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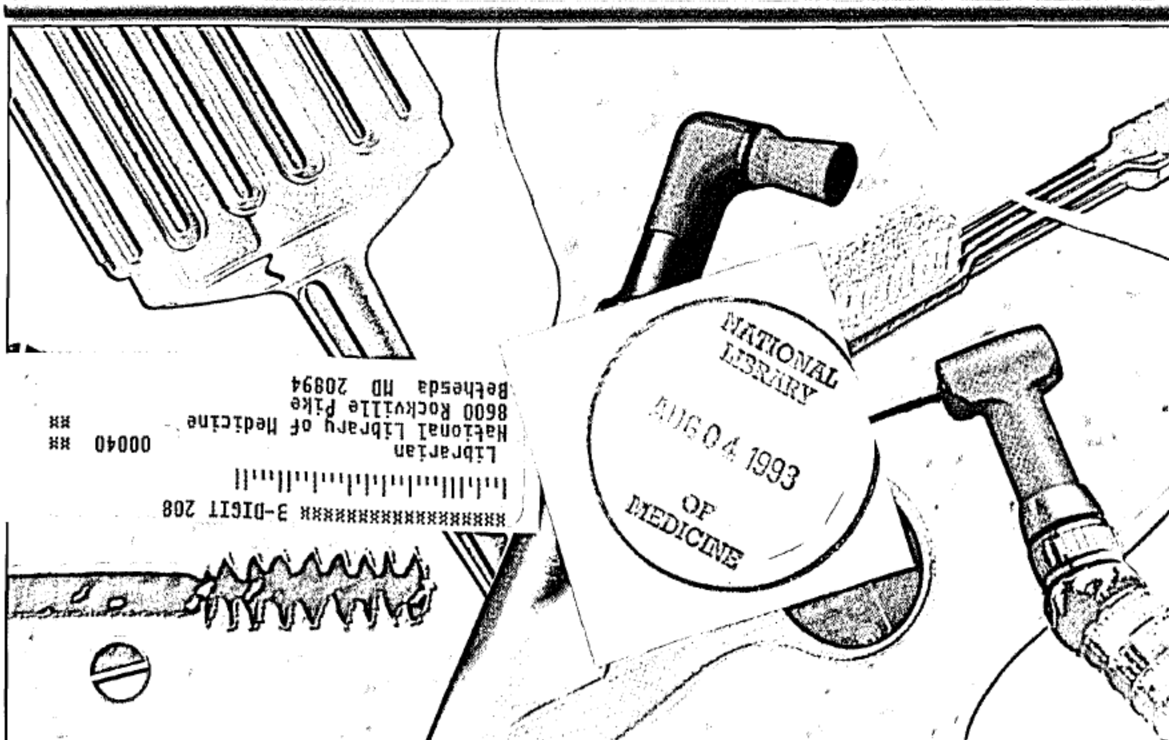

FEATURES

A Computerized Tomography (CT) Scan Appliance For Optimal Presurgical and Preprosthetic Planning Of the Implant Patient

Michael Klein, DDS • A. Norman Cranin, DDS • Aram Sirakian, DMD

This article describes the technique for using the CT (computerized axial tomography) scans, with specially designed software and an adjunct appliance, for accurate planning of dental implants and implant-supported restorations. The available bone can be evaluated, surgical problems anticipated, and errors in placement avoided. The learning objective of this article is an enhanced knowledge of the extended application of the CT scans and the use of the orientation and immobilization appliance.

The reported success of osseointegrated implants [1-5] is making implantology a part of everyday dental practice. The increased demand for dental implants has resulted in new technology by the dental product industry to improve and expand the currently available implant options. This new technology has provided the capability for more accurate presurgical evaluation, easier surgical care, and more aesthetic final restorations.

