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Comparison of the accuracy of CBCT radiation effective dose information in peer-reviewed journals, professional magazines, news sites and blogs

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Abstract

Objectives

Accessible sources of clinical information have proliferated over the past decade. These new sources contextualizing information for practice are user-friendly, although because much is not peer reviewed there are questions their accuracy. On the other hand, traditional peer-reviewed material can be somewhat removed from the needs of practicing dentists, and recently questions have been raised about the accuracy of journals as well. This study assessed the accuracy of cone beam computed tomography (CBCT) radiation safety information in both professional media and peer-reviewed journals.

Methods

Articles introducing CBCT technology to dentists and published in peer-reviewed journals were compared to articles appearing in professional magazines, clinically oriented news sites, and blogs written by clinicians for clinicians. Reported radiation dose of CBCT and conventional dental radiographs were recorded as well as conclusions about the comparative dose of the two imaging modalities.

Results

The proportion of articles reporting CBCT dose to be greater than, equal to or less than conventional dental radiographs was not different between peer-reviewed and professional media during this period. There is weak evidence that the conclusions of peer-reviewed journal articles (but not professional media) became more conservative after the publication of a New York Times article critical of misinformation about the safety and efficacy of CBCT in dentistry.

Conclusions

Non-peer-reviewed professional media were as accurate as peer-reviewed journals for this topic and during the time period assessed, which is somewhat surprising. However, the method used here necessitated a very narrow focus and certainly more studies are needed to broaden understanding.

Introduction

Frequent introductions of new technology into clinical practice present dentists with the challenge of learning about innovations and deciding whether to use them. As technology becomes more complex, overstretched dentists are challenged to the edge of their information processing and decision-making capacities. To cope with this increasing sophistication, clinicians turn to an array of resources to keep up to date – colleagues, conferences, study clubs, continuing education and peer-reviewed journals.[1-3] In addition to these traditional sources, an increasing number of clinical information media have emerged in recent years – magazines, news sites, blogs.[4] How accurately do these resources convey the complex, subtle, specialized information required to decide whether to use an innovative technology?

To explore this question, we focus on literature produced for dentists to inform their clinical practice: peer-reviewed journals, magazines, news sites and blogs. We examine one innovation: the introduction of cone beam computed tomography (CBCT) into dentistry. In the mid 2000s, CBCT was an innovation in dental imaging technology with many advantages over other imaging modalities and two well-known issues – cost and radiation exposure.[5] Dental x-ray radiation risk concerns the public,[6] therefore CBCT use needed to be justified by balancing the risks inherent in radiation exposure against the clinical benefit expected from the better image.[7] Dentists needed access to accurate information regarding CBCT radiation dose to decide whether to use the technology for clinical care.

CBCT radiation risk is difficult to understand

Radiation risk with dental radiography is difficult for dentists to assess for many reasons. The effects of low dose, imaging exposure cannot be seen in epidemiological data, and assumed risk is based on modeling. The possible harm, cancer, occurs randomly many years after radiation exposure which makes it difficult to attribute the cancer to a specific exposure.[8] For an individual, multiple images generate cumulative risk, but dentists have no way of knowing about other exposures. Standard methods of calculating radiation dose changed through the 1980s and 1990s, inconveniencing those trained before 2000. The International System of Radiological Protection (ICRP) changed the organs included in calculation of effective dose in 2007, raising the effective dose values for dental imaging. Therefore, it would not be surprising if clinicians who are not radiologists were unclear on radiation dose.[7] Research has demonstrated that non-radiologist physicians have moderate to poor knowledge of CT radiation dose.[9,10] Knowledge of risk from CT scans is particularly variable with a great deal of underestimation of harm but also some overestimation.[11] General dentists' knowledge is similarly poor.[12] A recent survey found limited and variable practices around CBCT radiation minimization, suggesting a void in knowledge of radiation safety.[13]

