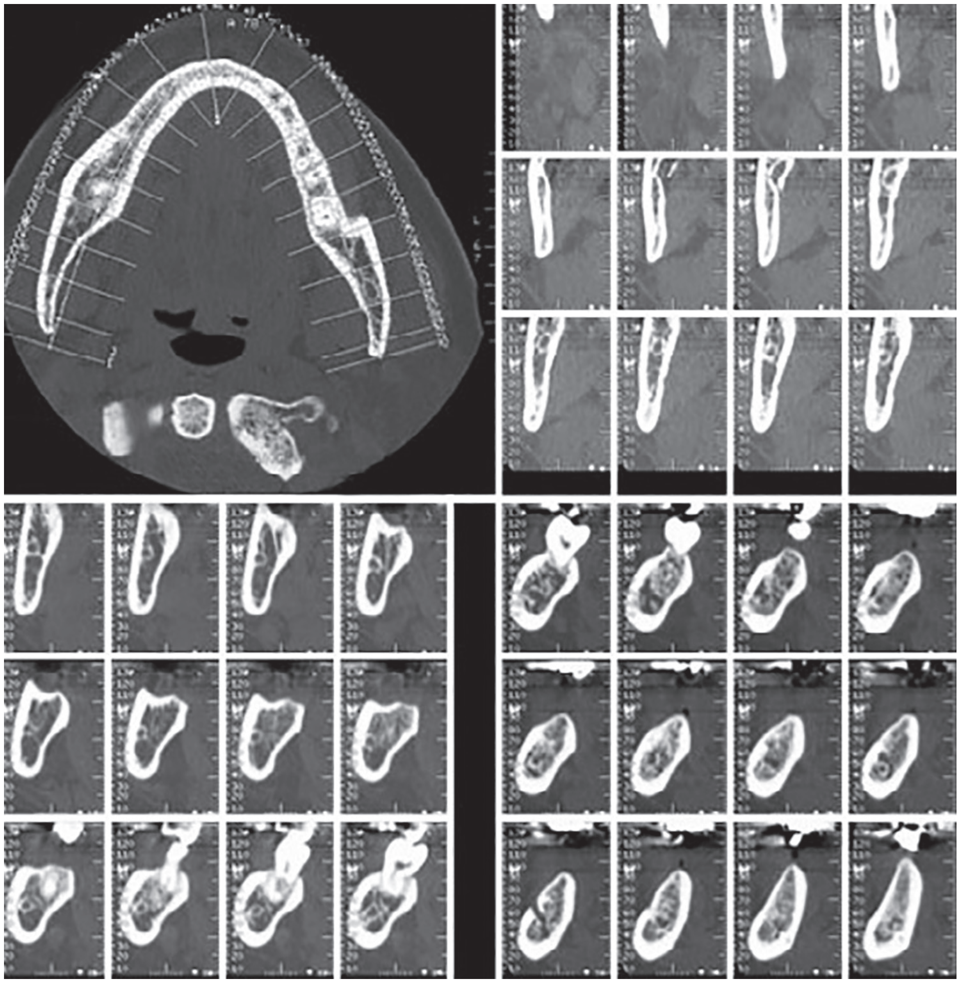

Fig. 2: The CT-guided implant

and natural teeth, as well as detecting mild or recurrent decay.[8] In the future, TACT applications in temporomandibular joint changes, peri-apical lesion localization, periodontal localized and generalized bone loss or growth, and identification of the 3D architecture of accessory root canals are areas to watch.

Cone-beam Volumetric Tomography

To overcome the limitations of traditional medical CT scanners, dental CT scanners have recently been designed to perform a method known as CBCT. In CBCT, an X-ray source and detector are mounted to a rotating gantry in order to create an image. It decreases the cost of radiation detectors in conventional CT and speeds up the collection of all the data for the field of view (FOV).[9]

Cone-beam Computed Tomography

Cone-beam computed tomography equipment revolutionized the clinical application of oral and maxillofacial radiology. Due to its small size, low cost, and low ionizing radiation exposure when compared to medical CT, CBCT was quickly adopted into dentistry settings. The CBCT offers minimum distortion 3D examination of the craniofacial region, similar to medical CT.

