Since its commercial introduction into dentistry in 2001, cone beam computed tomography (CBCT) has been rapidly evolving into a new standard of care in maxillofacial imaging. In just over a decade, CBCT has exploded onto the dental landscape and permitted dental professionals a degree of three-dimensional (3D) anatomic truth in maxillofacial imaging previously unavailable and unattainable. Like many other new technologies, which have progressed from the extraordinary to the ordinary and thus gained acceptance by professionals and patients, CBCT has advanced from exceptional use to almost commonplace use in dentistry as cost decreases, access to the technology increases, and potential adverse patient interaction (i.e. radiation exposure) is attenuated. Today, CBCT is seen by many in dentistry as the standard operating procedure for many dental implant, orthognathic, orthodontic, or endodontic cases.

The advancement of CBCT in dentistry has caught the attention of manufacturers of radiological equipment. In 2001, only one company sold a CBCT system. In 2014 there are at least 20 companies selling CBCT machines and technology. Henry Schein, a leading distributor of dental equipment, has seen CBCT sales expand from 3% of their digital imaging sales to almost 50% of digital imaging sales in the last five years.

CBCT has also been recognized by general dentists and specialists as a means by which they can separate, identify, and distinguish their practices as being on the vanguard of technology in patient care. Today’s patients expect their dentist and physicians to be contemporary with technology and services. CBCT provides the doctor with a technology which not only has significant advantages in treating patients but also has a noteworthy “wow” factor as the 3-D images are seen on a large screen in “real-time” for the doctor and patient to view. CBCT, like plain film radiographic studies, may be considered a revenue generator for a practice. The more a CBCT machine is utilized, the more revenue it will generate. Additionally, the owner may allow others in the profession to utilize the machine for a fee, thereby reducing his overall cost of operation.

Standard of care is a legal not a medical or dental concept. Standards of care are constantly evolving as methods and techniques in patient care improve. An appropriate definition for standard of care may include such language as: the dentist is under a duty to use that degree of skill and care which is expected of a reasonably competent and prudent dentist under the same or similar circumstances. Standards of care may be local, regional, or national.

**Standard of care influences**

The influence of an emerging technology, like CBCT, into a new standard of care involves many criteria. These criteria include but are not limited to: court verdicts, expert testimony, literature support, professional guidelines, cost and availability of the technology, reimbursement by third party payers, and multi-specialty use and recognition.

Talon individually, these criteria do not constitute a mandate for any technology as a standard of care. Nor are these the only criteria one may use in determining standard of care. Taken together, these criteria provide strong evidence that CBCT technology has sufficiently evolved to be considered the standard of care in maxillofacial imaging in selected cases to assist the dentist in treatment for patients in need of dental implants, orthognathic surgery, manipulation of difficult impacted teeth, orthodontics, endodontics, and many other facets of dentistry.

**The legal perspective**

The legal system in the United States is complex and fragmented. No database exists to search verdicts in dental malpractice cases in which CBCT has played an important or pivotal role. For a new technology to become admissible as a standard of care in court, it must pass the Frye test. This standard comes from Frye v. United States which is a 1923 in a case discussing the admissibility of a polygraph test as evidence. The Frye standard maintains that scientific evidence presented to the court must be interpreted by the court as “generally accepted” and expert testimony must be based on scientific methods that are sufficiently established and accepted.

In Frye, the court opined: “Just as a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidentiary force of the principle must be recognized, and while the courts will go a long way in admitting experimental testimony derived from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.”

In many jurisdictions and in Federal court, the Frye standard is superseded by the Daubert standard. The Daubert standard is used by a trial judge to make a preliminary assessment of whether an expert’s scientific testimony is based on reasoning or methodology that is scientifically valid and can properly be applied to the facts at issue. Under this standard, the factors that may be considered in determining whether the methodology is valid are:
- theory or technique in question can be and has been tested,
- it has been subjected to peer review and publication,
- there is a known or potential error rate,
- the existence of maintenance standards controlling its operation,
- widespread acceptance with a relevant scientific community.

The theory or technique behind medical grade computed tomography and CBCT has been tested and proven sound over many years of application in the medical and dental arena. The Hounsfield unit is the widely recognized standard quantitative scale for describing radiodensity and provides doctors with a known standard and error rate in computed tomography. The widespread acceptance of CBCT by the dental and medical community is demonstrated by the ever increasing presence in dental and medical practices of the technology. Additionally, The InterSocietal Accreditation Commission, an accreditation organization for medical and dental imaging, has developed guidelines and accreditation criteria for 3-D CBCT imaging. Thus CBCT appears to have satisfied both the Frye and Daubert criteria for acceptance as a standard of care technology.

