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 (3-D) 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.

CBCT, like plain film radiographic studies, may be considered a revenue generator for a practice. The more a CBCT machine is utilised, the more revenue it will generate. Additionally, the owner may allow others in the profession to utilise 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 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.

Taken 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 Frey test. This standard comes from Frey v. United States which is a 1923 in a case discussing the admissibility of a polygraph test as evidence. The Frey 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 Frey, the court opined: "Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognised, and while the courts will go a long way in admitting experimental testimony deduced from a well-recognised 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 Frey 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 within 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 recognised 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 medical and dental community is demonstrated by the ever increasing presence in dental and medical practices of the technology. Additionally, The Intersocietal Accreditation Commission, an accreditation organisation for medical and dental imaging, has developed guidelines and accreditation criteria for 3-D CBCT imaging. Thus CBCT appears to have satisfied both the Frey 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 Frey or Daubert criteria, the absence of CBCT is not de facto 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 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 2014.

_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 (Iowa, 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 correspondences. In the last five years, the author has noticed a remarkable increase in the number of cases in which plaintiffs and defence 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 defence 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 for the technology should exist. The literature must discuss the risk and benefits 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, cone beam CT + dental, cone beam CT + dental implants, cone beam CT + orthodontics, cone beam CT + oral surgery, cone beam CT + endodontics in the search line. The results are in 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 of dentistry. The vast majority of literature discovered pertains to addressing the use of CBCT in treatment planning and diagnosis of patients in dental implant therapy, 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 denounced 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 dental practice: A review of the literature. Gen Dent 2012: 60(5):390–400) and De Vos et al (Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: A systematic review of the literature. Int J Oral Maxillofax 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 dentist 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 patient care as far back as 2011. The AAOMS has worked with the IAC to develop guidelines and accreditation criteria for 3-D CBCT imaging. In a recent survey of OMFS residency programmes, 87% of programme directors acknowledged the use of CBCT in patient care by their residents.

The American Association of Endodontists (AAE) and the American Association of Oral and Maxillofacial 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 in CBCT, and the responsibility of the clinician to interpret the entire image. The position paper goes on to declare “the use of CBCT in endodontics should be limited to the assessment and treatment of complex conditions.” The article then lists nine of these “complex conditions”. In summation, 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 sponsor continuing 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 dentistry dates back to 1998. The AAMOR devotes considerable effort to continuing education relating to CBCT both on its website, through CE events, and at its annual meeting. All seven 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 AAO annual meeting lecture syllabus shows CBCT is a prominent topic for today’s orthodontist. 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,
- 73% of programmes report “regular” use of CBCT in patient diagnosis,
- Areas of CBCT use focuses on diagnosis and treatment planning for: impacted teeth, craniofacial anomalies, TAD placement, TMJ assessment, upper airway analysis, and maxillofacial development.

Literature discussing CBCT in periodontics first appeared in the AAP journal over a decade ago. The American Association of Periodontist annual meeting agenda and the Journal of Periodontology demonstrate a heavy influence of CBCT in the field of periodontics. All 51 post-doctoral US periodontal programmes use CBCT in patient care.

The International Congress of Oral Implantologists (ICOI), the world’s largest dental implant organisation and provider of dental implant continuing education with an excess of 25,000 active members, published a consensus report on CBCT in its journal Implant Dentistry in April of 2012. In the article, authored by many leaders in the dental implant field, the ICOI states: “The literature supports the use of CBCT in dental implant treatment planning particularly in regards to linear measurements, 3-D evaluation of alveolar ridge topography, proximity to vital anatomic structures, and fabrication of surgical guides.” The ICOI reminds the dentist that use of CBCT must be justified in each case and should be considered as an imaging alternative where conventional radiographs may not provide sufficient anatomic truth. Literature discussing the application of CBCT in implant dentistry is ubiquitous and comprises the lion’s share of research in applying CBCT technology to dentistry. The vast majority of post-doctoral residencies involved in dental implant patient care and all private dental implant training courses in the US incorporate CBCT in their dental implant education curriculum.

Many professional organisations in dentistry for general dentists and specialists have weighed in on CBCT by providing recommendations, guidelines, and a position paper. While these guidelines are beneficial in establishing a society or specialty’s position on CBCT, they are not mandates. Recommendations, guidelines, CE programmes, and posi-
tion papers are used by professionals to influence the practice of their discipline. As the practice of the discipline changes in response to many factors including, but not limited to court verdicts, expert testimony, literature support, professional guidelines, cost of the technology, and reimbursement by third party payers; the recommendations, guidelines, and position papers may facilitate the evolution of CBCT into a standard of care. Thus, in 2014 the professional organisations that comprise dentistry may not formally declare CBCT is the standard of care for every patient, but these organisations do recognise the influence CBCT is having on the profession.

_Educational Institutional Participation_

For a technology to be considered a standard of care, those in the profession must be educated 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 education in 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) programmes were surveyed regarding use of CBCT by their residents. Eighty-two programme directors responded to the survey. Of the 82 respondents, 56 (68 %) of program directors (PDs) responded 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. Of the 54 PDs responding 47 (87 %) affirmatively when asked if CBCT is used in patient care by their residents. In a phone survey of endodontic residencies, 44 of 47 PDs indicated their residents use CBCT in patient care. All seven ADA-approved oral and maxillofacial radiology programmes use CBCT in patient care. Additionally, all 51 periodontal residency PDs indicated that their residents employ CBCT technology in patient care. In orthodontics, 83 % of US-based orthodontic programmes 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$8,000 to US$20,000 range. As with any emerging technology, advances create a secondary market for slightly used machines. Each new step forward in technology renders the CBCT machine of 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 utilising 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 utilise 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-sourcing the software necessary to employ the images in treatment planning and diagnosis.

CBCT machines are becoming ubiquitous as more dentist purchase the machines and more third party non-dentist owned imaging centres enter the market. Since more dentist and more patients are becoming exposed to the technology, patient acceptance will 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 increase patient awareness of 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 health care is traditionally the last to embrace (i.e. pay for) a new service such as CBCT. Although codes for medical CBCTs 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 the technology of CBCT and thus acknowledged 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 (OMNSIC and MedPro) have influenced the evolution of CBCT as a new standard of care by offering coverage for 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 OMNSIC requires the owner/operator to have CBCT images interpreted by a dental or medical radiologist to minimise risk.

**Multispecialty 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 appropriate groups to produce a position paper on CBCT given their members 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 total overall 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 recognised by medical disciplines such as plastic and reconstructive surgery, ENT, Craniofacial/CLP surgeons, and OMFS trauma surgeons. These medical disciplines recognise the high quality 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 is 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 little dispute that CBCT provides superior representation of the anatomy verses 2-D plain films. Quality of product 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 more likely than not be determined by the invisible hand of the market as the Keynesians 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 contemporary. 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 definitively regarding CBCT:

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. What cases deserve a CBCT?
6. If the patient refuses a CBCT and the dentist believes a 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 (or concept in this case) which is subject to the laws of evolution must adapt in response to outside forces in order to survive. The standard of care 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 recognising that all that glitters is not gold, CBCT may soon represent a new gold standard by which many cases will be judged.

**Contact**

Lee M. Whitesides, DMD, MMSc  
4700 Chamblee Dunwoody Rd., Ste. 400  
Dunwoody, GA 30338, USA  
Drmac5678@gmail.com