General dentists wanting to understand CBCT radiation dose risk would face great difficulty. Turning to manufacturer promotional literature, they would be unlikely to find any mention of radiation dose. Examining a machine would be similarly unenlightening as early CBCT machines provided no readout of dose. New machines might provide a dose estimate, but non-specialists are unlikely to know that this number is produced using non-optimal methods of estimation.[14] Nor are non-specialists aware of the many parameters that need to be managed to make dose information comparable.[15] For example x-ray beams can be continuous or pulsed with exposure lower for pulsed beams providing the same image quality. Research and methodological debates surrounding CBCT radiation dose measurement occur in the radiology community, and a synthesis of this literature provided an unhelpful 382 dose values for adults and a further set of tables for children.[14]

Discussion of radiation risk in articles

Radiation dose is just one of many factors weighed by a dentist deciding whether to use, or to buy a CBCT machine. Therefore, general dentists curious about CBCT were unlikely to invest the time required to develop a sophisticated, specialty-level understanding of CBCT radiation dose. Instead, their needs were served by articles in peer-reviewed journals, professional magazines, news sources, and blogs introducing CBCT to the broader profession. Both peer-reviewed journal and media articles addressed the complex issue of dosimetry by referencing papers of dental radiologists, contextualizing this information with comparisons to radiation dose received from medical CT, conventional dental radiography, and/or naturally occurring background radiation. This framing provided the non-specialist with an explanation of dose relevant to deciding whether to use CBCT or not. For example, articles note that as an alternative to medical CT, CBCT's advantages include exposing patients to much lower doses of radiation.

In contrast, although each article reached a seemingly straightforward conclusion comparing the radiation dose of CBCT and conventional dental radiography, those conclusions differed. This was because the radiation doses of CBCT scans reported in the literature vary greatly - machines differ, more than a dozen imaging parameters can be varied and patients differ. The degrees of freedom are such that literature can be cited supporting any conclusion, i.e. CBCT radiation dose is more than, equal to, or less than that of conventional radiography.

CBCT radiation risk was not just discussed in journal articles or professional media. In November 2010 the *New York Times* published an article criticizing the discussion of radiation risk in the professional literature. The article highlighted "misinformation about [dental CBCT's] safety and efficacy, some of it coming from dentists paid or sponsored by manufacturers to give speeches, seminars and continuing education classes, as well as by industry sponsored magazines and conferences."[16] This article was influential in the dental community, widely discussed in forums and blogs and referenced by several journal articles.

Research questions

We were interested in assessing the accuracy of information available to non-specialist clinicians about dental CBCT when it was an innovative imaging technology. In particular, we investigated whether magazines, news sites and blogs were less accurate than the peer-reviewed literature. We examined the conclusions drawn in introductory articles concerning the relationship between CBCT and conventional dental x-ray radiation dose to determine whether there is any evidence that professional magazines, news sites and blogs are less accurate than peer-reviewed journal articles. We also examined whether discussion of CBCT dose in introductory articles became more conservative after publication of the *New York Times* article.

Methods

Collecting articles

Articles introducing CBCT were collected from both peer-reviewed journals and professional magazines, news sites, and blogs. Because this analysis is part of a larger study of the US dental profession, we downloaded US authored, English language peer-reviewed journal articles published after 1999, indexed in Web of Science and published in journals classified as "dentistry oral surgery medicine" or published in dentistry journals indexed in PubMed and published in the US. Aligned with De Vos et al.,[15] introductory articles were defined as those that did not present the results of a study, but rather provided the reader with an overview, introducing the new technology of CBCT. Because CBCT is the focus of such papers, their titles should contain the words: "cone beam" or "CBCT" or ("imaging" and not "magnetic resonance"). Among articles that met these criteria, introductory articles were identified by the generality of the words in their titles: endodontics, implants, orthodontics. In comparison, non-introductory articles had a narrow focus (mandibular kinematics, mesiodistal angulation, etc.) or reported the results of a study identified by the presence of these words in the title: accuracy, analysis, comparison, study, bone, root or maxillary. Articles reporting new guidelines, literature reviews and articles that did not mention radiation dose were discarded. Thirty-nine peer-reviewed journal articles were included in this analysis. Figure 1 summarizes this process.

