THE FUTURE OF TECHNOLOGY IN THE ORTHODONTIC PRACTICE: LOOKING BACK … LOOKING FORWARD

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ABSTRACT

In this chapter, we will attempt to provide a digest of the innovations the orthodontic profession has taken on during the last 40 years and will make some predictions on how clinicians might employ emerging technologies over the next 40 years. **WHERE HAVE WE BEEN?** Data access in both imaging and practice management has evolved to provide the orthodontist with more information from which to diagnose and plan treatment. As more and more information became electronic, it followed that formerly segregated operations of the orthodontic practice now would become integrated, creating a more streamlined workflow that included the embracing of computer hardware in the orthodontic office and the development of specialized software. **WHERE ARE WE NOW?** Advancements in bandwidth speed have led to the super-fast transfer of data, adding capability and flexibility to the orthodontic workflow. Business broadband, Wi-Fi, 4G/LTE technologies and Cloud computing all make it possible to work from virtually anywhere without hassle. The introduction of smaller, more capable hardware such as Smartphones, tablets and laptops has enhanced this experience. **WHERE ARE WE HEADED?** The original focus of employing technology in the orthodontic practice was on accuracy of diagnosis and results. Future technological advancements will help reduce treatment time and perfect results. Along the way, human intervention will be reduced for further automation and accuracy of data gathering and treatment. Traditionally, orthodontics has been one of the most progressive professions and is displaying an even faster rate of adoption moving forward.

KEY WORDS: digital orthodontics, practice management, 3D imaging, cloud computing, 3D printing

INTRODUCTION

Technology moves fast and affects everything around us—including all aspects of the orthodontic practice. It is intriguing to observe periodically how far we have progressed, incorporating various technologies into the typical orthodontic workflow. In this chapter, we will attempt to provide a digest of the innovations the orthodontic profession has taken on during the last 40 years and boldly will make some predictions on how clinicians might employ emerging technologies in the not-too-distant future.

WHERE HAVE WE BEEN?

Three main areas of advancement in the broader market technology have triggered advancements in the dental and specialty professions. First, data access in both imaging and practice management has evolved to provide us with more information from which to diagnose and plan treatment. As more and more information became digitized, it followed that formerly segregated operations of the orthodontic practice now would become integrated, creating a more streamlined workflow. Second, because digital data demands electronic hardware for access, computers replaced paper, thereby replacing manual tasks with automation—helping to reduce margin for human error in many areas of practice. Lastly, these first two advancements triggered the need for specialized software that was user friendly and designed specifically for the tasks of the orthodontist.

Imaging

The introduction in 1988 of the first consumer digital camera had a global impact on orthodontic practice: diagnostics, treatment planning, practice workflow and record keeping became streamlined and positioned to become integrated. The sudden ability to capture digital data with inexpensive equipment and very little operator instruction meant that orthodontic staff could obtain and create their own patient records, eliminating the need for a third-party vendor (Iwamoto, 2007). In addition, it paved the way for specialized software dedicated to image management. Many software companies took this a step further by developing complementary imaging and practice management systems that would integrate with each other, allowing one-stop shopping for practitioners looking to streamline their practice.

Now that imaging data was digital and easily available, there was so much more that could be done with it. The practitioner could organize a patient's image data such that it was accessible easily and not vulnerable to deterioration brought on by time and environment. Also, s/he could integrate those images with practice management systems, further customizing patient charts and enhancing all communications such as letters (Weinberger, 2008).

Cephalometric Tracing

Cephalometrics was introduced in 1931 by B.H. Broadbent and remains a vital diagnostic tool in orthodontics. Practitioners rely on this system to diagnose, plan treatment and monitor changes resulting from treatment and growth (Broadbent, 1931). Tracing of the cephalogram was performed manually until the early 1970s, when Robert M. Ricketts (Rocky Mountain Data Systems) created a computerized cephalometric tracing/VTO system. Cephalometric computer programs often contain hundreds of analyses, any number of which can be performed simultaneously under the direction of the operator. This instantaneous access to such a large spectrum of data enhanced the clinician's ability to make a more accurate diagnosis while also saving countless hours of labor (Wang and Randazzo, 2010).

In 1988, Dolphin Imaging introduced the DigiGraph, which used sonic technology to gather cephalometric information, thereby eliminating radiation from the process. While this approach was an interesting direction, before long it became apparent that the traditional method (x-rays) of gathering the cephalometric imagery was more practical.

