Without a doubt, during the past decade, 2D digital radiography of the craniofacial region has been established as the standard of diagnostic care in our profession of orthodontics. It is my opinion that our profession is now making another transition with cone beam computed tomography (CBCT), establishing itself as the new standard of care in both 2D and now also 3D digital radiographic imaging. CBCT was first introduced to the dental profession in the United States in April of 2001 with AFP’s NewTom machine. Today, there are several different CBCT machines that are now commercially available: i-CAT, NewTom, Iluma, Ewoo, Sirona, Planmeca and Kodak to name a few. Until recently, CBCT has been utilized for the sole purpose of diagnosis and treatment planning in clinical orthodontics. Approximately two years ago, another significant application was developed for CBCT as it became integrated into clinical orthodontics with the merging of the two technologies of i-CAT and SureSmile. This merged application of i-CAT and SureSmile, has given orthodontists the ability to create from a CBCT scan customized robotically bent SureSmile wires that can now be utilized for actual therapeutic treatment of our patients. The ramifications of this are incredibly significant as we can now treat our patients in the 3D world. In this article, I will provide a general overview of the benefits of CBCT for both diagnostic and therapeutic treatment in orthodontics.

The use of CBCT in clinical orthodontics has been limited until recently due to two main factors: cost and radiation exposure to the patient. Both these factors have become less of an issue as the cost of a CBCT machine has decreased approximately 50 percent since 2001. Radiation exposure to the patient has also decreased to a range from 30 – 160 microsieverts (µSv). In comparison, this radiation exposure range is the equivalent of three digital panorexes to a full mouth digital series. Radiation exposure can be controlled and is dependent upon two main factors: 1) field of view (FOV) that can be collimated from 20 cm to 6 cm and 2) resolution or voxel size ranging from 0.1 mm – 0.4 mm. The smaller the FOV and the lower the voxel resolution (i.e. – 6 cm at 0.4 mm) leads to lower radiation exposure.

As we all know, problems that have been associated with 2D radiography are superimposition, elongation, and distortion. With the advent of CBCT, this has now given our profession both superior 2D and 3D imaging capabilities. We are now able to isolate precise 2D slices in the axial, coronal, and sagittal planes without the problems associated with traditional 2D digital radiography. The advantages of this for diagnosis and treatment planning are immense as can be illustrated in the following case.

I was brought in by an attorney as an expert witness to review orthodontic treatment for a 15-year-and-six-month-old male patient (Figure 1). This young man had suffered an ATV accident at the age of 10 years and eight months and had been plated for an open mandible fracture in the right inferior border of the mandible. In January 2008, at the age of 14 years and 10 months, orthodontic treatment was initiated by another clinician. It was recommended by this clinician after several months of orthodontic treatment that the LR5 was ankylosed and should be extracted. When provided with a copy of a conventional non-digital panorex (Figure 2), my suspicion was that the
screws on the mesial and distal of his LR5 possibly could be preventing the eruption of this tooth. As a result, I suggested that we get a CBCT scan with our i-CAT for further evaluation of his situation. Utilizing Dolphin 3D Imaging to view an axial slice of the root of his LR5, it is clearly evident that the distal screw is embedded in the root of his LR5 and that the mesial screw is adjacent to the mesial root surface of his LR5 (Figure 3). Further analysis of the position of the screw with sagittal slices also led to concern for potential paresthesia during the removal of the plates and screws due to the proximity of the tip of the screw in relation to the inferior alveolar nerve (Figure 4). I was asked to take over his orthodontic treatment by his parents and all this was explained to his parents prior to plate and screw removal by the oral surgeon. My treatment plan also included surgical uncovering of his LR5 with sub-luxation of his LR5 and LR4 and placement of a TAD between his UR4 and UR5 for indirect anchorage to prevent canting of his maxilla as we attempted to extrude his LR5 and LR4 with vertical elastics. In only 4.75 months of treatment, it is clearly evident that there have been significant positive changes with the positions of his LR6-

LR3 (Figure 5). There was minor paresthesia that did develop as a result of the plate and screw removal although this has continued to improve over the past six months.

