Imaging in dentistry:
A clinical perspective

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_**Digital imaging in dentistry** is a field of expanding possibilities and applications. Within the broad context of imaging, there are diagnostic, clinical and administrative applications. Diagnostic imaging can be radiographic, ultrasound, visible light and laser fluorescence. The clinical applications include surgical microscopes, magnified video

Figs. 1a–e_ Our different websites over the years: 1993 (a); 1998 (b); 2005 (c); 2007 (d); and 2010 (e).

systems and optical impression systems. The administrative applications are concerned with digital record-keeping, computer simulation, consultative and communication applications. In considering the number and types of imaging applications and the number of companies who manufacture and market these to dentistry, it is not surprising that many dentists are frustrated and confused as to the efficacy, implementation and financial implications associated with incorporating these technologies. This article will address the clinical perspective of these technologies, and the manner in which our office has incorporated many of these applications over the last few decades.

_History

A brief history of our office is necessary to put all this in perspective. Our private practice is 34 years old and has been a leading-edge practice since its inception. As with many other early adopters, our decisions were not always well thought through and return on invested dollar was not always considered and not always successful. I have used our office environment as a learning laboratory, which has fuelled my lectures, and published articles on technologies and leading-edge applications for over 20 years. The journey began in 1982 with our first computer, which served as a billing and accounting system. From there we transitioned to a mini-mainframe (Alpha Micro system) with server and operatory workstations in 1985. Fast forward to today; we have two office locations in suburban Chicago, connected by a T1 line and a single Eagle-soft dental software database (Patterson Dental) in a completely chartless environment.

Our early technology environment did not become complicated until we wanted to add clinical applications to our system. There were many challenges with technology integration, not the least were the cart delivery systems used by most of the companies. The first intra-oral camera system was

analogue, which came on a cart with a video printer and monitor. When digital radiology was first introduced, it too came on a cart with a PC, monitor and thermal printer; shortly after that you were able to link the intra-oral camera to the same PC as the digital radiology system. This evolved further by putting PCs in all the operatories so that you could eliminate the carts for image acquisition and make room for the lasers and CAD/CAM applications, which also came on wheels. We have worked with numerous digital radiology systems: Schick Technologies, DENTSPLY NI-DX (no longer available), Welch Allyn Reveal sensor (no longer available), Gendex Dental Systems, Planmeca sensors, DMD sensors (no longer available) and Myray X-pod wireless sensor (Cefla Dental Group). Having multiple sensor systems has its complications and it is most efficient to use whatever sensor systems integrates best and seamlessly with your dental software program.

It is a fair description that the ideal technology-focused dental office is one that is in a perpetual state of change. The continuous flow of evolving applications makes it essential that all systems are designed to be sufficiently flexible to allow future integration with minimal interruption. One thing that we must remember is that we are in the business of providing oral health care, and technology should be incorporated if it helps us better serve our patients.

_The World Wide Web

In today's economy, we have to assume a more global perspective of the impact of digital imaging on your practice. We have to realise that even before your patient makes that first call for an appointment, their decision was probably influenced by the Internet. Dental consumers are using the Internet in greater numbers to find the right fit for their dental and medical needs. So a web presence is becoming a key component for attracting and keeping your patients.
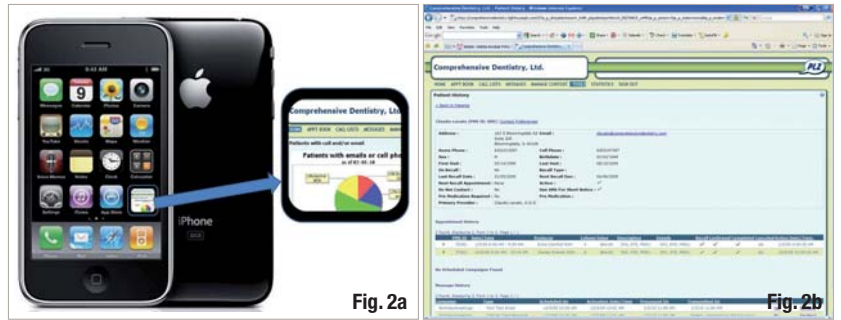

Fig. 2a

Fig. 2b

Once the patient has selected your office, everything that they experience will be measured by their expectations. It seems that today's society, especially those under forty, is always connected and in search of the immediate gratification of needs and wants. Technology is a tool that can facilitate meeting those expectations.