Traditionally, the clinical evaluation of the implant patient is based on visual examination, manual palpation, gauging tissue thickness, mounted diagnostic casts, diagnostic wax-up, and radiographic analysis, comprising panorex, periapical, and perhaps cephalometric x-rays. This analysis provided a tremendous amount of preoperative diagnostic information on the available bone, its location, and the potential prosthetic outcome.[6] However, it was not uncommon to discover conditions at the time of surgery that differed from what was anticipated, based on the diagnostic information obtained. For example, the bone may have been too thin for implant placement; the bone may not have been where it was necessary for placement of usable prosthetic abutments; the proper alignment of abutments may not have been impossible due to bone angulation. [7-11] When these situations occurred, it became necessary for the surgeon and the restorative dentist (if present) to decide, mid-surgery, where to place or not to place implants. If the restorative dentist was not present, this decision had to be made by the surgeon who might or might not have been capable of deciding if the implant would be restorable.

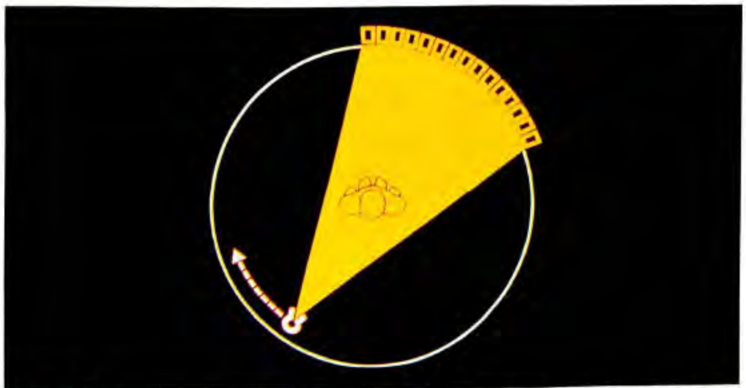

Figure 1. Diagrammatic representation of the radiation source and detectors as it rotates around the patient's head.

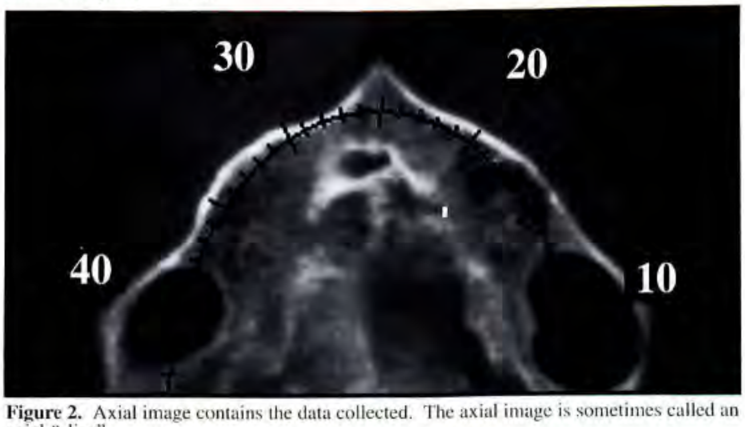

Figure 2. Axial image contains the data collected. The axial image is sometimes called an axial "slice".

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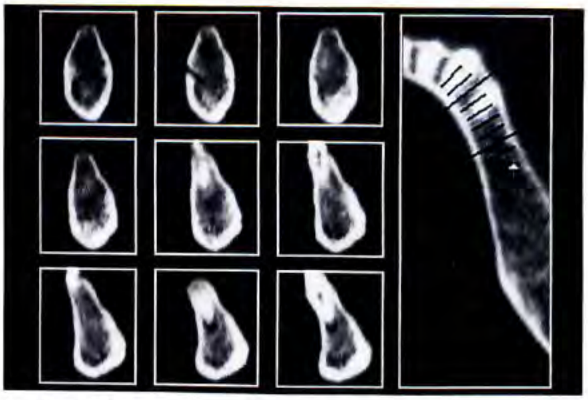

Figure 3. Cross-sectional image. One of the set-of-three images reformatted by the CT scanner.