Not to discount the value of CBCT imaging or its ability to successfully satisfy the Frye or Daubert criteria, the absence of CBCT is not fact evidence of lack of a standard of care imaging. Many patients present to their dentist with uncomplicated cases where traditional two-dimensional radiographic studies are appropriate and provide the dentist with standard of care imaging of the patient. For the more complicated cases, 3-D imaging may be employed to provide the dentist with superior anatomic evidence.
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in treatment planning and diagnosis. Three-dimensional imaging with CBCT can also be used in uncomplicated cases, but it may not necessarily be considered as the standard of care for every case in 2024.

**Expert Testimony**

An expert is a person with sufficient minimal qualifications to render an opinion on the subject at hand. Not all experts are created equal, and in fact in three states (Florida, South Dakota, and New Hampshire) an expert need only be qualified in a related field, to offer an opinion. Experts are used by the courts to educate the judge and jury as to what constitutes normal minimal acceptable care of a patient in a given environment.

Expert testimony is by definition the opinion of one practitioner. It is an opinion based on fact, evidence, experience, and knowledge which the expert believes to be relevant, valid, and upheld in the scientific community.

When reviewing a case for suspected malpractice the expert examines many things, including but not limited to: chart notes, radiographic studies, depositions, and professional correspondence. In the last five years, the author has noticed a remarkable increase in the number of cases in which plaintiffs and defense attorneys, as well as experts, rely on pre and/or post procedure CBCT imaging studies to assist in proving malpractice or defending good practice. Post-treatment radiographic imaging to prove malpractice or support good practice is not new to medicine. In fact in the years preceding WWII, some of the highest malpractice claims were awarded in cases where post-treatment radiographs played a pivotal role.

Logic would dictate that if plaintiffs and defense counsels and experts are making CBCT part of their strategy, then CBCT must be not only prevalent and pertinent but of significant value in the formation of an opinion by an expert (and the jury) when reviewing a case. CBCT can be seen as an additional and important piece of information to help explain why the doctor did what he did or why an unfortunate outcome occurred. Additionally, CBCT provides powerful and easily understandable images for layperson jury.

Recognising the value that CBCT adds to a case does not necessarily indicate that CBCT is the standard of care in each and every case. The decision to obtain a CBCT study before the procedure is determined by the dentist based on his experience and knowledge of the case.

**Literature Support**

For any technology to be considered as a standard of care, a plethora of literature in support of the technology, its application to patient care, and guidelines and protocols for acceptable use. To assess the influence of CBCT in the dental literature, the author performed a PubMed literature search in October for the words “cone beam CT” and “oral and maxillofacial surgery”. The results are the Table 1.

Evaluation of Table 1 data clearly shows a significant presence in the literature of articles pertaining to the use of CBCT in the various disciplines in dentistry. The vast majority of literature discovered pertains to addressing the use of CBCT in treatment planning and diagnosis of patients in dental implantology, oral and maxillofacial surgery, orthodontics, and endodontics. Articles on new applications of CBCT technology to patient care were also prevalent in the sample. Some articles addressed the risk and benefits of CBCT but none denoted CBCT as harmful to the patient or insignificant in treatment planning and diagnosis. Two similar PubMed reviews of the literature on CBCT were performed by authors Alamri et al (Applications of CBCT in the oral and maxillofacial region: A systematic review of the literature, Int J Oral Maxillofac Surg 2009; 38: 609–625). Both of these exhaustive articles demonstrate the plethora of literature addressing CBCT and its application in the many disciplines in dentistry.

**Professional Guidelines**

For a technology such as CBCT to become a standard of care in dentistry, guidelines for its use and application in patient care must be established by the organisational bodies of those disciplines in dentistry who employ the technology to treat patients in dentistry, the dental practitioners most involved in the use and application of CBCT in patient care include general dentists, oral and maxillofacial surgeons, endodontists, oral and maxillofacial radiologists, orthodontists, and periodontists.

The American Dental Association has over 180,000 licensed dentists representing approximately 75 % of dentists in the USA. The American Dental Association published an advisory statement article in its principal journal, The Journal of the American Dental Association, in August 2012. The article discusses the many positive aspects of CBCT, but stops short of calling CBCT a new standard of care. Rather, the ADA encourages the dentists to use CBCT “selectively, as an adjunct to conventional radiography.” The ADA further recognises the value and presence of CBCT by including CBCT-related courses at its annual meetings and continuing education courses during the year.

The American Association of Oral and Maxillofacial Surgery (AAOMS) has over 9,000 members representing approximately 95 % of oral and maxillofacial surgeons practising in the US. Literature addressing the application of CBCT in oral and maxillofacial surgery has been around since 2007. The AAOMS has offered continuing education in the use and application of CBCT for a technology over a decade ago. This article showed the following: 83 % of orthodontic programmes have access to CBCT, 79 % of programmes report “regular” use of CBCT in patient diagnosis, and 85 % of CBCT-related courses at its annual meetings and continuing education relating to CBCT as it relates to modern endodontics. Most residencies (44 of 47) in endodontics provide CBCT for patient care.