_Attracting new patients

The Internet has changed the way we use images and information. Years ago, we would work with a marketing company to produce a practice brochure with some direct mail pieces. The process would take months to create and implement, the downside to this approach is that it is costly and not easily amenable to changes. In today's Internet age, we can launch a simple website in hours and make changes whenever we need to. It is important to understand this new medium because creating a website that is not interactive is in some cases worse than no website at all. We have only a matter of seconds to attract and keep someone's attention, and if we do not have something to address their agenda, they move onto the next site. So website optimisation is actually more important than creating a beautiful site with animation and flash features that do not address the wants of your potential clients.

There are numerous companies that have been helping dentists navigate these waters successfully.

Fig. 2a_iPhone application for Lighthouse PLZ.
Fig. 2b_Patient history screen on phone through Lighthouse PLZ.

Fig. 3a_Initial digital photograph series.
Fig. 3b_Initial full series of digital X-rays.
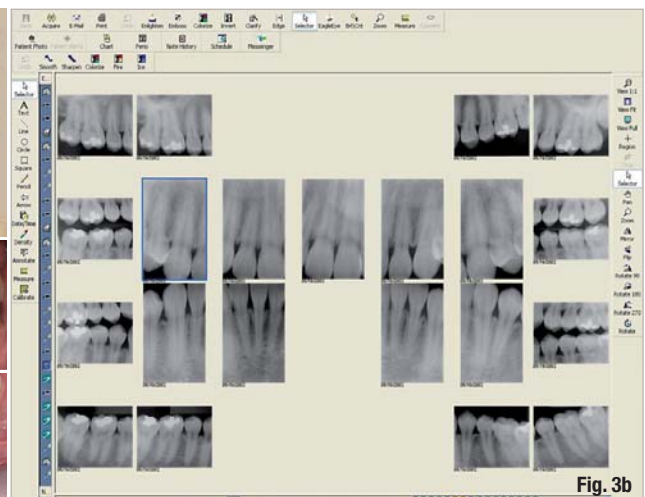

Fig. 3a

Fig. 3b

Fig. 4a

Fig. 4b

Fig. 4c

Fig. 4a_ProMax 3D (Planmeca): small scan imported into InVivo5.
Fig. 4b_MyRay Skyview (Cefla Dental Group): medium scan imported into InVivo5.
Fig. 4c_i-CAT (Imaging Sciences International): large scan imported into InVivo5.

We have used Curtis Marketing Group, Sesame Communications and Connect to Patients for creating and optimising our websites (Figs. 1a–e).

Patient access to schedule, account information and to paying bills online is provided by Sesame Communications as well. Lighthouse PLZ is another example of web-based solutions that work with your existing practice management software. We use this application to handle our re-care reminders (by text, e-mail or regular mail), electronic newsletter and our direct mail marketing, and to monitor practice statistics. They also have a smart-phone application to allow you to check patient schedule or history from your phone (Figs. 2a & b).

_Initial visit

During our initial visit, we review the medical history that the patient filled out on paper, which we scan into their digital chart, or we have them

Fig. 5_XCPT 2-D implant planning and consultative tool.

fill it out on a tablet PC, which can be signed directly. We also have signature pads attached to all our administrative workstations. After the dentist has met the patient and reviewed the concerns, we have our assistant gather the necessary photographic and radiographic images. We use a digital camera to take a series of digital photographs, which will serve as documentation of existing conditions and for Invisalign records, if required,

for cosmetic imaging or for referral communication (Figs. 3a & b).

Depending on the patient's concerns and existing condition, the radiographic imaging may be an intra-oral set of digital radiographs, a panoramic and bite wing set of digital radiographs, a CBCT (cone-beam computed tomography) scan for implant assessment and treatment planning. After acquiring the radiographic and photographic images, the clinical examination begins with an intra-oral video camera tour of the mouth, which the patient is able to view with the dentist, and examples of problem areas, as well as healthy areas, are shown in this co-discovery or co-diagnostic exercise.

