the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com
Volume 8 Number 6 September 1, 2007

A Method of Gauging Dental Radiographs during Treatment Planning for Dental Implants

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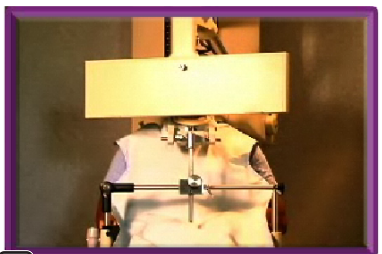

Abstract

Aim: The goal of pre-surgical dental implant treatment planning is to position the optimum number and size of implant fixtures to achieve the best restorative results. The purpose of this article is to describe the use of radiographic imaging software to calibrate and measure anatomical landmarks to overcome inherent distortions associated with dental radiographs. The procedure along with its potential use as an adjunct to radiographic interpretation in routine clinical implant practice is presented.

Background: Diagnostic imaging is an essential component of implant treatment planning, and a variety of advanced imaging modalities have been recommended to assist the dentist in assessing potential sites for implants. Although technological advances have resulted in new imaging innovations for implant dentistry, dental radiography remains the most widely used tool for determining the quantity and quality of alveolar bone as it is a non-invasive procedure. However, the unreliable magnification factor associated with conventional radiographs remains a major problem when estimating the amount of bone available at the implant site.

Summary: This image measurement technique is capable of assessing the bone quantity by measuring the height and width of the alveolar crest for a specified region in a two dimensional plane in any direction related to the visible landmarks in the oral cavity. These measurements can be used by the clinician to select the type of implant and its position. Since there is no additional equipment or cost involved, the technique can be used as an important adjunct in implant practice.

Keywords: Radiographic images, image analysis, dental implants, bone measurement, image distortion

Citation: Anil S, Al-Ghamdi HS. A Method of Gauging Dental Radiographs during Treatment Planning for Dental Implants. J Contemp Dent Pract 2007 September; (8)6:082-088.

Introduction

Comprehensive diagnosis and treatment planning are critical elements of the pre-operative phase of dental implant therapy needed to ensure success. The radiographic examination is an indispensable part of implant treatment planning required to estimate the morphologic characteristics of the proposed implant site and the location of anatomical structures.[1] The information acquired from radiographs is used to estimate the dimensions of the implant to be inserted, the number of implants needed, the location and orientation of the implants, and the possible need for bone augmentation.

Selection of optimum dimensions of the implant are of concern since studies have indicated failure rates have a direct association with the length and diameter of an implant.[2-6] The direction of implant placement also has to be considered at the time of treatment planning since the non-axial loading of an implant may lead to peri-implant bone loss and have an adverse effect on osseointegration.[7,8] An inappropriate inclination of implants may also lead to a poor esthetic result or necessitate the use of angled abutments.

A variety of radiographic imaging techniques exist for preoperative planning and evaluation of implant recipient sites.[9,10] Even though three-dimensional implant guidance systems are available, only a limited number of dentists have access to them.[11] Appropriate radiographic equipment, costs, and radiation exposure all play important roles in this regard. Ideally, the goal of a radiographic examination is to acquire as much information about the jawbones as possible with minimal patient radiation and cost.[10] All types of imaging techniques present advantages and disadvantages and, therefore, a combination of different imaging methods may be used in order to optimize the diagnostic outcome.[12] A survey conducted among dentists showed 63.8% of them prescribed only panoramic radiographs for dental implant assessment.[13]

Panoramic radiographs provide useful preliminary evidence of the general status of the dentition and the relationship between alveolar bone, basal bone, and key anatomical structures that may preclude routine implantation.[14] Although the panoramic image is magnified, the length of implants and the number that may be placed in an edentulous span to support the prosthesis can be estimated.[15] Due to inherent distortions these images are not well suited for estimating the amount of alveolar bone, particularly in the horizontal plane.[16] The intraoral periapical radiograph is valuable for estimating the mesiodistal dimension of a potential implant site and to obtain a preliminary estimate of vertical dimensions. A combination of panoramic and intraoral images is often recommended for a preliminary evaluation of an intended implant site.[10]

Two-dimensional periapical and panoramic radiographs have limitations as diagnostic tools because they don't provide a third dimension. In an effort to minimize implant alignment problems a variety of radiological, surgical, and combination templates and techniques have been proposed for precise bone mapping.[15] The accuracy of image measurement is an essential requirement of any radiographic technique used for dental implant diagnostics.

Studies of radiographs using an image analysis system have been found to be a useful aid in assessing the peri-implant bone in animals and humans.[17-20] Image analysis has been widely used in research and is based on calibrating images from either the threads of implants or gauges placed during radiographic procedures.