**Literature pertaining to CBCT in dentistry dates back to 1998.** The American Association of Periodontists annual meeting agenda and the Journal of Periodontology demonstrate a heavy influence of CBCT in this field of periodontics. All 51 post-dental US periodontal programmes use CBCT in patient care.

**The International Congress of Oral Implantologists (ICOI)** is the world’s largest dental implant organisation and provider of dental

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**Radiologists (AAOMR) have released a formal position paper on CBCT.** This paper makes many important points, such as limiting the field of vision to minimise radiation exposure and increase resolution, careful patient selection, and the responsibility of the clinician to interpret the entire image. The position paper goes on to declare “the use of CBCT in endodontic cases should be limited to the assessment and treatment of complex conditions.” The article then lists nine of these “complex conditions”. In summarisation, the position paper recognises the value of CBCT as an adjunct to 2-D images and “CBCT may provide dose savings over multiple traditional images in complex cases”.

**Literature pertaining to the use of CBCT in endodontics first appeared in the Journal of Endodontics in 2003.** The American Association of Endodontists has continued education in endodontic related CBCT on their website and the organisation devotes valuable time at its annual meeting to CBCT as it relates to modern endodontics. Most residencies (44 of 47) in endodontics provide CBCT for patient care.

**Literature pertaining to CBCT in endodontics first appeared in 1998.** The American Association of Periodontists considers the use of CBCT in endodontics to be a standard of care. In a recent article in the Journal of Endodontics, the ADA approved residencies in Radiology incorporate CBCT education and training into the resident curriculum.

The tremendous value of anatomic truth in complex orthodontic cases involving patients with cleft lip and palate, impacted teeth, and maxillofacial deformities is widely recognised and discussed in the literature. Review of the ADA annual meeting lecture syllabus shows CBCT is a prominent topic for today’s orthodontists. In a recent article in the Journal of Dental Education by Smith et al use of CBCT in orthodontic programmes in the US and Canada was evaluated. This article showed the following: 83 % of orthodontic programmes have access to CBCT, 79 % of programmes report “regular” use of CBCT in patient diagnosis, and 85 % of CBCT-related courses at its annual meetings and continuing education relating to CBCT as it relates to modern endodontics. Most residencies (44 of 47) in endodontics provide CBCT for patient care.
dentistry may not formally declare CBCT is the standard of care for every patient, but these organisations do recognize that advanced CBCT is having on the profession.

Educational Institutional Participation

For a technology to be considered a standard of care, those in the profession must educate itself in its application in patient care. In US, 56 of the 57 dental schools (98%) have CBCT available for patient care for pre-doctoral students. Forty-seven (84%) incorporate CBCT into their pre-doctoral curriculum. In a survey performed by the author and others 202 general practice residency (GPR) and advanced education in general dentistry (AEGD) programs were surveyed regarding use of CBCT by their residents. Eighty-two programme directors responded to the survey. Of the 82 respondents, 56 (68%) of programme directors (PDs) reported affirmatively when asked if CBCT was used in patient care by their residents. The author also surveyed 102 PDs in oral and maxillofacial programs in the US. Fifty-four PDs responded 47 (87%) affirmatively when asked if CBCT is used in patient care by their residents. In a phone survey of endodontic residents, 44 of 47 PDs indicated their residents use CBCT in patient care. All seven ADA approved oral and maxillofacial radiography programs use CBCT in patient care. Additionally, all 51 periapical residency PDs indicated that their residents employ CBCT technology in patient care. In orthodontics, 83% of US based orthodontic programs use CBCT in patient care.

Cost and Availability

The cost of CBCT machines today range from US$150,000 to US$250,000 with yearly maintenance fees in the US$2,000 to US$3,000 range. As with any emerging technology, advances create a secondary market for slightly used machines. Each new step forward in technology requires education for only a few years ago slightly out-of-date, despite its obvious value and its superiority to two dimensional films. As time progresses and advancement in the quality and capabilities of the newest machines demonstrate themselves, the slightly non-contemporary machine will represent a significant advancement for the dentist versus 2-D radiography, while not burdening the dentist with significant cost. This will undoubtedly lead to an increase in the number of dental professionals utilizing CBCT in their practices. The bottom line for most practices in regards to CBCT machines is can I afford this for my practice?