The initial examination is in actuality a two-way street where we, as well as the patient, get to know and evaluate each other. Anything that will facilitate communication and provide options and solutions for the patient will go a long way towards building a trusting relationship. Technology is a double-sided sword; if it is used to impress or pressure a patient into accepting care, it can become a very negative experience, whereas if it is used as a vehicle to address their concerns and to help them co-diagnose their condition, the patient will most likely move forward with care.

Many practices have also incorporated stand-alone applications, such as VELscope (LED Dental, Inc.) and the Identafi 3000 (Trimira Remicalm), for help in oral-cancer screening by using high-energy light sources to visualise tissue fluorescence. Giving the patient an opportunity to see what we see is a very powerful tool in helping them own their dental condition and allowing us to become their advocate for care.

_CBCT

CBCT has been available since 2000; the driving force for this technology has been implant therapy. The cost for this technology has come down somewhat with the introduction of newer technology
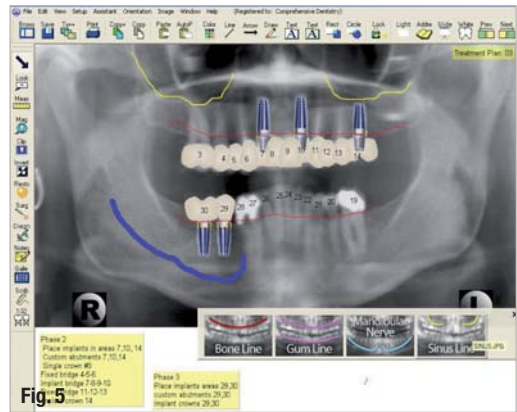
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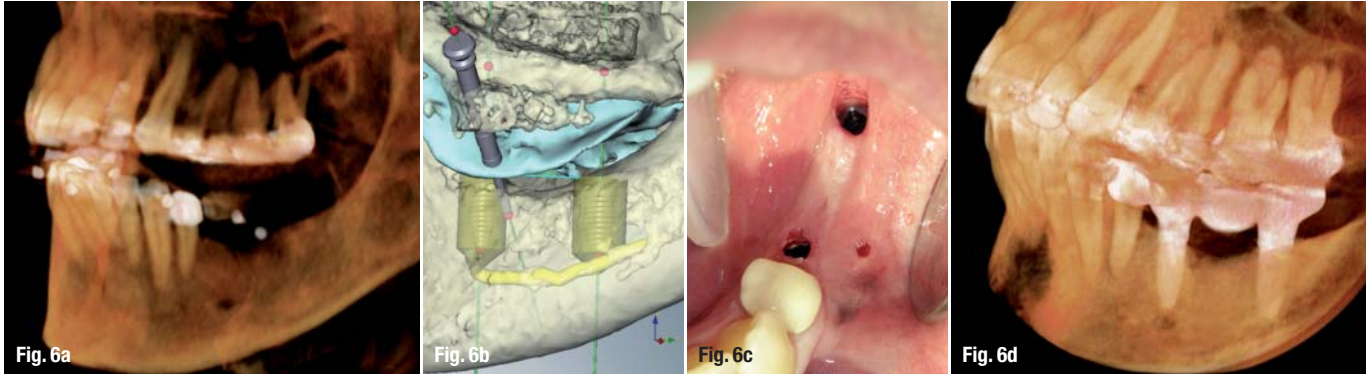E-mail: info@gnydm.com
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Fig. 6a

Fig. 6b

Fig. 6c

Fig. 6d

Fig. 6a_Pre-op CBCT scan with radiographic guide.
Fig. 6b_NobelGuide guided surgery plan.
Fig. 6c_Post-op implants seated with surgical guide prior to seating laboratory-processed provisional.
Fig. 6d_Post-op CBCT scan with implants and immediate provisional prosthesis.

and increased competition. There are currently at least 20 CBCT scanners available in the US, with more undergoing the FDA approval process.