Articles from professional magazines, news sites and blogs were collected during 2016 by scraping all available articles from the websites of the following US based professional magazines and news sites: *Dentistry Today, Inside Dentistry, Dr. Bicuspid,* and *Modern Dental Network*. In total 15,789 articles published 2006-2016 were found. In addition, *DentalTown* blogs were collected – 4,836 articles. Finally, blogs by US practicing dentists that discuss clinically relevant material were collected; 25 were found containing 19,286 articles. Among these 39,911 articles, CBCT articles were identified by searching for titles or text containing the strings: "cone beam" or CBCT. These CBCT articles were examined and were discarded if they were about a conference, training, were promoting a device, or mentioned CBCT only in passing, leaving 435 posts. From these, posts that included at least one of three terms: dose, Sievert, Sv were extracted, and false positives were eliminated, for example articles containing "Loui**sv**ille." In total, 45 articles, from the media outlets as well as three blogs: *Dental Geek, Endo Blog* and *Spindel* included these terms and are analyzed here. Figure 2 summarizes this process. Hereafter, we refer to these as the professional media or media articles.

Quantitative and qualitative dose comparisons

Effective dose is the unit in which CBCT dosimetry is discussed. The international unit for effective dose is the sievert (Sv) which represents a 5.5% chance of developing cancer. CBCT radiation dose is expressed in micro-sieverts or μSV, 1 μSV = 0.000001 Sievert. Data collection involved searching all 84 articlespeer-reviewed for mentions of dose, Sievert and Sv. The highest and lowest reported effective dose values for CBCT and conventional dental radiography were recorded. Statements drawing conclusions about whether CBCT radiation dose is greater than, equal to or less than that of conventional dental radiographs were also noted.

The analysis has two parts: quantitative and qualitative. In the quantitative analysis, the ranges given for CBCT and conventional radiation dose were compared. The qualitative analysis tabulates statements concluding that the CBCT radiation dose is greater than, equal to or less than conventional dental radiography. It is important to note that none of the statements is in error. Different conclusions about the relative radiation dose of CBCT vs conventional radiographs are the product of different ways of constructing the comparison.

Six journal articles and 16 media articles were excluded from both analyses because their conclusions were ambiguous, or simply acknowledged wide dose variation or because they provided a few device dose numbers only. Twenty-one journal articles and 19 media articles drew unambiguous conclusions about the comparison between the radiation dose of CBCT and conventional dental radiography, and are included in the qualitative analysis. In the quantitative analysis, the maximum and minimum values provided for CBCT and conventional effective dose were compared. Twenty-one journal articles and 13 media articles reported such information and are included in the quantitative analysis. Nine journal articles and three media articles are included in both analyses, see Figures 1 and 2. Thus, we analyze here 33 peer-reviewed articles from 21 journals and 29 media articles from 4 commercial channels and 7 blogs.

<Figures 1 & 2 about here>

Results

Canonical radiation dose values

Figure 3 displays canonical values for CBCT (red diamonds) and conventional dental x-rays (blue circles) as well as values for one year of natural background radiation and the radiation exposure on round trip flights between New York and Los Angeles and between Paris and Tokyo (yellow triangles). Because the values span a very wide range, the y-axis is logarithmic, meaning the distance from 1 to 10 is the same as the distance from 10 to 100 and from 100 to 1000.

<Figure 3 about here>

Although the radiation dose from most conventional radiography is below 50 microsieverts, it is possible using conventional equipment and less than state-of-the-art film (D speed film, round collimation) to expose patients to much higher effective doses of between 150 and 400 microsieverts. Of course, it is also possible in discussing CBCT to choose those high values as the comparison to CBCT dose.

Figure 3 also displays information on CBCT effective dose. Of the many parameters that can be varied, two are shown – field of view (small, medium or large) and region imaged (maxilla or mandible). For each, the maximum, minimum, mean and standard deviation recorded in the meta-analysis of Ludlow and colleagues (2015) are plotted. The figure establishes that while the mean values of CBCT effective dose exceed the effective dose of state-of-the-art conventional x-rays, the wide range of CBCT dose values published in the literature provides ample scope for authors to reference figures that support any conclusion..

Quantitative dose comparisons

Figures 4 and 5 report the maximum and minimum values of effective dose for CBCT and conventional x-rays given in introductory CBCT articles. Figure 4 concerns peer-reviewed journals and Figure 5 concerns professional media. In both figures the y-axis scale and the display of conventional as blue circle and CBCT as red diamond is the same as in Figure 3. Shading i demarcate articles. The year of publication is at the top. The type of imaging is given along the x-axis. The symbols along the top (< = >) note the conclusion drawn from comparing the values for CBCT and conventional effective dose in each article. Counting these symbols produces Table 1 below.