To determine affordability, the price of the machine (purchase and maintenance) must be considered against potential revenue generated by the machine. Revenue can be directly from patients, insurance companies, or from other dentists who utilize the CBCT machine. A cost-effective alternative to owning and operating a CBCT device can be the outsourcing of the study to a third party (dentist or facility) and in outsourcing the software necessary to employ the images in treatment planning and diagnosis. CBCT machines are becoming ubiquitous as more dentists purchase the machines and more third party non-dentist owned imaging centres enter the market. Since more dentists and more patients are being exposed to the technology, patient acceptance is expected to increase, facilitating the incorporation of CBCT into the mainstream culture of dentistry. The increasing omnipresence of CBCT technology will not singularly make it standard of care, but it will serve to introduce the technology, which in turn will influence what the public perceives as a standard of care.

The insurance industry

Reimbursement from major insurance companies and government sponsored care traditionally has been the last to embrace (i.e. pay for) a new service such as CBCT. Although codes for medical imaging and CBCT have been around for decades, specific codes for in office CBCTs began to materialise in 2009. Current reimbursement rates for in office CBCTs average around US$300, provided the study is covered.

By providing dentists with a CPT code, the insurance industry has validated its value in treatment planning and diagnosis. As time progresses, insurance companies may, as they have in the past, require CBCT owner/operators to obtain a certification via the IAC or some other regulating entity for an owner/operator to qualify for financial reimbursement from any third party payer.

Two of the major malpractice carriers of the insurance industry (OMNISIC and MedPro) have influenced the evolution of CBCT as a new standard of care by requiring CBCT owner/operators commensurate with the level of risk to which the owner/operators are exposed. Were CBCT studies believed to be of little value or represent minimal risk these leaders in the dental malpractice industry would not offer such coverage. Additionally OMNISIC requires the owner/operator to prove CBCT images interpreted by a dental or medical radiologist to minimise risk.

Multipurpose use and recognition

Dentistry has nine recognised specialties; four (oral and maxillofacial surgery, endodontics, oral and maxillofacial radiology and orthodontics) and the American Dental Association have produced literature to address the impact of CBCT on patient care. Of the remaining five specialties, periodontics and prosthodontics could logically be included as separate groups to produce a position paper on CBCT given their membership participation in dental implant treatment of patients. Paediatric dentistry may soon provide a position paper once the long-term studies have been done to assess the risk versus benefits analysis with respect to the overall total radiation dose and its effect on the paediatric population. The specialty of dental public health is unlikely to weigh on the matter.

The value CBCT has in diagnosis and treatment of patients is widespread and recognized by medical disciplines such as plastic and reconstructive surgery, ENT, Craniofacial/CLP surgeons, and OMS trauma surgeons. These medical disciplines recognize there is no doubt that three dimensional detail CBCT provides and assists doctors in the treatment planning and diagnosis of their patients. Such widespread and multidisciplinary application of CBCT imaging contributes to CBCT becoming a new standard of care.

CBCT in the dental culture

Many in the dental profession acknowledge the benefit of 3-D imaging to patients and doctors. There is a little dispute that CBCT provides superior representation of the anatomy versus 2-D plain films. Quality of product has acknowledged, at least four aspects of CBCT must work their way through the dental culture before CBCT becomes a standard of care: cost, availability, legal, and patient expectations. Two of these aspects (cost and availability) will likely more than not be determined by the invisible hand of the market as the Keynesian laws of supply and demand move the dental industry to provide the best possible service at a price patients and insurance companies are willing to pay. The third (legal) will be slowly determined in the court systems as attorneys and experts begin to rely more on CBCT in support of their clients’ cases.

Patient expectations are difficult to accurately ascertain. We know patients expect our practices to be current. Buying the latest and greatest machine for your practice may not be wise if cost exceeds benefits both clinically and financially. As CBCT becomes widely accepted and expected by our patients due to aggressive marketing or clinical relevance, incorporating the technology into one’s practice may not be entirely necessary but prudent as others in the profession who possess the technology appear to be more contemporary and advanced in their patient care.

There are many questions yet to be answered, in particular:

1. Who is responsible (and liable) for interpreting the images?

2. Is an entire field of view interpretation necessary or simply the pertinent structures?

3. Must all images be interpreted by a board certified oral and maxillofacial radiologist or can the ordering doctor interpret the images?

4. What level of training is sufficient to own and operate the machine, as well as, and interpret CBCT images?

5. Will CBCT machines become general practice treadmill equipment?

6. If the patient refuses a CBCT and the dentist believes CBCT is necessary for successful case completion, must the dentist complete the case without the CBCT study or can he refuse the case without fear of legal repercussions?

Lastly, as mentioned earlier, standard of care is an evolving concept. Darwin stated clearly any organism that is not able to adapt to outside forces in order to survive will become endangered in dentistry is adapting to CBCT as forces (legal, financial, clinical, and consumer) act upon the industry to account for the powerful influence CBCT has on treatment planning and diagnosis of patients. While recognizing that gold is not gold, CBCT may soon represent a new gold standard by which many cases will be judged. }