COMPUTERIZED TOMOGRAPHY–BASED IMAGING AND SURGICAL GUIDANCE IN ORAL IMPLANTOLOGY

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Computerized tomography (CT)-based imaging and surgical guidance carry both radiographic information such as height, density, and width of bone and clinical information such as axis of orientation for a successful prosthodontic result, thus determining the trajectory, depth, and distribution of the implants. The objective of this report is to review the associated literature and recent developments in CT-image–based information and surgical guidance systems. This report attempts to provide an argument for the development of evidence-based research on the utility of such systems and their effect on outcome in oral implantology.

INTRODUCTION

The clinical significance of computerized tomography (CT)-based imaging, planning, and surgical guidance as it pertains to critical anatomical landmarks such as the mandibular canal, maxillary sinus, and adjacent teeth has generated much professional debate in recent years.

In the mid 1990s, utilizing different review methodologies, 2 manuscripts[1,2] forecast the future of imaging technologies in dental implantology. In this report, we compare the published forecasts with the actual events that occurred since the publication of these manuscripts.

In 1995, Frederiksen[1] conducted an extensive review of the literature on a variety of diagnostic imaging modalities used in dental implantology, including intraoral and extraoral film, digital radiography, conventional tomography, and CT. He concluded his section on plain film radiography by saying that "for the accurate determination of the quality and quantity of available bone, more sophisticated imaging techniques are required." This statement was a prelude to his next sections discussing film tomography, both conventional and computerized. Later, he suggested that "CT has several advantages over other imaging techniques that produce cross-sectional views of the jaws. . . . It has been found to most accurately reflect the true osseous morphologic condition of the jaws."

In 1997, Almog and Heisler[2] conducted a computer analysis study, analyzing all the available sets of literature databases dealing with diagnostic imaging modalities in dental implantology. To identify relevant information on the subject, they conducted a MEDLINE search with the key words "implantology," "imaging," "radiography," "periapical," "panoramic," "tomography," "CT," and "MRI." The search identified 34 manuscripts published between 1980 and 1996. All manuscripts were included in the study without examination of content. A special computer analysis program assigned a significance rate to every idea (cognitive unit) in each manuscript's text. Of the 3552 expressions in the manuscripts, the program assigned the highest ratings to 3 clusters of ideas.

Frederiksen[1] forecasted an increased demand for CT imagery by dental implantologists. Similarly, the first and third highest significance ratings assigned by the computer analysis program were assigned to ideas selected from Smith and Borrow.[3] Like Frederiksen,[1] they described the importance and advantages of multiplanar reformatted CT in the preoperative planning of dental implants over traditional dental radiography.

The second highest rating assigned by the computer analysis program was assigned to an idea selected from Modica et al.[4] This idea described the helpfulness of an imaging guidance device used in conjunction with CT in the preoperative planning of dental implants to determine the trajectory and depth of the fixtures to be implanted.

The computer program analyzed the meaning of what all the authors said (semantics) and the way they said it (grammar and syntax), utilizing psycholinguistics, cognitive psychology, and motivation theories, among other methods. Therefore, Almog and Heisler suggested that the program selected the imaging guidance device idea from Modica et al,[4] which was unique at that time, because it addressed a major concern in dental implantology, that is, the violation of anatomical landmarks during surgery.

Since the publication of these 2 literature review papers,[1,2] several events occurred.

In 2000, a position paper from the American Academy of Oral and Maxillofacial Radiology (AAOMR) announced, "After reviewing the current literature, the AAOMR recommends that some form of cross-sectional imaging be used for implant cases. . . . Imaging information from panoramic, cephalometric and intraoral films is inadequate to evaluate the bony architecture of any implant site completely. The AAOMR recommends that evaluation of any potential implant site include cross-sectional imaging orthogonal to the site of interest. This information is best acquired with tomography, either conventional or CT."[5]

At the same time, numerous companies from a technology-transfer and commercial standpoint have introduced technology platforms that offer planning and guidance systems to facilitate dental implant placement procedures (Figures 1 and 2). These companies consist of 2 categories: CT-based image-guided navigation systems and CT-based surgical guidance templates.

CT-based Image-guided Navigation Systems

These systems provide sensors and software to transfer the presurgical plan to the patient, indicating when the dental practitioner placing the implants has physically deviated from the predetermined drilling parameters. They also provide automated monitoring of the surgical process. The procedure is limited by the physical navigation control of the dental practitioner placing the implants and the fact that the sensing device is sensitive to line of sight. With some systems, calibration of implant placement is derived from viewing the virtual surgical site on a monitor.

The primary companies in this sector are Artma Medical Technologies Inc, Munich, Germany (http://www.medlibre.org/mission.html); DenX Ltd (GuideDent IGI), Jerusalem, Israel (http://www.denx.com/); RoboDent GmbH, Berlin, Germany (http://www.robodent.com/);Vector Vision 2, BrainLAB GmbH, Munich, Germany (http://www.brainlab.com/scripts/website_english.asp?pageTypeID=3&application_id=7&article_short_headline=IGS%20>%20Cranial&menuID=594&colorID=595); and IVS Solutions AG, Chemnitz, Germany (http://www.ivs-solutions.com/english/english.htm).