<Figures 4&5 about here>

Figure 3 suggests that reasonable values for conventional imaging could be below 10 microsieverts and go as high as 50 microsieverts. Reasonable representative values for CBCT would be the means which range from about 80 to 200 microsieverts. Figures 4 and 5 record values straying far outside these bounds. Some papers even compare the full mouth, D speed film exposure to CBCT.peer-reviewed

In Table 1, comparisons of the dose ranges in Figure 4 are tabulated. Overlapping ranges of CBCT and conventional dose were coded as less than or equal to (≤), or greater than or equal to (≥). In Table 1 these categories are collapsed into the < and > categories. Thus Table 1 reports that one journal article (5%) concluded CBCT doses are less than conventional films, 8 (38%) reported equal doses, and 12 (57%) concluded CBCT doses are higher than conventional films. Figure 5 shows thirteen professional media references. One (8%) concluded CBCT doses are less than conventional films, 5 (38%) reported equal doses, and 7 (54%) concluded CBCT doses are higher than conventional films.

<Table 1 about here>

Qualitative analysis

In the qualitative analysis, statements drawing conclusions about the comparative value of CBCT and conventional radiation dose were assessed. Twenty-one journal articles and 19 professional media references contained such statements. Statements that CBCT is equal to a few conventional radiographs were coded as greater than or equal to (≥). Table 1 shows that 5 journal articles (24%) concluded CBCT doses are less than conventional films, 9 (43%) reported equal doses, and 7 (33%) concluded CBCT doses are higher than conventional films. Three professional media articles (16%) concluded CBCT doses are less than conventional films, 3 (16%) reported equal doses, and 13 (68%) concluded CBCT doses are higher than conventional films.

Combined results

In three of the four columns of Table 1, more than half the articles concluded the radiation dose of CBCT exceeded that of conventional dental radiography the exception being qualitative analysis of peer-reviewed journal articles. Coding </≤/=/≥/> as 1, 1.5, 2, 2.5 and 3, a two tailed t-test assuming equal variances suggests that the probability of the articles being drawn from the same distribution is greater than 10%, meaning there is no difference between journal articles and professional media in how conservatively they report CBCT radiation dose in relation to conventional radiography (quantitative, T 0.10, P 0.92; qualitative, T, -1.43; P 0.16;)

By combining the two analyses, the number of articles becomes large enough to examine the question of whether the publication in 2010 of a *New York Times* (NYT) article critical of misinformation about CBCT safety influenced authors of introductory articles to be more conservative in their conclusions. Table 2 reports the conclusions of articles published before and after the NYT article. Three journal articles (one before and two after) included in both the qualitative and quantitative analysis were deemed to draw contradictory conclusions in their qualitative statements and quantitative data and so were excluded from this combined analysis. Less than half of journal articles concluded that CBCT radiation doses were higher than conventional radiography (33%) before the NYT article. After the NYT article, the majority of journal articles concluded CBCT radiation dose exceeded conventional radiography (78%) suggesting that authors of peer-reviewed journal articles were more conservative in assessing risk associated with CBCT radiation dose after publication of the NYT article. Authors of media articles were less influenced, with a majority concluding CBCT radiation dose was higher than conventional radiography both before (56%) and after (60%) publication of the NYT article. A one tailed t-test suggests that reporting of dose changed after the NYT article for journal articles (T -1.82; P 0.04), but not for professional media articles (T -0.23; P 0.41).