Digital Study Models

Historically, study models are the major record used for treatment planning. The *American Association of Orthodontists* (AAO) includes "dental casts (or digital models)" in its list of recommended pre- and post-treatment orthodontic records in the publication *Clinical Practice Guidelines for Orthodontics and Dentofacial Orthopedics.* The traditional plaster study model can be digitized, allowing the practitioner to process these data and incorporate the data set into the patient's electronic record.

In 1999, OrthoCAD™ was the first company to offer a digitizing service to the orthodontic community, followed by eModels™ in 2001. Digital models also assist in patient education, as the younger generation is comfortable with computer-generated information. This methodology serves to improve communication between clinician and patient and enhances informed consent (Peluso et al., 2004).

Cone-beam Computed Tomography

Cone-beam computed tomography (CBCT) was introduced for use in dentistry in the early 1999. CBCT provided low-radiation, single-scan volumetric datasets that gave practitioners access to an enormous amount of accurate anatomical data. In 2001, the NewTom 9000 (Quantitative Radiology, Verona, Italy) was installed at Loma Linda University, CA, marking the first U.S. installation of a CBCT scanner for dentistry. Within just a few years, there were a handful of companies producing CBCT machines and the i-CAT® (Imaging Sciences, Hatfield, PA) would become the most popular unit on the market.

The CBCT output also could serve as a patient's singular dataset from which to derive all the traditional image views of an orthodontic workup. In fact, studies have shown that landmark identification is more precise when performed on multi-planar views of a CBCT dataset than on a traditional lateral cephalogram (Ludlow et al., 2009). Further, the views could be manipulated onscreen for optimum evaluation. Collectively CBCT emitted less radiation than did a traditional series of images (Lagravère et al., 2008).

Practice Management

In the 1980s, UNIX and DOS entered the arena, opening the doors to practice management systems. These computerized databases allowed practices to streamline financial transactions, schedule patient appointments and create electronic treatment cards. In addition, the programs were customizable so that details such as color coding, number of columns, procedure names and sizes of time slots all could be user defined.

Software

The arrival of digital data prompted the development of specialized software used to organize, process and integrate the orthodontic practice. Software was developed specifically for an end-user lacking a formal technological background. The dental professional now was empowered with a lot more information and more sophisticated tools from which to make a more accurate diagnosis and treatment plan.

All this changed the flow and décor of the orthodontic practice: computer monitors and workstations now appear in all areas of the orthodontic office, becoming the primary means for accessing and communicating information not only in the front office, but also in the practice at large.

WHERE ARE WE NOW?

As technology advanced, so did the means of accessing and processing the data being handled by the technology. Faster bandwidth meant faster download and transfer of data, lending added capability and flexibility to our everyday lives—including the orthodontic workflow. Business broadband, Wi-Fi, 4G/LTE technologies and Cloud computing that offered not only mobility but large online storage all made it possible to work from virtually anywhere without difficulty. Enhancing this experience was the introduction of smaller, more capable hardware such as Smartphones, tablets and laptops that could be transported easily in a pocket, purse or briefcase.

Faster Bandwidth

While Internet technology was created in the 1960s by the government for military purposes, it did not become available commercially until 1992. Since then, online access and the World Wide Web have become integral to everything that we do. In the last decade, increasing bandwidth speeds coupled with wireless technology have allowed us to become less reliant on wired Internet plugged into our PCs: in 1996, the first mobile phone had Internet and studies showed that more people accessed the Internet *via* mobile phones in 2008 than through their PCs. While broadband generally is defined as data transfer rates greater than 256Kbps, today's 4G networks can transfer data at 100Mbps (Stewart, 2011). This increased speed is having a profound effect on what we can do with our practice data and how that, in turn, affects our office workflow environment.

Smaller, More Capable Hardware

Laptops have become as powerful as any desktop PC, with batteries lasting up to 12 hours. Other portable devices such as tablets

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and Smartphones also can provide most or all of the capability of a desktop computer with the added benefit of mobility. Because of this portability, more people are opting to work directly from their laptop or other mobile device. These mobile solutions are connected with very fast speed Internet, allowing access to the latest medical research at the point of care and instantaneous communication with colleagues around the world (Burdette et al., 2008; Dala-Ali et al., 2011).

Dolphin developed its Dolphin Mobile application in order to address these needs of the orthodontic community. Dolphin Mobile allows the practitioner to access his/her Dolphin database and operate all Dolphin programs from Smartphones and tablets with both the Android and iOS operating systems. Depending on the Dolphin products that a practice uses, it can have full access to the practice's calendar and detailed schedule, financial and demographic information, in addition to image records including 3D records.