Cone-beam computed tomography is used to visualize the maxillary sinus, mandibular inferior alveolar nerve canal, and mental foramen in the mandible. CBCT can more clearly show buccolingual alveolar ridge patterns in edentulous people, such as irregular, narrow crestal or knife-edge ridge, undulating concavities, and alveolar bone quality and quantity. CBCT can assist in preventing excessive bleeding during implant implantation by measuring the distance between the sinus floor, the edentulous alveolar crest, and the vascular canal as well as the course of the vascular canals in the maxillary sinus walls.[8]

For the purpose of implanting a miniscrew, this technique accurately measures the thickness of the hard palate and its surrounding mucosa. The cone-beam technique employs a single 360° scan in which the patient's head is held by a head holder as the X-ray source and a reciprocating area detector move synchronously around it.[9] In order to create a 3D volumetric data set from these picture data that can be utilized to produce primary reconstruction images in three orthogonal planes, these image data are processed by software applications that employ advanced algorithms (axial, sagittal, and coronal) (Figs 3 and 4).

To determine the proper location for the prosthesis, occlusion, and related supporting implants in a virtual environment, a CBCT scan in conjunction with software modeling can be used. For each implant site, the following can be performed using a CBCT scan:

- Using 3D CBCT, the height and width of the bones (bone dimensions) can be determined.