Computer assisted measurement of bone levels in intraoral radiographs offers a high level of accuracy and reliability.[21,22] The principle is based on the assessment of the degree of distortion of a radiopaque gauge or object placed during a radiographic procedure. The image analysis

software will help convert the pixel size of the images to a linear scale based on the distortion factor computed from the known dimension of the radiopaque object. The procedure is cost effective since software is available at no cost and no special equipment is needed. The technique can accurately measure vital anatomical landmarks in a two dimensional plane. It can also be used in conjunction with cross sectional tomograms to make linear measurements and to locate anatomical landmarks. One such software application is very useful in dental implant treatment planning and is described below.

Methods and Materials

Image Analysis Software

NIH Image is a public domain image processing and analysis program for Macintosh computers. The software was developed at the Research Services Branch (RSB) of the National Institute of Mental Health (NIMH) which is a part of the National Institutes of Health (NIH) of the United States. A free PC version of the software (Scion Image for Windows) is available (Scion Corporation, Frederick, MD, USA) and can be downloaded from the company's website at http://www.scioncorp.com. Scion Image can be used to acquire, display, edit, enhance, analyze, and animate images. It supports many standard image processing functions including contrast enhancement, density profiling, smoothing, sharpening, edge detection, median filtering, and spatial convolution with user defined kernels. The software can be used to measure area, mean, and centroid of an area within a perimeter of a user defined region of interest. It provides tools for measuring path lengths and angles.

Digitizing and Calibrating Conventional Radiographs

In order to use the software, radiographs have to be calibrated using a radiopaque reference device of known dimensions that is included in the image during exposure of the radiographic image of the implant patient. The reference device is placed in the oral cavity using a custom fabricated stent to hold it in place. Alternatives for holding it in position are: a disposable bitewing film holder, interocclusal registration wax, or by using a partial impression during film exposure (Figures 1 and 2).

Radiographs are taken with the guide in position (Figure 3). Care should be taken to place the guide close to the implant site and perpendicular to the long axis of the X-ray beam. In panoramic radiographs placing more than one guide near the area of interest is advised since magnification may vary in the same radiograph.

Figure 1. Calibration devices. (a dummy implant, metal ball or any radiopaque metal piece).

Figure 2. The dummy implant embedded in a partial impression.

Figure 3. Panoramic radiograph with a dummy implant fixture (guide) of dimension 10 x 3.75 mm in the edentulous area.

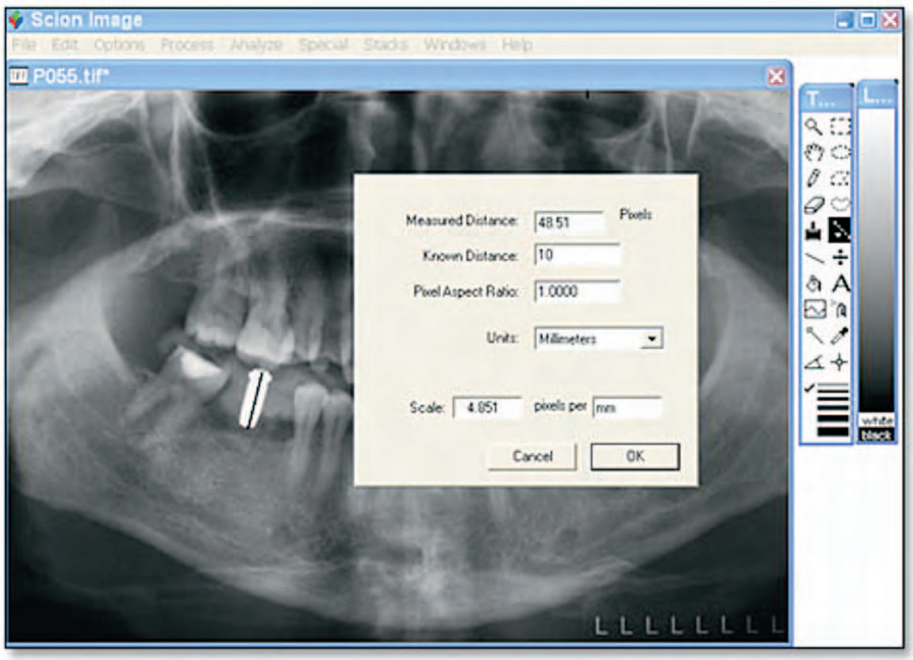

Figure 4. The radiograph loaded in Scion Image software with the calibration window showing the known measurement (10 mm to 48.51 pixels).