All CBCT units provide 3-D information; however, each manufacturer approaches the project differently regarding its choice of patient positioning, scanning parameters and viewing software. CBCT units are most commonly categorised by their X-ray detection system, image-intensifier detector (II) or flat panel detector (FP). IIs are an older and less expensive technology that generally result in more noise than FPs and need to be preprocessed to reduce geometric distortions inherent in the detector configuration. The radiation beam is 3-D in shape

tact a fluorescent screen that emits light captured by a charge couple device camera. The software then reconstructs the sum of exposures using proprietary algorithms calculated by the manufacturers into as many as 512 axial-slice images.

Many CBCT units have a variable field of view (FOV) that allows the clinician to limit the radiation exposure to the region of interest. The limiting factor is the size of the image detector, which comes in a number of sizes depending on the manufacturer, but for the sake of simplicity we will categorise them into small (<15 cm), medium (15 cm), large (23 cm) and extra-large (30 cm) FOVs. The maximum image of a small FOV usually can accommodate most of the adult dentition. The maximum medium FOV can accommodate all the adult dentition extending into the condyles and sinuses. The maximum large FOV image encompasses the maxillo-facial anatomy, including the condyles and most of the orbits. Finally, the extra-large FOV can accommodate the full skull in most cases. Regardless of the volume capacity of the unit, it is important to restrict the FOV for the region of interest, which has a significant effect on the amount of radiation absorbed.
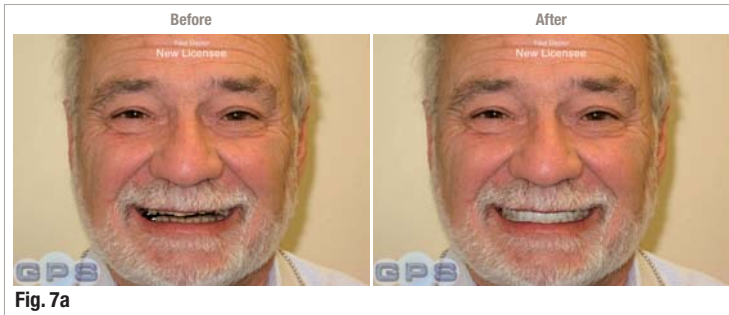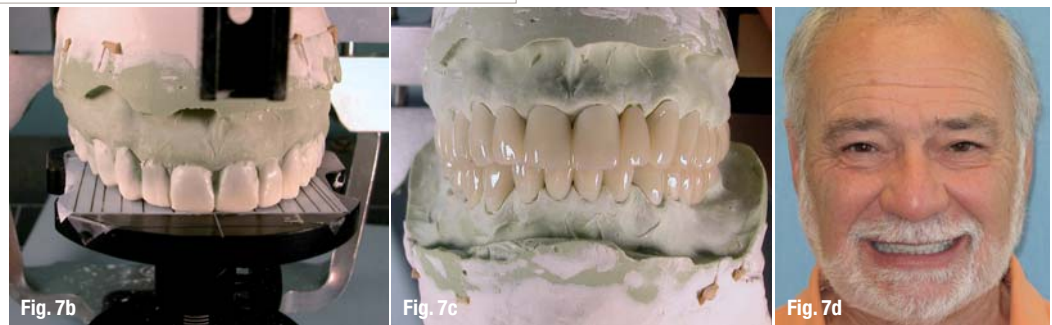

Before

After

Fig. 7a

Fig. 7a_Prosthodontic simulation using Dental GPS.
Fig. 7b_Models being waxed up in the laboratory using Dental GPS.
Fig. 7c_Finished provisional restorations using Dental GPS.
Fig. 7d_Competed provisional reconstruction.

Fig. 7b

Fig. 7c

Fig. 7d

and similar to photon energy used in digital or conventional dental radiology.

The receptor captures 2-D images either directly through the FP, which absorbs the photons that are converted to an electric charge, which is measured by the computer or with the II, which captures the photons and converts them to electrons that con-

DICOM format images are standard for handling, storing, printing and transmitting information in medical imaging, including those from CBCT. In 3-D imaging, this becomes a great asset in exporting this data set to third-party software programs that will facilitate image renderings, implant-planning programs and making surgical guides to assist in implant placement (Figs. 4a–c).