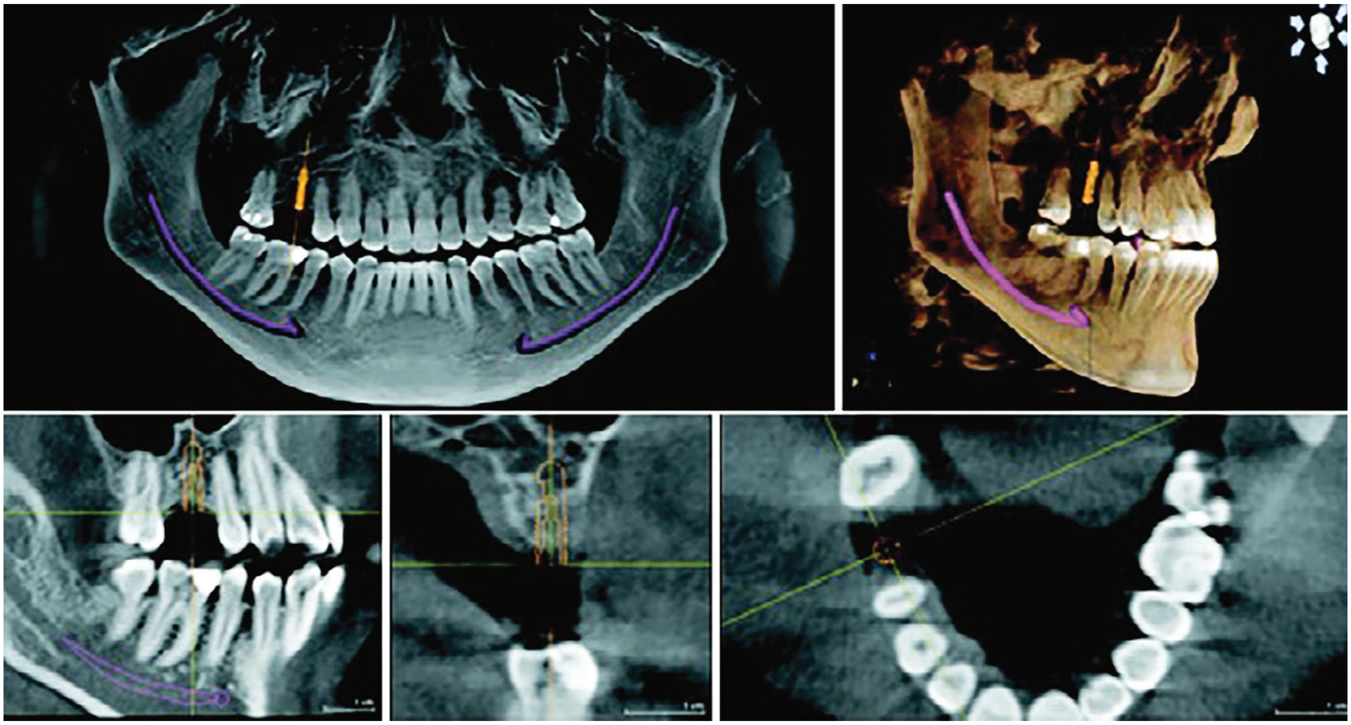

Fig. 3: The CBCT-guided implant

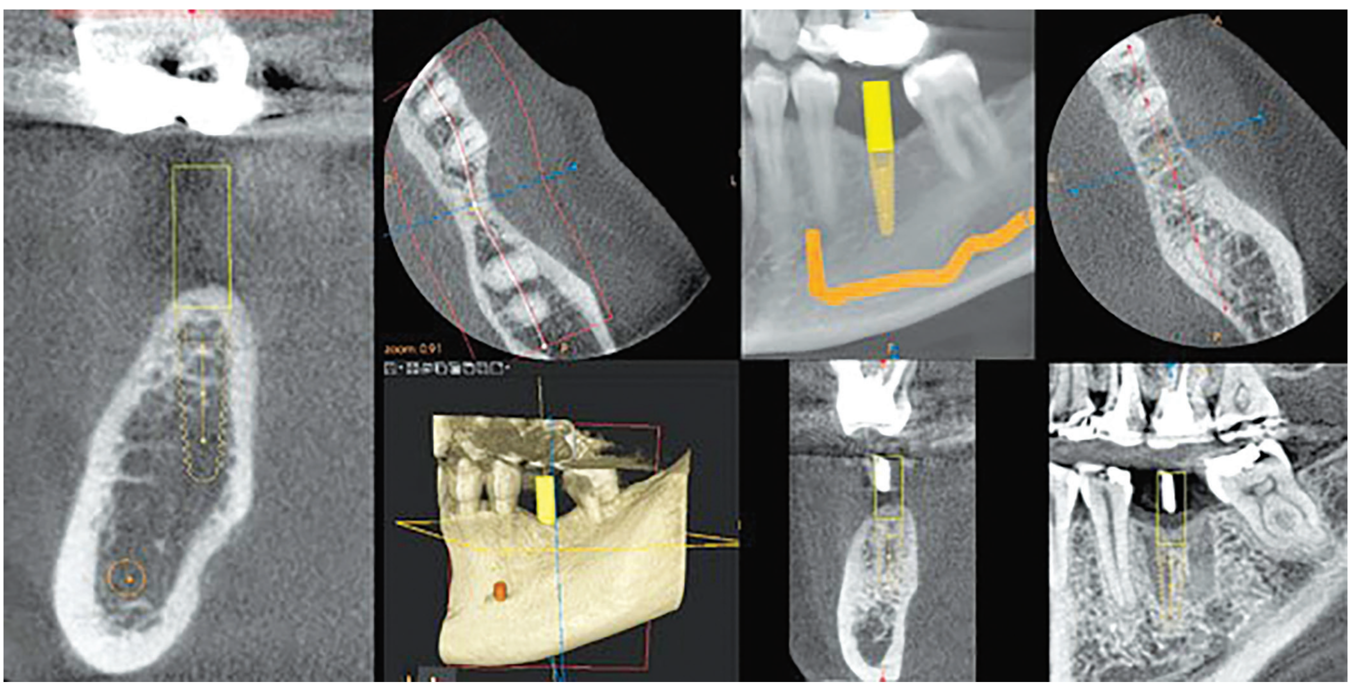

Fig. 4: The CBCT-guided implant

- Assess bone quality using a 3D comparative density study.
- Identify the alveolar bone's long axis.
- Locate and identify internal anatomies like sinus cavities and nerves.
- Establish the jaw's borders.
- Describe and scale pathology in three dimensions.
- Information exchange regarding radiographic planning.
- Disseminate information on radiographic diagnosis and planning.

The operator has been able to get beyond the drawbacks and inadequacies of the different other procedures owing to CBCT. To ensure precise implant placement, CBCT can also be used in conjunction with surgical templates and virtual implant placement software.

Advantages of Cone-beam Computed Tomography

Cone-beam computed tomography can generate all 2D scans, including orthopantomograms and lateral cephalograms, create 3D datasets (digitally rebuilt images with 670 projections), and scan vertically while the subject is seated. Cone-beam computed tomography can be used to visualize anatomical structures, bone trabeculae, periodontal ligament (PDL), and root growth. A quick scanning method, a lesser radiation dose, less disturbance of metal artifacts, a lower cost, greater accessibility, simple handling, and digital imaging and communications in medicine (DICOM) compatibility are further advantages.

Cone-beam computed tomography has some shortcomings. It provides less information about the inside soft tissue, has a poor contrast range, a narrow FOV, a smaller scanned volume due to the small detector size, and greater noise from scatter radiation and artifacts.

Dentascan Imaging

With the revolutionary new computer software program Dentascan, the mandible and maxilla can be imaged using CT in three different reference planes: axial, panoramic, and oblique sagittal (or cross-sectional). The clarity and scale of the multiple views allow for consistent measurements and cross-referencing of anatomical structures across all three planes.[10] The advantages of Dentascan include assessing crucial qualitative parameters for implant placement, determining bone height and width, identifying soft and hard tissue pathology, and pinpointing anatomical structures. The cost, and radiation exposure this imaging technique exposes you to, are its two key shortcomings.

Magnetic Resonance Imaging

The first person to discover MRI was Lauterbur (MRI).The presence of ferromagnetic metals (metals with a high magnetic susceptibility) might cause the magnetic field to be distorted, compromising the photographs. Image deformations do not exist in non-ferromagnetic alloys, but they are abundant in non-precious ferromagnetic alloys (cobalt-chromium). The Brånemark system's implants have no effect on MRI pictures.