Cloud Computing

Cloud computing offers a secure, convenient means for a practice to enjoy all the advantages of information technology without needing to be bothered with technical hassles and costs of maintaining hardware and software. The very concept of Cloud computing eliminates reliance on local hardware and its configuration. Practitioners are able to access their practice data by connecting to the Internet *via* a device such as a laptop, tablet or Smartphone. A side benefit is the extra space in the office that normally would house the server (Torrieri, 2012).

Relatively speaking, Cloud computing is not a new concept. Commercial and consumer use of Cloud services began soon after the Internet was made available to the public in the 1990s. Email services such as Hotmail and AOL are some of the first examples, while document-sharing services such as Google Docs and Dropbox went a step further, allowing the storage and sharing of files on the Internet—or "Cloud." Photo-storing and photo-sharing sites such as Picasa and Flickr, and social networking sites like MySpace and LinkedIn, are more examples of Cloud computing. In 2000, Dolphin introduced AnywhereDolphin, a Cloud service that lets one share patient data online with patients and referrals.

Within orthodontics, practice management systems were among the first to migrate to the Cloud, with more products and services following every day. The recent introduction of Dolphin Cloud allows users to access and operate all Dolphin software from anywhere there is an Internet connection.

Paperless Practice Management

The term "paperless" often is in reference to the gradual adoption of the Electronic Health Record (EHR) system. However, technology has replaced far more in the medical/dental practice than paper charts and appointment calendars. Innovations such as fingerprint scanning for patient check-in, electronic signature for authorizing consent and other documents, patient educational videos, online payment and email and text messaging for communicating are just a few examples of how far we have come in the quest to conquer paper.

Social Media

Social media offers a brand new way to interact with patients and referrals, in addition to providing a dynamic platform for marketing your business. In fact, many medical and social media professionals feel that creating and monitoring an online presence is vital for a doctor and practice to maintain patient trust.

The Internet has become the resource of choice for patients to gather information about their provider, medical conditions, treatment options and voice opinions about their experience. If a patient is venting online, it is in the provider's best interest to know about it immediately so s/he may deal with it effectively. In addition, there exists a proliferation of questionable health information and advice being made available by "non-experts," diluting the voice and authority of real medical professionals (Chen, 2013).

Interacting with patients on social media platforms gives you the opportunity to gather feedback and gauge collective attitudes about health conditions, medications and treatments (Dolan, 2012). Popular platforms among patients include Facebook, YouTube and Twitter.

Digital Impressions, CAD/CAM, 3D Printing

3D printing first was used in dentistry in the 1980s with the separate contributions of three pioneers of CAD/CAM systems. These included Dr. Werner Moermann, who developed the Sirona CEREC® product that combined a digital impression system with a chairside 3D printer to create single-visit ceramic restorations such as crowns, inlays and overlays (Miyazaki et al., 2009). In the late 2000s, more advanced digital impression systems and 3D printing technology made possible a far broader application of CAD/CAM beyond crowns and overlays. Progressive practices already are using the integration of these technologies to streamline the entire diagnostic, treatment planning and treatment process.

As mentioned earlier, study models are an integral tool used by the orthodontist in the treatment planning process. The ability to scan plaster models and import the digital data for a broader range of applications was a huge leap in the data gathering process. Now, digital impression systems such as iTero® use an intraoral scanner to capture data directly from the patient's mouth, completely bypassing the need for traditional PVS impressions. The datasets gathered from intraoral scanning systems can be used to create both stereolithographic and three-dimensional (3D) digital models and have been determined to be a valid and reproducible method for measuring distances in a dentition (Cuperus et al., 2012).

The scanners are being used by both doctors and staff, with typical scanning time being reported less than ten minutes for the entire process. These digital files have lots of uses—they can be archived easily, imported to systems such as SureSmile® and Invisalign®, and merged with a patient's CBCT scan as part of their comprehensive record.

Digital Orthodontics

The digitization of data over the last several decades has led to more than the integration of all aspects of the orthodontic practice—it also has allowed for the development of alternate modes of treatment outside of bands and brackets. Examples include: Invisalign®, a sequence of clear aligners that rely on digital data not only to create the appliances, but also customize them for each patient; Incognito™ lingual braces, which are customized for each patient; and SureSmile®, which uses 3D imaging, treatment planning software and robotics to create customized wires for each patient.

These systems step up from conventional braces in that they address the movement of each tooth individually, while directing all the teeth to move in concert to a more precise result. Most of the products enable the clinician to place virtual brackets and simulate treatment, allowing for the exploration of alternative treatment plans. Some products allow the clinician to reposition or torque each tooth individually.