CT-based Surgical Guidance Templates

These systems analyze CT scans to aid in planning the surgery and produce physical surgical drilling guides. They also stabilize the drilling procedure while the dental practitioner placing the implants performs the procedure by restricting the degrees of freedom of the drill trajectory and depth. The dental practitioner placing the implants uses drill guides that guide the surgical drill exactly to the planned implant location.

These guides are manufactured in such a way that they perfectly match the treatment plan.

At present, the primary manufacturers in this sector are Materialise, Leuven, Belgium (http://www.materialise.be/simplant/main1_ENG.html); Oralim, Medicim NV, Sint-Niklaas, Belgium (http://www.medicim.com/products_oralim.html); Implant Logic Systems Ltd, Cedarhurst, NY (http://www.implantlogic.com/); med3D GmbH, Heidelberg, Germany (http://www.med3d.de/); Tactile Technologies Inc, Rehovot, Israel (http://www.implantconnections.com/tactiletech.html); and I-Dent Ltd, Hod Hasharon, Israel (http://www.ident-surgical.com/).

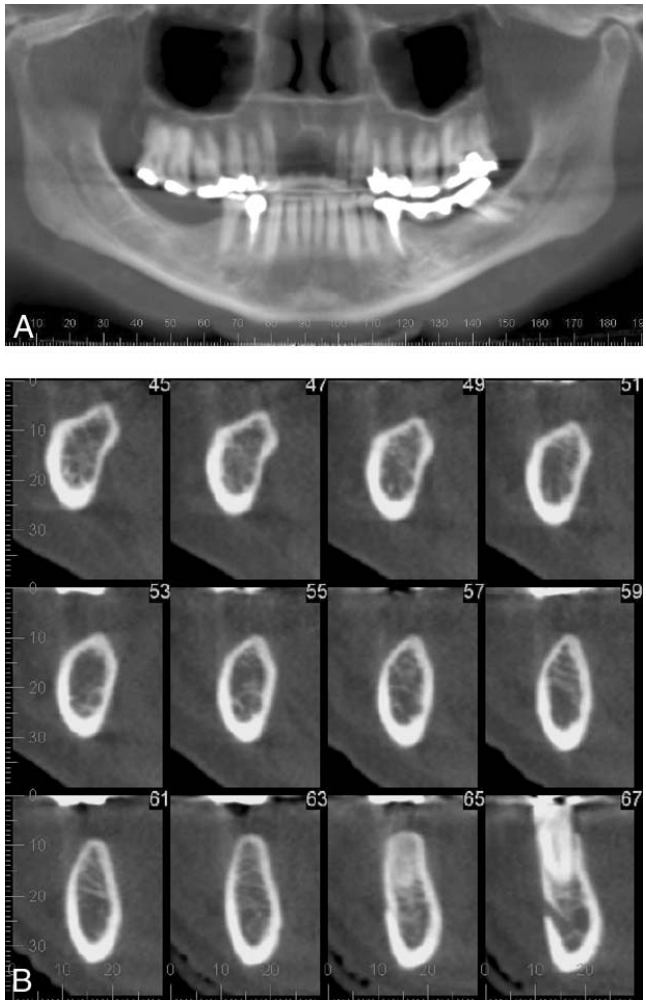

FIGURE 1. A coned-beam computerized-tomography study performed with the i-CAT 3-D imaging technology (Imaging Sciences International, Hatfield, Pa). Images are shown in 2 dimensions: (A) panoramic slice and (B) cross sections or slices. Note the mandibular canal depicted in slices 45 to 65 and the mental foramen in slice 67. These cross sections correspond to the patient's lower right edentulous region.

Discussion

To a certain extent, CT-based imaging in oral implantology was already anticipated in the 1990s, and the 2000 recommendation by the AAOMR supported that view. Moreover, it can be said that the notion of a CT-based surgical guidance device was also anticipated the in the 1990s.

However, the AAOMR position paper[5] on preoperative implant site assessment generated a professional debate shortly after it was published that challenged its validity. In a follow-up editorial, Brooks[6] asks, ''Where's the evidence?'' Where, indeed, is the evidence? Does CT imaging in the preoperative stage of dental implants have any value, or is it simply another relatively expensive test that has no effect on the outcome in the majority of cases? Other questions raised in the editorial ask whether the clinician's experience level makes a difference in what type of imaging is necessary, whether the amount of bone determined clinically makes a difference, and whether there are alternative methods to obtain information about undercuts and bone inclination that work better and are less expensive.

One year later, the American Academy of Oral and Maxillofacial Radiology, ad hoc Committee on Parameters of Care, issued an official report regarding parameters of radiologic care, including imaging of dental implant sites.[7] This report states that panoramic imaging alone is not sufficient for imaging of dental implant sites, whereas tomography, either conventional or computerized, does provide the necessary radiographic information such as height, density, and width of bone.