By using MRI, which also reveals the fat in the trabecular bone, it is possible to identify the inferior alveolar canal and neurovascular bundle from the nearby trabecular bone. Magnetic resonance imaging eliminates the radiation dangers related to CT.

Patients with ferromagnetic metallic implants should maintain a strategic distance from MRIs. Cross-sectional MRI images are created using conventional reformatting rather than multi-plane reformatting because there isn't software support for MRI data. As a result, MRI is ineffective in determining bone mineralization.[11]

Recent Advances in Imaging

Using the SCANORA platform, the 3DX Accuitomo limited-volume CBCT system was developed (Sordex Orion Corporation, Helsinki, Finland). With technology inherited from the AZ3000, a dento–maxillary multimodal tomographic device, the PSR9000N is also a limited-volume CBCT system (Asahi Roentgen, Japan).

These dental tomographic platforms produce cross-sectional images of the jaws and dental arches in a specific, constrained area. One important advantage of limited-volume CBCT is the decrease in radiation exposure.

The biggest drawback of CBCT is the inability to obtain accurate CT readings, which results in subpar soft tissue resolution. The reduction of metal and beam hardening artifacts, both of which are prevalent in CT imaging, is made possible by this, though. In limited-volume CBCT imaging, the FOV is small compared to the head, and the number of visible X-rays varies during the 360° scan. Metal objects are frequently found in conventional fan-beam CT scans. Metals that can create artifacts are usually observable. Because the cause of halation artifacts is beyond the imaged area, it is difficult to notice their appearance in CBCT. More research is needed to determine the features of these halation artifacts.

Implant Software

Computer software has shown to be quite helpful in implant diagnosis and treatment planning when paired with CT and CBCT. These software programs enable the construction of surgical templates for transferring important information to the patient's mouth as well as nearly original 3D images. Stereolithographic models are often the foundation of this method. In order to provide a 3D image for optimum implant placement treatment planning, the CT data is processed in the DICOM 3 format.

Various implant software systems are described below.

Sidexis (Sirona Galileos)

Galileos Implant software aids even novices in the implant planning process since it depicts the bones in all three dimensions and depicts the nerve canal in color. Through careful design and execution, the implant can be completely adapted to the patient's anatomy, decreasing stress.

Planmeca Romexis

By offering accurate implant, abutment, and crown models, Planmeca Romexis assists in treatment planning and implant placement evaluation. By importing and superimposing a soft-tissue scan and crown design with CBCT data, this software facilitates implant planning.

Anatomageinvivo 5 (Gendex)

Treatment planning is aided by the clinical information provided by cone-beam 3D scans produced by Gendex 3D imaging technology. The *Invivo* 5 software uses the cone-beam 3D scan data to augment it and provide you additional design freedom for crowns, abutments, and implants. You are given the resources you require to organize restorative implants. You can import standard tessellation language (STL) files using the software's open interface, which enables you to add digital impressions made with an intraoral scanner. With the help of CBCT information and the original bite registration from the intraoral scan, the resulting digital impressions can be linked with other images in the appropriate area.

Veraviewepocs 3D (J. Morita 3D Accuitomo)

Since Veraviewepocs 3D R100 offers complete arch imaging, clarity, and a low patient dose, it is a helpful tool for organizing implant treatment. In order to determine the buccal and lingual positions of the implant as well as the distance to the implant, it offers cross-sectional images of the dental arch and illuminates the mandibular canal. The entire jaw can be captured in a high-resolution volume image, which gives the patient a clearer understanding of the implant treatment procedure.

CS9300 3D (Carestream Kodak)

In order to suit the patient's diagnostic demands, the CS9300 3D (Carestream Kodak) gives greater versatility and the ability to collimate the field of vision. The recommended fields of view for implantology with the CS 9300 are 10 cm × 5 cm; 10 cm × 8 cm; and 10 cm × 10 cm.

Anatomical elements can be seen in three dimensions thanks to computer-assisted implant planning. Implametric®, SimPlant®, Nobel Guide®, and other programs are among the other programs.

Conclusion

The success and pleasure of implant implantation can be enhanced by the imaging modalities that are currently available. When selecting projections, it is important to consider the position, surrounding anatomy, size, and quantity of implants. CBCT imaging should be the method of choice for implant placement since it provides excellent diagnostic-quality pictures in a brief amount of time. Despite the fact that there are numerous imaging modalities for implants, the approach should be chosen depending on the circumstances and the clinician's skill in deciphering the captured image.

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