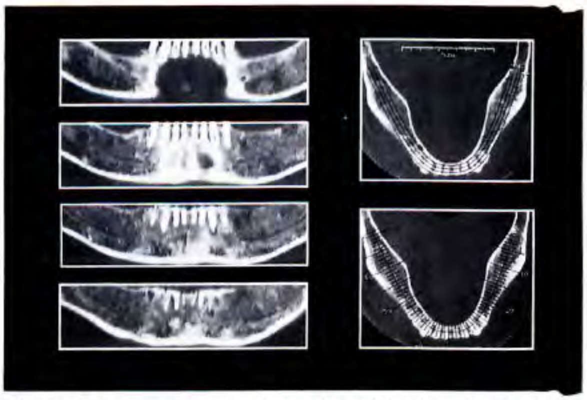

Figure 4. Panoramic image is another of the three images reformatted by the CT scanner.

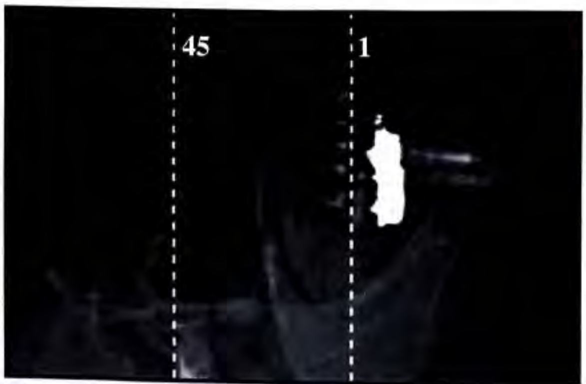

Figure 5. Scout view of maxilla is a cephalometric view, obtained by the CT technologist before any axial slices are taken.

Figure 6. A diagnostic wax-up of the proposed final restoration is completed.

New technology has enabled to make intraoperative decision-making a problem of the past. Computerized axial tomography (CT scans), aided by specially designed software, has made it possible to optimally plan the restoration of a dentition through implant-supported restorations prior to the surgical placement of dental implants.

CT scans have been in medical use since 1973.[12] In 1987, special software was designed, enabling the surgeon to see and evaluate the available bone for dental implants in all 3 dimensions (conventional radiology allows only 2-D views).[13] (CT scans allow easy identification of vital anatomic structures, such as the inferior alveolar canal, maxillary sinus, and nasal cavity.[14,15] Height and width of bone are easily measured. Concavities and convexities of bone are identified and errors in placement of implants can be avoided.) The maximum number of implants with maximum height and width can be safely placed.[16,17] CT scans may also be used to evaluate the status of previously placed implants.[18,19]

Although all this information is available for precise placement of dental implants, malalignment, poor angulation, and poor position of emergence of implant abutments still remain a prosthetic problem.[20] The purpose of this paper is to describe a CT scan method for determining the optimal surgical and prosthetic treatment of the implant patient, enabling the surgeon to anticipate not only the surgical problems but also the previously mentioned prosthetic problems.

Specific protocols need to be followed in order to obtain optimal diagnostic information. An understanding of how the CT scanner makes images allows the use of the scanner to its greatest diagnostic potential:

The CT scanner has a large doughnut-shaped gantry; it has a hole in its center of about 5 feet in diameter. A bed lies perpendicular to the scanner at a point which allows the bed to pass through the center of the doughnut. Within the gantry is a radiation source, and 180 degrees opposite the source are detectors that record the amount of radiation passing through the patient. The source and detectors, mounted in a fixed relationship to each other, can rotate 360 degrees (Figure 1). The patient lies on the bed, as the bed is moved into the center of the scanner. Radiation is emitted from the source, passes through the patient, and is recorded by the detectors. This occurs as the source and detectors rotate 360 degrees around the patient's head. The data collected is then reconstructed into a transaxial image, sometimes called an axial "slice" (Figure 2). The axial slice thickness used for the dental implant scanning is typically 1.5 mm thick. The bed is then moved (typically 1 mm) into (or out of) the scanner gantry, and another slice of information gathered. This sequence is repeated until the anatomy under evaluation is covered. These images or "slices" can be viewed on the CT scanner monitor or printed on x-ray film.[21]