More Capable Software

In 1965, Gordon Moore, co-founder of Intel, predicted that the number of transistors on a microchip could double every 24 months (Moore, 1965; Twist, 2005). Known as "Moore's Law," this prediction has held true for more than 40 years. The consequence of this prediction has been the rapid pace of software evolution, with more powerful software being released each year. This rapid increase has included more sophisticated solutions for the orthodontist regarding diagnosis, treatment planning, case presentation and patient communication. One example is the dynamic, interactive patient-education systems that have appeared in the last few years. Doctors are discovering that the animated imagery used by these systems greatly enhances a patient's comprehension of the diagnosis and treatment process.

WHERE ARE WE HEADED?

Technology in the orthodontic office continues to become more sophisticated as bandwidths get faster and hardware devices become smaller and more mobile. In the beginning, the focus of employing technology was to increase accuracy of diagnosis and results; as a result, workflow became more streamlined. Technological advancements in the future will help to reduce treatment time and further perfect results. Along the way, human intervention will be reduced for further automation and accuracy of data gathering and treatment. Traditionally, orthodontics has been one of the most progressive professions. It is displaying an even faster rate of adoption moving forward.

3D Imaging

Image records are an integral dataset for any practitioner. In the future, the routine gathering of the necessary information will be safer, faster and more comprehensive. Already in use in select emergency centers around the world is Lodox® Statscan (LS), an x-ray machine capable of imaging the entire body in 13 seconds using linear slit scanning radiography (LSSR). Currently in limited use for evaluating trauma patients, LS has a future in broader applications due to its high speed, high quality, low dose, single whole-body scans. It delivers up to ten times less harmful dose than regular x-ray systems. In addition, it offers 3D reconstructive functionality (Evangelopoulos et al., 2009; Whiley et al., 2012).

3D Printing

As mentioned earlier, CAD/CAM technology and 3D printing has progressed in recent years beyond mere restoration to create appliances such as splints and retainers. In the future, we see a far more streamlined process with a single fast, low-resolution body scan providing all the data needed for diagnosis, treatment planning and appliance or prosthesis generation.

This scenario really is not so outrageous. True story: in early 2008, the University of Hasselt (Belgium) announced that Belgian and Dutch scientists successfully replaced a lower jaw with a 3D printed model for an 83-year-old woman. According to the researchers, it was the first custom-made implant in the world to replace an entire lower jaw. The mandible of the woman was infected badly and needed to be removed. Considering the age of the patient, a “classical” microsurgical reconstructive surgery takes too long and can be risky. Therefore, a tailor-made implant is the best choice. Normally it takes a few days to produce a custom implant, but with 3D printing technology, it takes only a few hours (Richmond, 2012).

With desktop 3D printers already on the market, it is not difficult to predict that one day soon they will be a staple piece of equipment in the orthodontic office for on-site production of study models, retainers and other appliances.

Machine 2 Machine (M2M)

Machine-to-machine (M2M) technology already is being used in a wide range of applications—from security and surveillance to traffic control and healthcare. M2M uses wired or wireless connectivity to exchange information and communications between Web-connected devices without the need for human intervention. In healthcare, application of M2M involves a remote sensor—usually worn by the patient—that gathers source data such as blood pressure, heart rate and glucose levels, then transfers it *via* the Internet to a controlling server where it is analyzed and acted upon by a host system such as a medical facility (Bodhani, 2012).

A. *Nanomedicine*

Nanotechnology is the manipulation of matter at the atomic and molecular scale to create materials with remarkably varied and new properties (Paddock, 2012). Nanomaterials differ from other materials in two aspects: the increase in relative surface area and quantum effects. These two aspects work in tandem in that as size is reduced to the nanoscale, quantum effects begin to dominate affecting the optical, electrical and magnetic behavior of materials.

Nanotechnology promises applications in the areas of electronics, construction, alternative energy sources, biotechnology and dozens of others including medicine, specifically dentistry. In medicine, nanomaterials can be engineered for use in diagnostics, gene therapy, drug delivery, and tissue and bone repair. Dental applications could include local anesthesia, tooth renaturalization, prosthetic and appliance durability and more (Kanaparthy and Kanaparthy, 2011). One example of nanotechnology already being employed is SimpliClear® from BioMers Pt Ltd, a medical technology company based in Singapore. SimpliClear uses translucent composite polymer wires made strong through nanotechnology (Universidad Carlos III de Madrid, 2012).

Alternative Computer Control Interface

For decades we have been dependent on the mouse, keyboard and carpal/metacarpal dexterity to operate computers and access our data. While this system of computer control has become second nature, limitations of all three components have spurred development of alternative methods. Interfaces that allow the ability to control the computer using voice, gestures, brain waves, eye movement and just plain physical motion already are being implemented in business and consumer sectors. Apple’s iOS personal assistant Siri and Google’s Google Voice are widespread examples of voice control technology, while Microsoft's motion-sensing Kinect has been a driver in gaming technology.