Discussion

This study used reported comparisons between CBCT and conventional radiography effective dose as markers for the accuracy of information in peer-reviewed and professional media sources. The non-scholarly sources for such articles have proliferated over the past decade, providing more accessible and practice relevant resources for dentists seeking clinical information. In 2001, the FDA approved the first CBCT scanner for the US market. Use in dentistry began to grow only in 2006-07[21] with the first educational sessions on CBCT at the ADA national conference in 2006. Contemporaneously, electronic media emerged with the first dental blogs and DentalTown appearing in 2000, *Inside Dentistry* in 2005, *Dr. Bicuspid* in 2007 and *Modern Dental Network* in 2012.[4,22]

The rise of electronic media brought increased awareness of the importance of credibility in medical information sources. As such, the validity of claims made in dental advertisements has been evaluated and found to be lacking,[23,24] paralleling a similar circumstance in medicine.[25-27] Many studies have evaluated the credibility of information about various conditions that patients might find in an internet search and found that quality is variable.[28-39] Six studies investigated the accuracy of clinical information on websites for patients.[40-45] In these studies, clinicians devised lists of items that should appear in any discussion of a condition and then scored websites based on how many of these items appeared. Five studies concluded that websites presented low-quality information, and one study concluded that 20-30% of sites offered good-quality information. Electronic media are seen as simultaneously beneficial -in that information access is broadened and asymmetries between patients and clinicians are reduced, and concerning –in that the quality of the information tends to be poor.[46] The present study extended this line of inquiry by examining information for clinicians.

In addition to concerns about the quality of information on electronic media, recently serious questions have been raised about the reproducibility of previously unimpeachable peer-reviewed literature[47-49] This recent questioning adds to longstanding credibility concerns connected with industry sponsorship. The 2010 *New York Times* article singled out the flagship peer-reviewed *Journal of the American Dental Association*, JADA, as well as the Association's annual conference for, respectively, publishing a special section underwritten by a manufacturer and in a conference saturated with cone beam manufacturer demonstrations, presenting a panel on cone beam in which three of four panelists had received payments from manufacturers.[16]

It is possible that the proliferation of new information sources makes dentists vulnerable to misinformation, but our analysis is reassuring on this point. There was no evidence that professional media differed in their presentation of the relative risks of CBCT and conventional radiography. The reliability of peer-reviewed articles is increasingly questioned and indeed we found both peer-reviewed and professional media articles espousing the minority position that CBCT radiation risk is lower than that of conventional radiography. There is evidence that high-profile discussion of CBCT radiation dose in the *New York Times*, may have prompted more conservative conclusions about CBCT radiation dose to be drawn in peer-reviewed journal articles.

This study is unique in examining clinically relevant information written for clinicians. Other studies of accuracy of medical information examine websites aimed at patients. The focus on dentistry and these information sources is also unique as far as we are aware. This study also differs in examining the conclusions drawn in articles, rather than scoring articles on a checklist of topics covered. However, this method required a very narrow focus. There are many other dimensions that could be examined, even in articles introducing CBCT to dentists.

Conclusion

Easily accessible electronic professional media now provide a wide range of clinically relevant information for dentists, in addition to the more-traditional commercial information about product costs and buyer guidelines for product usage. Our study finds no evidence that professional electronic media are less accurate than peer-reviewed journal articles, at least in discussion of CBCT relative radiation dose. Based on the current analysis, professional electronic media and other venues should not be ignored or dismissed as possible sources of accurate information in clinical dentistry. Newer information providers serve the dental profession in a responsible fashion and draw on the peer-reviewed literature, often very quickly. peer-reviewed. The greater variety of information sources provides opportunities for a greater volume of relevant information to be better contextualized for practicing dentists than can be done in peer-reviewed journals. Future research should investigate whether this conclusion holds in other clinical areas and how information gleaned from these sources combines with peer-reviewed material to shape clinicians' decision making.

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Tables

Table 1 Number of articles concluding CBCT radiation dose is </=/> radiation dose from conventional dental radiography

	Quantitative		Qualitative	
	Journal Articles	Professional Media	Journal Articles	Professional Media
< or ≤	1	1	5	3
=	8	5	9	3
> or ≥	12	7	7	13
Total	21	13	21	19

Table 2 Number of articles concluding CBCT radiation dose is </=/> radiation dose from conventional dental radiography before and after publication of *New York Times* article

	Journal Articles			Professional Media		
	Before	After	Total	Before	After	Total
<	3	1	4	1	3	4
=	11	1	12	3	5	8
> or ≥	7	7	14	5	12	17
Total	21	9	30	9	20	29