This report was also followed with a letter to the editor[8] from an individual claiming it to be an unrefereed opinion. Shortly afterward, a rebuttal[9] from the Academy of Oral and Maxillofacial Radiology, ad hoc Committee on Parameters of Care, explained that the Academy's position is one of caution and is derived from adverse effects described in the literature.

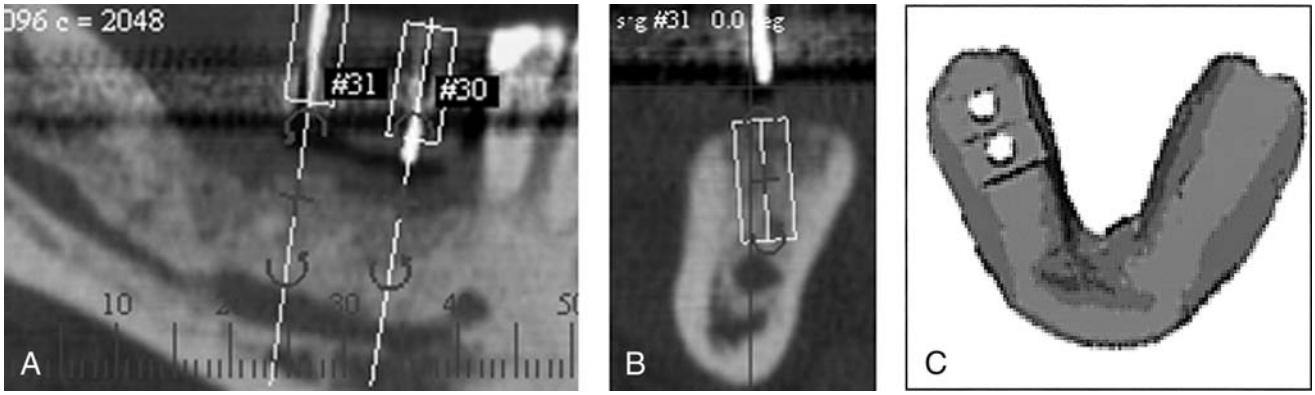

FIGURE 2. A coned-beam computerized-tomography study was performed with the i-CAT 3-D imaging technology (Imaging Sciences International) while the patient wore an imaging guide. The imaging guide was constructed with radiopaque restorative pins seen in (A) the panoramic slice and (B) the cross section. These pins represent optimal prosthetically driven access holes and trajectory for teeth 30 and 31. Residual bone trajectory and the mandibular canal were also used as guiding basics for implant trajectory, depth and length, and diameter. By utilizing ImplantMaster (I-Dent Ltd, Hod Hasharon, Israel), a 3-D reconstruction of a patient's anatomy was achieved and a surgical guidance template (C) was designed and computer manufactured with precise drilling-hole distribution and trajectory.

Many variables need to be considered when reviewing imaging modalities for preoperative assessment of the dental implant site. The amount of information provided and its accuracy and applicability need to be weighed against cost, convenience, availability, radiation dose, and training required to produce and read the output of each modality.

Over the years, numerous anecdotal reports and preliminary clinical studies documenting clinical complications with implants and implant prostheses have been published.[10–12] Furthermore, a recent meta analysis[13] reports extensively on such complications. In addition, a textbook chapter[14] discusses different implant radiology modalities, their relative strengths and weaknesses, and supplementary imaging guides that might be helpful.

Similarly, the concept of using CT-based dental imaging coupled with surgical guidance templates is gradually becoming evidence-based through review of recent preliminary clinical studies and case reports.[15–23] These studies describe interactive imaging programs that allow CT imagery to be used to plan and construct a surgical guidance device or navigate the delivery of dental implants at the time of implant placement. The objectives of these preliminary studies were to assess the accuracy of CT-image–based dental implantation planning and surgery. The authors of these studies concluded that these technologies show enhanced progress in implant dentistry. However, only 1 study demonstrated correlating evidence to imaging technology. It showed that the use of conventional cross-sectional tomography before installation of single-tooth implants increased the efficacy of periapical plus panoramic images, with respect to the prediction of appropriate implant size, by a factor of 2.5.[24]

CONCLUSIONS

This report reviews recent developments in CT-image–based information and surgical guidance systems and attempts to provide an argument for the development of evidence-based research on the utility of such systems and their effect on the outcome in oral implantology.

Outcomes assessment research, including cost-to-benefit analysis, is difficult but is critical in answering these and other questions about implant site assessment and surgical guidance. Furthermore, the recent introduction of numerous associated commercial CT-based imaging and surgical guidance platforms and its expected effects on the way the profession views and practices oral implantology provides sufficient argument for the necessity of large prospective clinical trials on the quantitative relationship between successful dental implant treatment outcomes and CT-based dental imaging coupled with surgical guidance systems.

NOTE

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