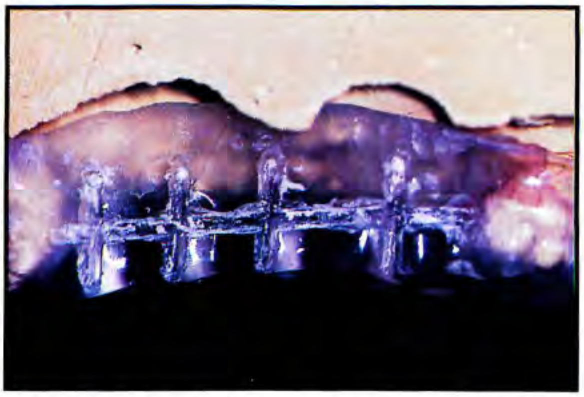

Figure 7. A 1-2 mm wide groove is cut parallel to the occlusal plane, down the midfacing.

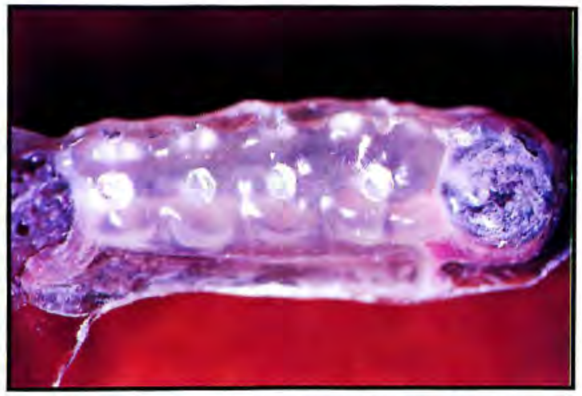

Figure 8. A groove is cut down the center of each tooth that is a potential implant site. The groove is parallel to the long axis of the tooth.

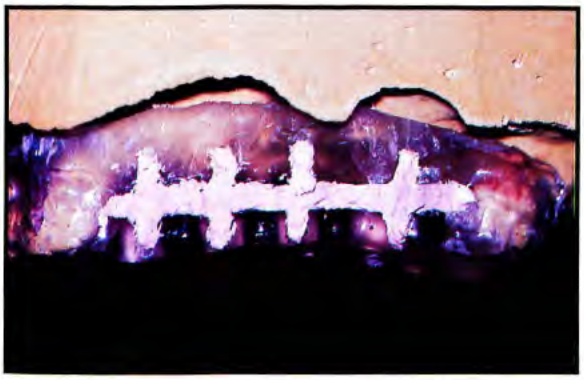

Figure 9. Horizontal and vertical grooves filled with gutta percha.

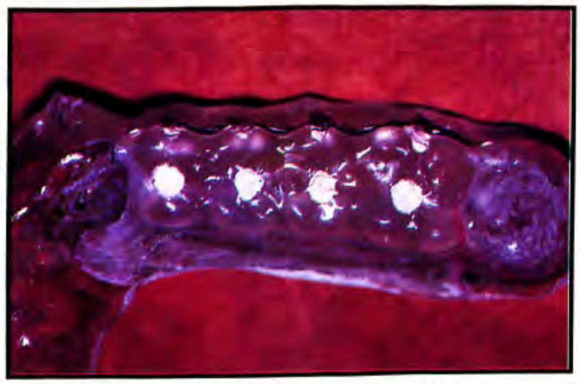

Figure 10. Grooves filled with gutta percha; another view.

With the help of newly-developed dental software, the CT scanner can reformat the axial data into three additional sets of images, allowing 3-dimensional views of the structure scanned. The 3 new image sets are:

1. Cross-sectional images(Figure 3).
2. Panoramic images (Figure 4).
3. Three-dimensional perspective images.

These images yield valuable diagnostic information. However, the patient cannot be scanned arbitrarily. There are guidelines that need to be followed in order to obtain useful information. If these guidelines are not followed, problems may arise.

The following problems may be encountered due to incorrectly scanned patients:

1. Measurements made on the vertical cross-sections can be clinically inaccurate.
2. Images may be distorted or "wavy," making it difficult to achieve accurate measurements.
3. Transferring the precise information from the images to actual clinical treatment may be difficult.