Once the radiographs are exposed and processed they are scanned to create a digital image at a resolution of 600 ppi. This can be done with a flat bed scanner or a film scanner. Digitally produced radiographs can also be used to eliminate the scanning process. The images are saved in either a TIFF (Tagged Image File Format) or BMP (Bitmap) file format for analysis using either the NIH image (Mac) or Scion Image for Windows (PC) software (Figure 4).

Each image is calibrated using the known distance from the radiopaque object placed during the radiographic procedure (Figure 5). The amount of distortion for this guide will be used as the standard to measure the linear

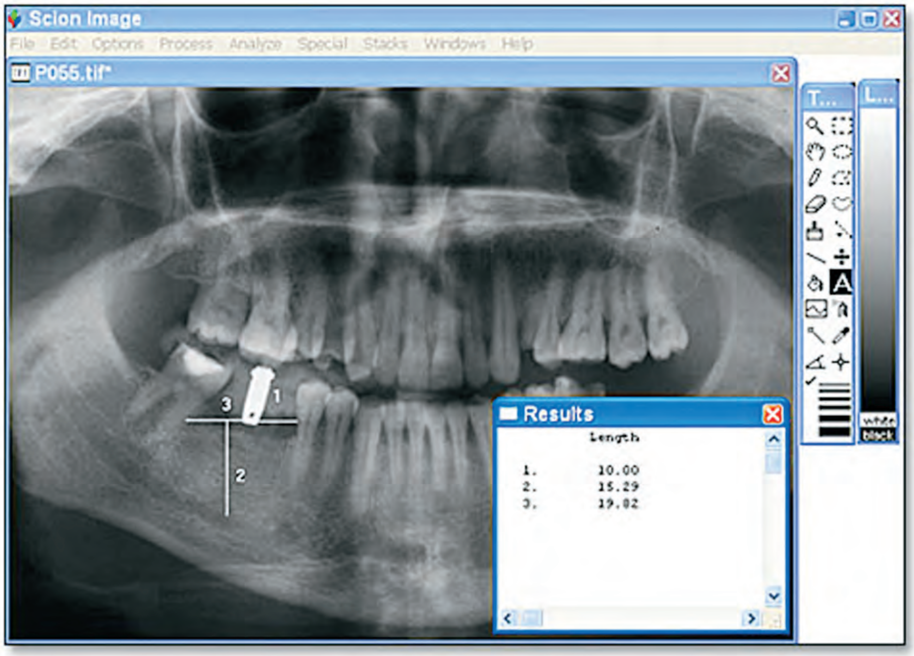

Figure 5. The radiograph showing the actual measurements based on the dummy implant.

and area measurement in the panoramic and periapical radiographs. A brief demonstration of the software in use can be seen by clicking on the video icon on the online Journal article.

To facilitate measurements, the software has a function that allows an image to be rotated slightly around its vertical axis. The software also provides for image adjustment to improve the contrast between the bone and implant as well as to sharpen the image. To improve visual contrast between the bone and implant the image processing procedure such as sharpening or contrast adjustment can be done.

The measurements obtained can be printed or exported for future reference. For immediate implant cases, instead of placing a premeasured gauge or device, the teeth being extracted can be used to calibrate the radiographic image. The extracted teeth or root remains are measured using a caliper, and the radiograph can be calibrated by entering the known distance in the software during the procedure. A spherical object such as a 5 mm metal ball (Figure 1) is recommended rather than a dummy implant to avoid the distortion (elongation) of the object during the radiographic process.

The same method can be applied to conventional tomographic images for assessing the anatomical landmarks and bone quantity measurement of maxillary and mandibular buccolingual dimensions (Figure 6).

Discussion

The success of dental implant treatment depends on careful preoperative planning. In order to accurately plan an implant procedure it is essential to obtain information regarding the volume, quality, and topography of the bone at a potential implant site. It is also important to determine the relationship of the proposed implant to important anatomical structures such as nerves, vessels, teeth, nasal floor, and sinus cavities at the implant site. This information can be obtained with a clinical examination and appropriate conventional radiographs.[1] Diagnostic information can be enhanced by the use of appropriate radiopaque markers or restorative templates.[15]

Developments in cross-sectional imaging techniques such as spiral tomography and reformatted computerized tomograms have become increasingly popular in the preoperative assessment and planning for dental implant procedures.[12] Moreover, several proprietary software products are available to clinicians that