CBCT also gives us the capability to easily transition between the 2D and 3D world. As a result, pathologies are now clearly evident when compared to traditional 2D radiography. This is clearly evident with the following patient. This 2D digital panorex taken in July 2005 (Figure 6) does not display the traumatic bone cyst that is clearly evident on the 3D i-CAT panorex taken in January 2007 (Figure 7). The reason for this is because with traditional 2D radiography there is superimposition of the dentition with bone, the tongue, airway space, and vertebrae along with elongation, which leads to distortion. However, with the i-CAT panorex, we are able to create a focal trough that allows us to see only the specific regions of interest (Figure 8). We can also very easily view the lesion utilizing Dolphin 3D imaging with a combined 2D and 3D approach (Figure 9).

3D images derived from CBCT scans also give us the capability to view our patients from multiple planes and as a result
we are able to precisely determine crown and root morphology and orientation of unerupted teeth within bone. We are also able to better evaluate the potential for root resorption of the adjacent teeth while actively extruding these teeth. Both of these points are clearly illustrated with the following patient (Figures 10a and 10b). Because we know precisely the crown orientation of the LR3 and that the adjacent root morphology is intact, the oral surgeon was able to bond a button with gold chain in a position so that I could direct the proper vector of force to a temporary anchorage device (TAD) that I placed between the roots of his LR4 and LR5. After 16 months of treatment the crown of the LR3 has just penetrated through the mucosal tissue and we will be able to bond a bracket on the tooth in the very near future (Figures 11a, 11b, and 11c).

The superior benefits of 2D and 3D imaging with CBCT for the diagnosis and management of transposed and impacted teeth are clearly evident with the following case. It is very evident that the UL3 and UL4 are transposed on this i-CAT panorex (Figure 12). In combination with a 3D slice from the axial view, we are able to precisely determine the exact positions of these two teeth as well as that of the impacted UR3 (Figure 13). As a result, on the day of the initial bonding of his maxillary arch, a soft tissue laser was utilized to uncover his UR3, UL3, and UL4 with placement of an open coil spring between his UL3 and UL5 for anchorage of his UL5 to retract his UL4 and to protract his UL3 (Figure 14). As a result, we are able to make definitive treatment decisions that lead to a higher quality of care and more efficient treatment for our patients (Figure 15).

Although the significant advantages of CBCT for diagnosis and treatment planning cannot be questioned, until a little more than two years ago, CBCT did not offer any means to actively treat our patients. In September 2006, our practice in Green Bay, Wisconsin, initiated a beta-testing project with Orametrix (the producers of SureSmile) and Imaging Sciences International (the producers of i-CAT) to evaluate the possibility of integrating i-CAT’s 3D scans to substitute for the use of SureSmile’s intraoral scanner to create SureSmile’s 3D virtual treatment models. SureSmile incorporates very powerful software applications to give the orthodontist the ability to create 3D virtual treatment simulations resulting in the fabrication of customized, robotically bent SureSmile wires. Because of the positive results that we saw with the quality and development of this project, in January 2007, we began utilizing i-CAT’s 3D scans for the actual fabrication of our patient’s SureSmile virtual treatment models and wires. This was the first time ever in the history of orthodontics that a CBCT scan was utilized to create a customized therapeutic appliance for clinical orthodontic treatment.

There are several benefits for the patient with utilizing an i-CAT scan instead of SureSmile’s intraoral scanner. First and foremost is patient comfort. The time necessary to take a SureSmile scan is 20 seconds with the i-CAT Classic and is 26.9 seconds with the Next Generation i-CAT. This is in comparison to an average of 20-30 minutes for an intraoral SureSmile scan. Also, the clinical time savings utilizing the i-CAT is without a doubt very significant on any SureSmile practice’s financial bottom line. Because the scan gives us full crown and root anatomy, our SureSmile virtual setups are more accurate as we can truly evaluate everything in the 3D world. The benefits of the integration of i-CAT and SureSmile can be demonstrated with the following case.