Reformatted dental images have been shown to be dimensionally accurate. However, measurements on the scan may not always be clinically useful. To understand why this happens, the process of scanning the patient needs to be reviewed:

Before any axial slices are taken, the CT technologist positions the patient's head. An exposure, which appears as a 2-dimensional lateral head view (cephalometric view) (Figure 5), is seen on the technologist's monitor. This is called a scout view. The technologist superimposes dotted lines on this view, indicating the plane of the x-ray beam and the anatomical area to be scanned. The lateral scout view, with its superimposed dotted lines, shows the cant of the head in relation to the axial slices that are to be taken. Head position is important, since the panoramic and cross-sectional images, reformatted by the dental software, are perpendicular to the axial slices.[21] Different orientations of the head will produce axial slices through different planes. The resultant reformatted images may then measure different lengths, depending upon the angulation, although all measurements are accurate for the plane in which they are taken. For the scan to be accurate for clinical measurements, the reformatted images to be used for measurements must be in the same plane and location as the desired clinical measurement.

To accomplish this, the orientation of the implant in the bone of the patient should be predetermined. Ideally, the forces of occlusion should pass through the long axis of the implant.[22,23,24] The implant should then be placed perpendicular to the predetermined plane of occlusion of the patient's final restoration. If the transaxial scan plan is parallel to the plane of occlusion, the reformatted cross-sectional and panoramic images will be perpendicular to the scan plane and thus

Figure 11. Grooves are cut and filled with gutta percha as in the partially edentulous patient.

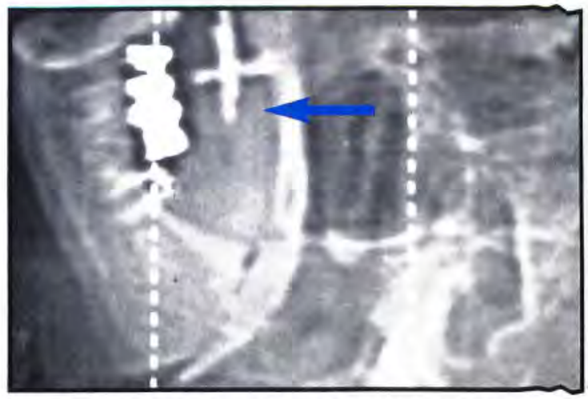

Figure 12. Gutta percha line parallel to the occlusal plane is seen as a radiopaque line; it should parallel the dotted lines on the scout film.

Figure 13. Immobilization at the patient's resting vertical dimension will help prevent muscle fatigue.

Figure 14. The position of the available bone relative to the proposed restoration may be seen.

to the occlusal plane. By paralleling the dotted lines on the initial lateral scout view to the patient's anticipated final plane of occlusion, the measurements from the reformatted images will correspond precisely to the depth of the bone at the selected implant receptor site.

Wavy (distorted) images, or images that appear to have discontinuity in the cortical bone, are caused by movement of the patient during the scanning process. After the CT technologist aligns the patient in the gantry, they program the CT scanner and select the level of the first and last axial slices and the bed movement between slices (typically 1 mm). By selecting a gantry tilt of zero degrees, the transaxial images will be parallel to each other. This scan protocol is then recorded with the transaxial slices.

All transaxial scan positions are relative to the position of the patient at the time of the initial scout view. The CT scanner is unable to detect or register a new patient position. Thus, when the dental reformatting software produces images, it also assumes that the patient was scanned at the original position.[21] If the patient moves during the scanning procedure, the relative position of the anatomy, from one scan slice to another, is not correct. This appears as wavy or discontinuous reformatted images. Immobilization of the head and jaws in a comfortable position helps assure accurate images.

Measurements made on reformatted images are helpful as long as they can be accurately related to the patient. If the patient is partially edentulous, measurements can be made relative to the position of existing teeth. However, in the completely edentulous maxilla or mandible, relating specific images to clinical locations becomes very difficult. In the mandible, measurements can be made from the mental foramen. However, the additional manipulation of the mental nerve to serve as a point from which to measure may cause unnecessary paresthesia. In the edentulous maxilla, there are no practical reference points from which to make measurements. Placing radiopaque markers that do not distort the CT scan allows easy transfer of scan information to the patient.