_Consultative and treatment planning

Once the examination and diagnostic records have been collected, the process of interpretation, diagnosis, treatment planning and consultation come into play, with a myriad of applications to facilitate those processes. Current state-of-the-art systems are based on 3-D applications, but there are systems even for those who have been most conservative with technology applications. With a minimum investment in a laptop computer, a digital camera and software, a dentist can incorporate digital treatment planning and interactive consultation by using XCPT (XCPT, LLC). XCPT provides visuals of proposed treatment, such as crowns, bridges and implants on the patient's X-rays, CT scans, or photographs. The software saves time, reduces paperwork, streamlines workflow in the office and allows patients to grasp treatment concepts quickly and intuitively (Fig. 5).

When it comes to working in 3-D, there are a number of software applications that import DICOM files from any CT or CBCT unit, and then allow you to plan your case more accurately and many of these programs will also allow you to have a surgical guide made for guided implant surgery and immediate prosthetic restoration.

Programs such as InVivo (Anatomage, Inc.), Dolphin Imaging and Management Solutions, NobelGuide (Nobel Biocare) and SimPlant (Materialise Dental, Inc.) will all help you analyse your CT or CBCT scan and plan your implant treatments, but surgical guide construction can be influenced by which implant system you choose to work with.

If you work primarily with Nobel Biocare implants, NobelGuide—their proprietary software application—will allow you to format the DICOM data file from any CT or CBCT unit, design the case and directly order the surgical guide along with all the implant surgical, prosthetic hardware needed to complete the case. By working with a laboratory that has the NobelGuide software, your provisional prosthesis can also be constructed from the CT or CBCT data set (Figs. 6a–d).

There is a growing trend towards guided implant surgery. The benefit for the patient is that the surgical placement of implants and the insertion of the prosthesis can be done during the same visit. This is more costly but there is always a premium for the convenience. The challenge is that there is no room for error, so the dentist has to be prepared with a back-up plan, should there be complications during surgery.
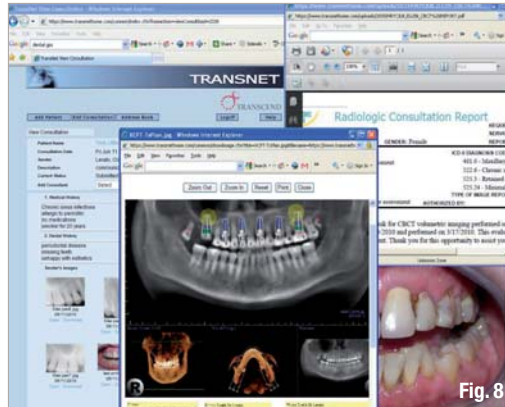

Fig. 8_Multiple open windows of different file types in Transnet.

_Cosmetic imaging

Cosmetic imaging has been around for over 20 years, but recently a company has taken this application to the next level. Dental GPS (Dental GPS, Inc.) can simulate anything, from whitening to full-mouth reconstruction, with the subtle twist that it can morph the teeth into the existing soft-tissue envelope. What this means is that it can facilitate the predictability of your provisional and final prosthesis from the photographic simulation. By using the Kois Dento-Facial Analyzer System (Panadent) with face bow, the simulation can give the laboratory a guide to waxing up the case for provisionals (Figs. 7a–d).

Figs. 9a & b_Example of radiographic report and report images returned by radiologist.
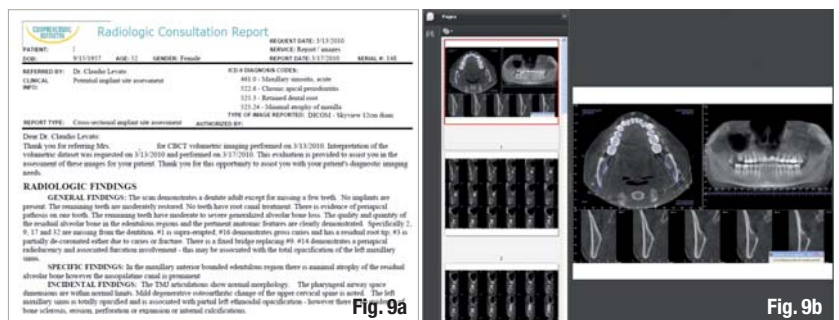
_Imaging communication

One of the most significant advantages of digital imaging is the ability to share images with colleagues for referral or second opinions. It facilitates interdisciplinary care and can save patients significant time and money. In today's fast-paced society, time is becoming a very limited commodity. Once you have examined the patient and have uncovered conditions that require other input, you can upload any kind of digital file and send it to any number of colleagues for input. We have been using an application called Transnet (Transcend) since 2000, which has significantly reduced the need for specialty consultation prior to treatment.