This young lady presented to me at 16 years and one month of age. She is a Class III with open bite skeletal growth pattern (Figure 16). My treatment plan consisted of 2 options for treatment. The first was to wait on completion of her growth and then to treat her with full fixed orthodontic appliances in combination with 2-jaw orthognathic surgery. The second option for treatment was to proceed with full fixed orthodontic treatment and the placement of two TADs in her mandibular arch for distalization of her L7’s. These two TADs would then later be repositioned between her L6’s and L7’s for correction of her Class III and open bite. Her medical insurance claim was rejected for her orthognathic surgical procedures and as a result her mother chose to proceed with option two.

Orthodontic treatment was initiated for this young lady on 10/16/07 with open coil springs placed between her LR6 and LR7 and LL6 and LL7 and utilizing two TADs placed just distal
to the roots of her LR6 and LL6 for indirect anchorage (Figure 17). These two TADs were then repositioned just mesial to her LR7 and LL7 after about five months of treatment with direct anchorage to the TADs with powerchain (Figure 18). Because the vectors of force to the two TADs are down and back, this helps to correct both her Class III and open bite malocclusion with retraction of the segment anterior to the TADs and intrusion of her molars. After 7.5 months of treatment, she was ready for her SureSmile scan utilizing the i-CAT (Figures 19a and 19b). Her SureSmile wires were inserted 6 weeks after her SureSmile i-CAT scan. 5/16” Class III elastics with 3 ½ ounces of force were worn bilaterally full-time from her U6’s to L3’s and U3’s from March 17, 2008, to September 15, 2008. Total treatment time was 13.2 months as her orthodontic treatment was completed on November 20, 2008 (Figure 20).

Summary and Conclusions:

The advances with CBCT over the past eight years in dentistry have been very significant. Scan times (8.5-40 seconds), resolution, and radiation exposure have all improved over the years. However, the transformation of CBCT from a purely diagnostic application to a combined diagnostic and therapeutic application has been truly phenomenal!!! SureSmile’s i-CAT generated wires are only the second appliance that has ever been utilized in dentistry for active therapeutic treatment of patients; with the other being 3D implant guided surgical guides.

Improvements that I would like to see with CBCT are: 1) precision 3D modeling of the bone and 2) decreased scan times with increased resolution, as head movement can sometimes still be an issue especially with younger patients. I believe that the cost for CBCT machines has dropped significantly over the past 6 months and I do not see them going much lower than their current price range as the companies need to make a return on their investment. Options for CBCT machines will continue to increase as there are an increased number of companies that are entering into the CBCT market place. My advice is to be very careful and selective with the brand and company that you select as you want to make certain that you will receive high quality IT support, service, and product development as their technology should always continue to improve. My belief is that not all of these companies will be around in the next five years and a $150,000 to $200,000 loss is a hard pill to swallow.

What the future holds is incredibly exciting if you sit back and realize that CBCT has only been around for the past 8 years. It is truly amazing how quickly the technology has advanced!!! I welcome and embrace any new development in our profession of orthodontics that will lead to an improved quality of care and treatment for our patients.

Dr. Ed Lin is a full-time practicing orthodontist and partner at both Orthodontic Specialists of Green Bay (OSGB), in Green Bay, Wisconsin, and also Apple Creek Orthodontics (ACO) in Appleton, Wisconsin. Dr. Lin received both his dental and orthodontic degrees from Northwestern University Dental School (‘95 - DDS and ‘99 - MS). OSGB and ACO are completely digital practices and have been at the forefront of the orthodontic profession in implementing technologies such as SureSmile, i-CAT, Dolphin and OrthoSesame. Their transition into a completely digital practice has led to more efficient systems in every aspect of their practice including scheduling, financials, digital records, and patient care. Dr. Lin is an internationally recognized speaker and has taught at both Marquette University and the University of Minnesota Dental Schools. He was a featured speaker at the 3rd International Congress on 3D Dental Imaging in Chicago, Illinois, in June 2009.