Adequate bone for endosteal implant placement may be identified on the dental images. However, the bone may be at such an angulation that an implant placed there might be unrestorable or restored in a compromised manner. Radiopaque markers at the positions of desired abutments may be used to show angulation and relation of the proposed restoration as it relates to available bone, seen on the reformatted study. An additional software program (IM/PLANT, Columbia Scientific Inc., Columbia, MD) allows the fabrication of 3-dimensional implant forms that may be placed into the CT scan picture by the surgeon and restorative dentist. The combination of radiopaque markers and implant forms allows easy identification of potential implant angulation problems or other prosthetic reconstruction difficulties.

Figure 15. Pretreatment photo reveals edentulous spaces, faulty restoration, and carious teeth.

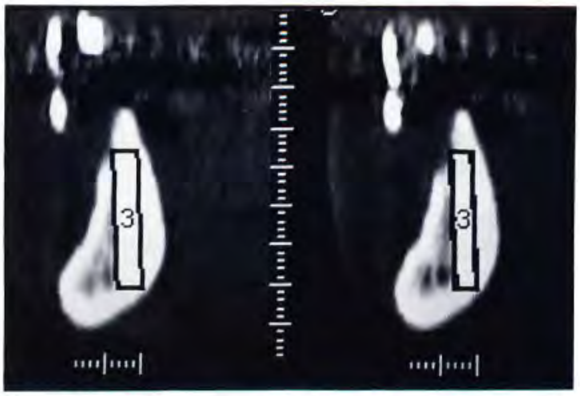

Figure 16. ACT scan taken with a CT appliance demonstrates a potential implant position (SIMPLANT).

Figure 17. All implants were positioned with a CT appliance converted into a surgical template.

Figure 18. Screw access hole position with the patient's provisional restoration shows the reliability of implant positioning.

This prosthetic appliance is to be used by the patient during the CT scan to preoperatively demonstrate prosthetic positions on the CT scan. The method of fabrication will follow.

METHODS OF FABRICATION

Fabrication of two orientation and immobilization appliances are described, one for use with the completely edentulous arch and the other for the partially edentulous arch.

For the Partially Edentulous Arch:

- Diagnostic casts are mounted and duplicated, and a diagnostic wax-up (or trial set) of the final restored case is completed (Figure 6).
- The wax-up of the arch to be scanned is replicated in stone by making an alginate impression of the waxed-up model and pouring the impression in stone.
- An omnivac of the new cast is made, using 0.02-inch omnivac material. The omnivac is cut and trimmed so that it covers the height of counter of all teeth present in the patient's mouth while it comes down to the ridge in the edentulous area. The omnivac is tried back into the original unwaxed model.
- Clear self-curing acrylic is poured into the teeth shapes in the omnivac, which were formed by the waxed-up teeth.
- The omnivac is then reseated onto the original model, expressing all the excess material and allowed to cure in a pressure pot.
- After final curing, the omnivac is removed from the model and trimmed.
- A groove, 1 to 2 mm deep and 1 to 2 mm wide is cut through the buccal facings of the posterior teeth. This groove should be parallel to the planned occlusal plane.
- A groove, 1 to 2 mm wide, is cut down the midfacing of each tooth where implants are to be placed (Figure 7). This groove should be parallel to the long axis of the proposed tooth, and it should extend from the incisal edge to the cemento-enamel junction.
- A groove, approximately 2 mm wide, should be cut in the center of the occlusal surfaces of each tooth site planned for implants (Figure 8). This groove may go from the occlusal surface to the edentulous ridge and should parallel the long axis of the tooth.
- All grooves are filled with gutta percha (Figures 9 and 10).
- The appliance is tried into the patient's mouth, the patient's resting vertical dimension established, and an anterior vertical stop formed.
- A lubricant is applied to the patient's opposing dentition and the posterior occlusal surfaces of the appliance are roughed with an acrylic bur.
- A doughy mix of clear self-curing acrylic is placed onto the right and left posterior surfaces of the appliance.
- The patient then closes into his centric relation position at his resting vertical dimension.