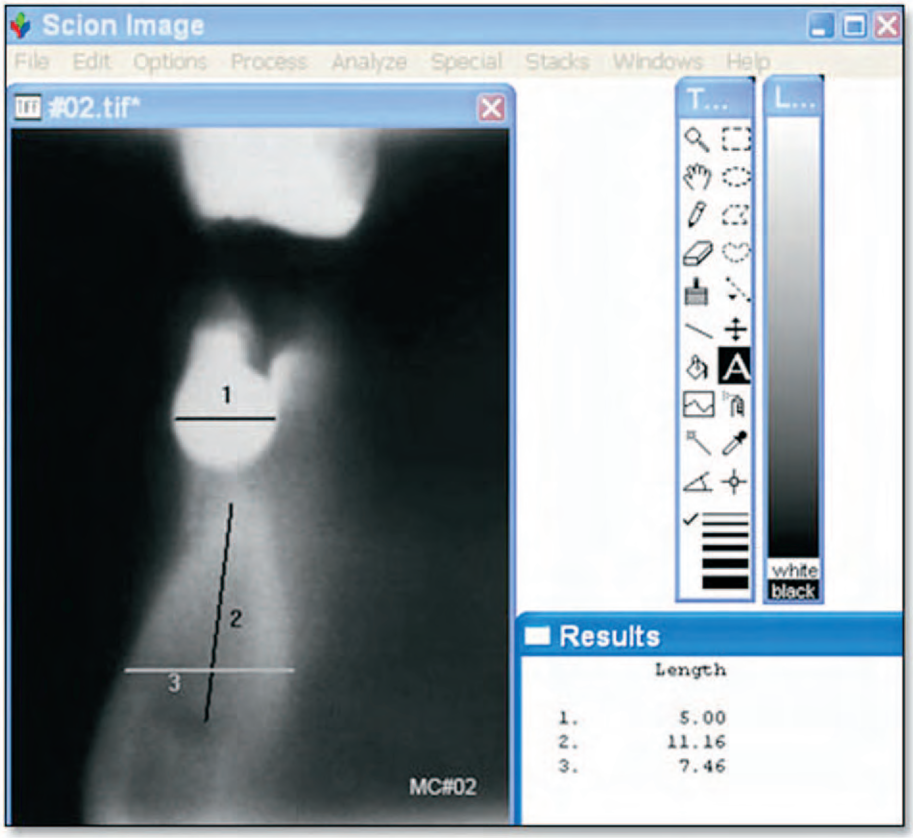

Figure 6. A tomogram showing the metal ball of diameter 5 mm used to assess the mental foramen and the buccolingual width of available bone (the window showing the measurements in mm).

allow the manipulation of digital radiographic images.[23] However, the rapid adoption of these sophisticated techniques into routine practice might lead to a significant increase in the radiation burden on patients without a proper risk-benefit analysis.[24,25] Also, the information obtained from computed tomography (CT) with or without the use of proper templates cannot be transferred precisely to the surgical site without intraoperative navigation.[26,27] The consensus workshop of the European Association of Osseointegration (EAO) has reviewed this situation and recommended the use of cross-sectional imaging based on clearly identifiable needs and clinical requirements.[1]

To date there is a lack of consensus regarding guidelines for pre-implant radiographic planning. In a paper by the American Academy of Oral and Maxillofacial Radiology, Tyndall and Brooks[10] recommended conventional cross-sectional tomography as the method of choice for most implant patients. Nevertheless, the authors emphasize there is no scientific evidence at present for this recommendation and acknowledged the implant success rate as high even without imaging in multiple planes.[10]

Intraoral and panoramic radiography are associated with low radiation doses.[28] The radiation dose from a conventional tomography is comparable to intraoral radiography[28] while CT is associated with a high radiation exposure to the patient.[24,29]

Summary

Intraoral radiographs, panoramic radiography, lateral cephalography, or a combination of these images are proposed for treatment planning of single-implants since they are suitable in the anterior and premolar areas in both jaws.[30] The application of digital technology as well as the improvements in conventional radiographic techniques has facilitated the quality of radiographs and reduced the distortion in panoramic radiography.[16] The technique described here is useful in obtaining the following important information without additional cost or exposure to radiation:

1. The location of the inferior alveolar canal in the mandible.
2. The floor of the maxillary sinus.
3. Assessing the available space between adjacent tooth roots, especially in the anterior aspects of the jaws.
4. Determining the position of the surface of the alveolar ridge in edentulous spaces compared with the height of the alveolar crest around adjacent natural teeth.
5. The mental foramen and its relative location to the adjacent teeth.
6. The buccolingual dimension of a potential implant site using conventional tomograms.

Moreover, this technique is capable of assessing the bone quantity by measuring the height and

width of the alveolar crest at a specified region in a two dimensional plane in any direction related to the visible landmarks in the oral cavity. These measurements can be used by the clinician to select the type of implant and its position. Since there is no additional equipment or cost involved, the technique explained here can be used as an adjunct to implant practice. Although more user friendly software products are available, most of these commercial products are based on the same principle used in the Scion image analysis software.

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