We have been using the same network of specialists for years and know the information they
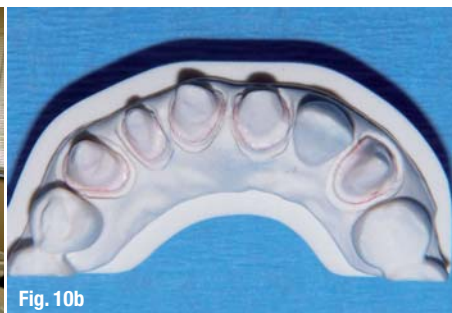
Fig. 10a

Fig. 10b

Fig. 10c

Fig. 10a_Assistant in one of our operatories taking optical impression with iTero.
Fig. 10b_Milled model from iTero scan that was sent to laboratory.
Fig. 10c_Finished restorations on iTero model.

would need to render an opinion and determine a fee for the procedure. They respond to our communication and we inform the patient and review the treatment and fee. Then the patient merely calls and sets up the treatment visit. This works extremely well for routine referrals, but complex cases still warrant separate specialty examinations (Fig. 8).

With CBCT's dramatic impact on diagnostic imaging, Internet data transfers are becoming more important. Most dentists are still unfamiliar with reading 3-D radiographic images and in the US, many dentists use the services of oral and maxillofacial radiologists to interpret those images in order to rule out possible pathologies. These image files are very large and thus usually need to be uploaded to an FTP site (Figs. 9a & b).

Another expanding 3-D technology that was first introduced 25 years ago was the original Cerec CAD/CAM system (Sirona), a 3-D optical impression system. There are several major companies that use different imaging technologies with similar results that exceed the accuracies of traditional impression materials—3M Lava COS uses streaming video, iTero (Cadent, Inc.) uses laser optics, Cerec AC (Sirona) uses Blucam—and there are some companies ready to introduce confocal digital impression technology (Figs. 10a–c).

_Conclusion

Hopefully this article has painted a realistic picture of what is actually possible in a clinical practice. Dr Omer Reed, a dentist visionary from Phoenix, Arizona, said over 40 years ago, "If something has been done, it is probably possible." There are dentists all over the world solving clinical issues for their patients by expanding the applications of existing technology in unique and different ways, pushing the envelope of science and art beyond the original intention and capability. Technology should not be the focus of the dental practice, but should be transparent and used when it provides solutions for your patients' concerns. The focus of technology is to allow us to provide better and more cost-effective services. As Dr Gordon Christensen, founder of Clinical Research, has been saying for decades: "Better,

faster and cheaper is the mantra for justifying the investment expense for technology integration."

So it is evident that imaging in dentistry has become an integral part of every phase of dentistry. Unfortunately at this time, there is no single source that provides all these applications in a neat package; thus, the challenge of total seamless integration remains elusive and may never be fully realised.

If I have learned anything from my personal journey in technology implementation, it is that as soon as I have incorporated any new application, there undoubtedly will be limitations with new and different solutions right around the corner._

"The only constant is change, continuing change, inevitable change that is the dominant factor in society today. No sensible decision can be made any longer without taking into account not only the world as it is, but the world as it will be."
—Isaac Asimov

_about the author

cosmetic dentistry

Dr Claudio M. Levato is in a private practice that has invested heavily in leading-edge technologies for over 30 years, spanning five computer systems and transitioning different operating systems to create a fully integrated digital patient record shared in two locations. Dr Levato is an author and lecturer on leading-edge technology and serves on several clinical advisory boards for radiology and restorative dental companies. He can be contacted at:

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