- After initial curing, the appliance is placed into a pressure pot for complete curing.
- Excess acrylic is trimmed, but enough acrylic is left to index the opposing teeth so that the patient will not slide his teeth and will still remain comfortable and immobile.[24]

For the Edentulous Arch:

- A trial denture is fabricated and duplicated in clear autopolymerizing acrylic.
- Grooves are prepared and filled with gutta percha as in the partially edentulous patient.
- All potential implant sites should be marked in the edentulous patient. This may mean placing markers in 12 to 14 teeth.
- Since this may be confusing on the CT scan, an additional set of grooves is added to help in identifying specific tooth positions on the scan.
- This fourth set of grooves begins approximately 2 mm below or above the CEJ in the denture phlange and runs vertically to the end of the phlange. This set should be placed by only 6 teeth.
- The positions to be marked are the right and left second premolars, right and left cuspids, and the right and left central incisors.
- These grooves are also filled with gutta percha (Figure 11).

DISCUSSION

The patient wears this appliance during the CT scan procedure. Accurate measurements may now be made on all images seen. The radiopaque gutta percha line, which parallels the patient's plane of occlusion, may be easily seen by the CT technologist both clinically and radiographically. The technologist positions the patient's head so that the gutta percha line (parallel to the patient's plane of occlusion) is parallel to an infra-red beam emitted by the CT scanner; this beam is coincident with the transaxial scan plane. The technologist then takes a scout image which is displayed on a monitor. The gutta percha line is seen as a radiopaque line on the scout image (Figure 12). A series of dotted lines also appear on the monitor. These lines parallel the orientation of the axial slices that are going to be taken. The radiopaque gutta percha line should be parallel to these lines. If they are not, the patient's head has to be reoriented so that the lines are parallel; the technologist confirms this with a second scout film. All axial slices are now parallel to the anticipated final plane of occlusion and, therefore, all measurements on the reformatted images (vertical cross-sections) are accurate in the direction of the anticipated implant placement.

Fabrication of a single appliance which stabilizes the mandible and maxilla prevents movement which causes distorted images. The scanning procedure lasts 20 to 30 minutes, less if the patient is dynamically scanned (without time between slices). The patient may require 1/3 to 2/3 rad radiation to the exposed area. The beam collimation of the CT scanner is very fine, with very little scatter of radiation to unexposed areas. By dynamically scanning the patient, the process may be cut to as little as 5 minutes, without detraction from data quality. The patient must remain immobilized in a single fixed position the entire period of time. Therefore, in order to avoid muscle fatigue, the appliance is made at the patient's resting vertical dimension, to allow the patient a more comfortable position in which to be immobilized (Figure 13).

Claustrophobic patients may have to be sedated for the CT-scan. There are no other contraindications to the procedure, and the cost of the procedure varies in different regions of the country.

Vertical gutta-percha lines accomplish several tasks. They are seen on the panoramic and cross-sectional views and may be used as markers to make measurements during surgery. This is done by orienting all measurements to and from a specific marker on the film and then using this same appliance at the time of surgery. All measurements are then made clinically from the marker on the appliance. The vertical marking lines have a second important function. If they are placed down the long axis of a specific tooth through the mid-facial point, several things can be learned: The inclination of the bone and the anticipated implant placement may be seen, as it relates to the orientation and position of the desired tooth in the final restoration (Figure 14).

Decisions may be made as to whether that position will be restorable or aesthetically acceptable. Gutta percha points may be placed at every proposed implant location to help identify potential implant angulation problems on the vertical cross-sectional slices. The gutta percha line through the occlusal surface will show the position of the center of the restoration as it relates to the available bone. Gutta-percha is used as the radiopaque marker, due to its easy manipulation, low cost, accessibility, and because it does not cause distortion of the CT images. Except for titanium, metals do cause distortion.