Freeing up the hands and reducing the hardware has benefits beyond mere convenience. It makes computer technology accessible to people with disabilities, reduces the incidence of repetitive stress injury, diminishes the spread of germs and allows for multi-tasking. In medicine, the implications are more far reaching: surgeons routinely refer to patient images and records during surgery, but stepping away from the operating table to touch a keyboard and mouse can delay the surgery and increase the risk of spreading infection (Venere, 2011).

On the opposite side of the healthcare sector, disabled patients have benefited from alternative interfaces since the 1980s. The Eyegaze Edge® Communication and Analysis Systems from LC Technologies (Fairfax, VA) uses eye-tracking technology to help patients with spinal injuries and motor disorders communicate and interact with the world around them. More recently, researchers are exploring the use of brain-computer interfaces (BCIs) for communicating with both Alzheimer's patients and those in a non-responsive, awake condition due to brain trauma. By communicating their brain waves directly to an external device, the disabled patient bypasses the normal output pathways of peripheral nerves and muscles (Liberati et al., 2012; Naci et al., 2012).

ACCELERATING CHANGE

Forty years ago, Gordon Moore proposed the concept of exponential growth in reference to semiconductor circuits. The realization of his predictions allowed for astounding technological advancements that have transformed orthodontics. In 1999, Ray Kurzweil (futurist) applied that concept to a broader range of evolutionary systems, including but not limited to technology. "… We won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today's rate). The 'returns,' such as chip speed and cost-effectiveness, also increase exponentially…" he wrote in a 2001 essay entitled *The Law of Accelerating Returns*. Kurzweil's vision (2001) includes the eventual merging of biological and non-biological intelligence.

Of course, wild predictions such as Kurzweil's are difficult—if even possible—to comprehend today. We know, however, that the one thing we can count on for the future is the profession's continued dedication to help improve patient care, treatment outcomes and overall quality of life for doctor and patient.

20-YEAR VISION: ORTHODONTICS IN 2033

Considering the exponential rate of technological advancement, orthodontic practice in the coming generations is poised to be exceptionally different than it is today. The following is a scenario based on the technologies discussed in this chapter:

The patient meets with the clinician either in person or remotely for consultation, preliminary diagnosis and treatment options. The patient then would receive a super-low dose full-body scan, either at the clinician's office or a facility. From this scan, the clinician will finalize a treatment plan and forward it to the patient's personal information device.

The patient's personal information device will communicate with an in-home 3D printer that will produce the customized appliances—aligners, brackets (labial or lingual, based on the patient's requirements and suitability), wires and the like. All these items would be personalized completely in size, shape and materials.

Minutes after the appliance kit is completed, the patient will attach the appliances without any assistance: if brackets have been prescribed, they require no adhesive; brackets will be placed in a specialized tray (also generated *via* in-home 3D printer), that the patient simply places into the mouth. Once inserted, the orthodontic professional (remotely) will activate the brackets.

The brackets then would fuse to the teeth automatically *via* nanotechnology. To remove, the office would issue a command to reverse the process remotely. The attachment would be permanent until it is deactivated by the clinician.

Nanosensors already would be in embedded in these brackets, wires and aligners, allowing treatment with a single aligner or wire from start to finish. The sensors allow the clinician to evaluate and even make adjustments to the prescription of the appliance remotely, based on the information provided by the nanosensors.

Following a schedule set by the clinician, a central control system automatically would check on each patient remotely (on hygiene, position, attachment status) and automatically make any necessary adjustments or correction. It is able to do this because the bracket itself—including the slots—can alter physically in angles and shape (based on the mechanical design of the appliance). The wire length and shape can be altered as well based on the survey from the latest check-up. The automated system also can evaluate the patient's progress in real-time constantly and issue alerts on any necessary interventions. Otherwise, it will be on autopilot treatment/adjustment.

Further, by 2053—20 years later—orthodontic gene therapy will be discovered and mastered. Orthodontic specialists in the 2050s would prescribe the patient a new gene that would cause the patient's teeth to move gradually into the correct position and onto perfectly sized and positioned jaw structures. This corrected gene then will be passed to the children and subsequent offspring. Preventive gene therapy also would be available. And so orthodontics—at least as we know the profession today—will cease to exist in our world. Since this will not happen for a couple of more generations, we have sufficient of time to prepare for the evolution in this revolution.

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