After all the measurements of bone have been made, implant sizes and locations may be selected. Three-dimensional implant forms of those sizes can be generated on the computer. The surgeon and restorative dentist can place these forms into the proposed implant location and visualize in 3 dimensions the surgical and prosthetic implications of that implant size location and angulation. By seeing available bone, implant position and the position of prosthetic restoration all in the same picture, it can be easily decided if this is prosthetically and surgically acceptable. These implant forms can then be moved to any position by use of a mouse until its optimal position is achieved. Photographs of this can be made and used as a blueprint for the surgeon during surgery for ideal implant placement. The restorative dentist will preoperatively know of any prosthetic compromises he/she might have to make (Figures 15 through 18).

This appliance may now also serve as a surgical template. A lingual or palatal window is cut through the acrylic, leaving just the facings of those teeth to guide the inclination and location of the implant placement. This surgical guide along with the radiographic blueprint, decided upon by the surgeon and restorative dentist, leave it only to the technical ability of the surgeon to properly place the implants.

CONCLUSION

The combination of a CT scanner and special dental software provides considerable presurgical planning information if the patient is scanned properly. To facilitate this, an appliance should be fabricated which provides guidance to the CT technologist on proper patient head orientation, immobilizes the patient's jaws in a comfortable position, allows correlation of information seen in the scan to clinical application, and demonstrates the proposed prosthetic treatment plan as it relates to available bone and, therefore, implant position. Precise presurgical planning allows predictable and aesthetic restorations.

ACKNOWLEDGEMENT

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PRACTICAL PERIODONTICS & AESTHETIC DENTISTRY

Self-Instruction Exercise No. 26

The 10 multiple choice questions for this exercise are based on the article "A CT scan appliance for optimal presurgical and preprosthetic planning of the implant patient" by Michael Klein, DDS, A. Norman Cranin, DDS, and Aram Sirakian, DMD. This article is on Pages 33-39. Answers for this exercise will be published in the September, 1993, issue of *PP&A*.

LEARNING OBJECTIVES:

The purpose of this exercise is to acquaint the reader with the extended application of CT scans and the use and fabrication of an orientation and immobilization appliance. This exercise provides the reader with:

- Understanding of the stabilization procedure.
- Ability to implement the procedure for the optimum accuracy in preplanning implants.

1. The CT scan can be used to evaluate:
   a. Bone width.
   b. Bone height.
   c. Location of vital structures.
   d. All of the above.

2. CT scan views are called:
   a. Cross-sectional view.
   b. Panoramic view.
   c. Axial view.
   d. All of the above.

3. Axial slice thickness for dental implant evaluation is:
   a. 0.15 mm
   b. 1.5 mm
   c. 15 mm
   d. 150 mm

4. Wavy images are caused by:
   a. Patient movement.
   b. Scanner movement.
   c. Computer error.
   d. All of the above.

5. CT scan measurements that do not correlate to clinical measurements occur because:
   a. The patient moved.
   b. The cross-sectional plane orientation was not the same as the clinical plane.
   c. CT scans are not accurate.
   d. All of the above.

6. The patient should be scanned so that the axial plane is:
   a. Parallel to the patient's occlusal plane.
   b. Perpendicular to the patient's occlusal plane.
   c. Parallel to the patient's mandibular inferior border.
   d. Perpendicular to the patient's mandibular inferior border.

7. Patients must be scanned with a CT appliance:
   a. To get accurate clinical measurements.
   b. To prevent patient movement.
   c. To determine potential prosthetic outcome.
   d. All of the above.

8. The CT appliance:
   a. May be converted to a surgical template.
   b. Is used for the scan and then discarded.
   c. May be adjusted and used for more than one patient.
   d. Is only necessary for completely edentulous patients.

9. The radiopaque markers in the CT appliance:
   a. Demonstrate the position of the buccal facing of the potential restoration.
   b. Demonstrate the position of the center of the potential restoration.
   c. Aid in correct surgical placement of the implant.
   d. All of the above.

10. Three-dimensional implant simulation on the CT scan:
    a. Is only a prosthetic tool.
    b. Allows the surgeon and restorative dentist to make presurgical decisions.
    c. Is only a surgical tool.
    d. All of the above.