Figure 1 Journal article identification process

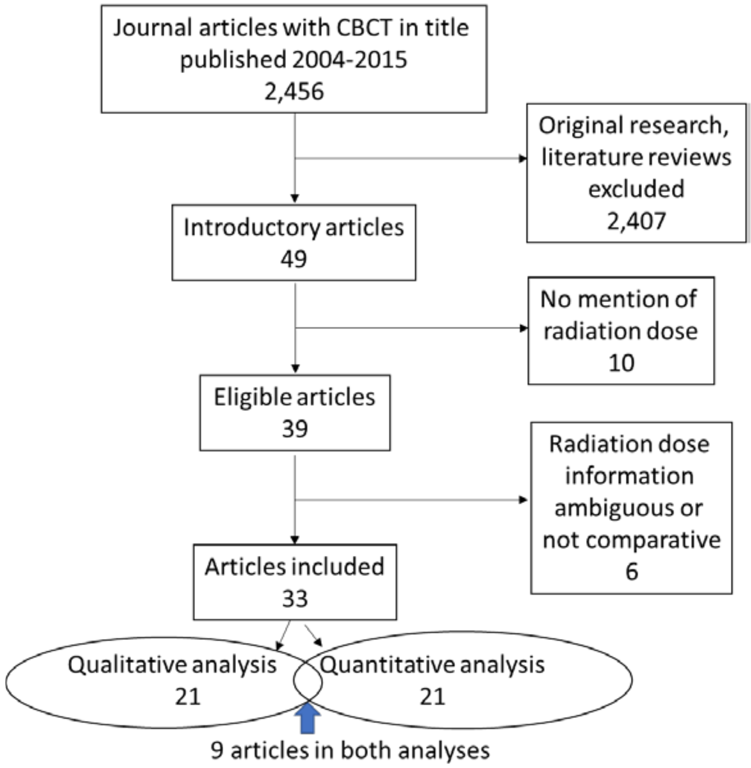


Figure 2 Media article identification process

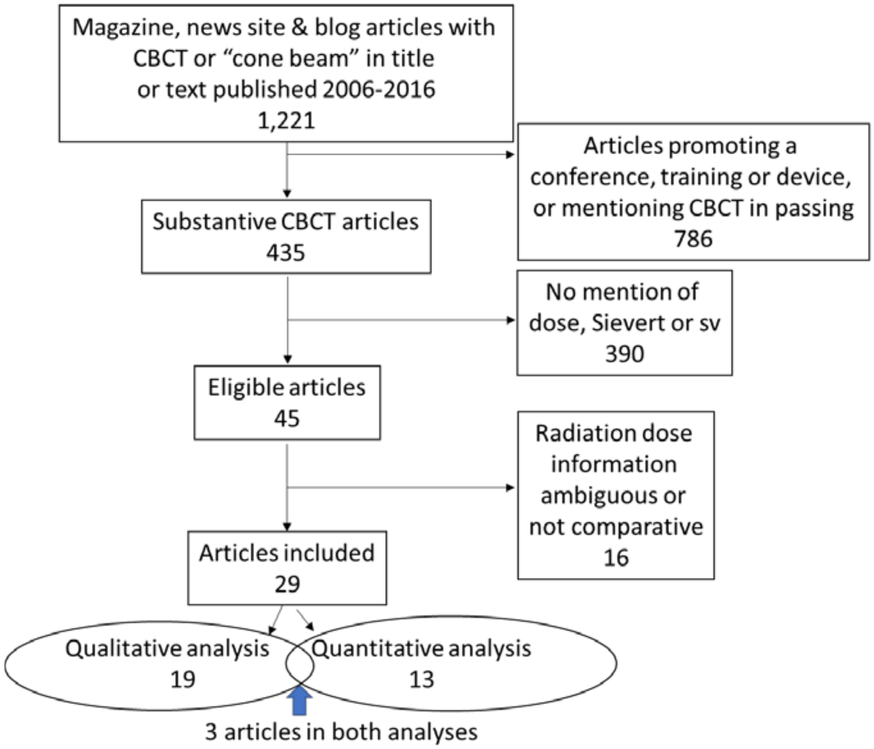


Figure 3 Effective Dose Reference Values (2007 ICRP)[17-20,14]

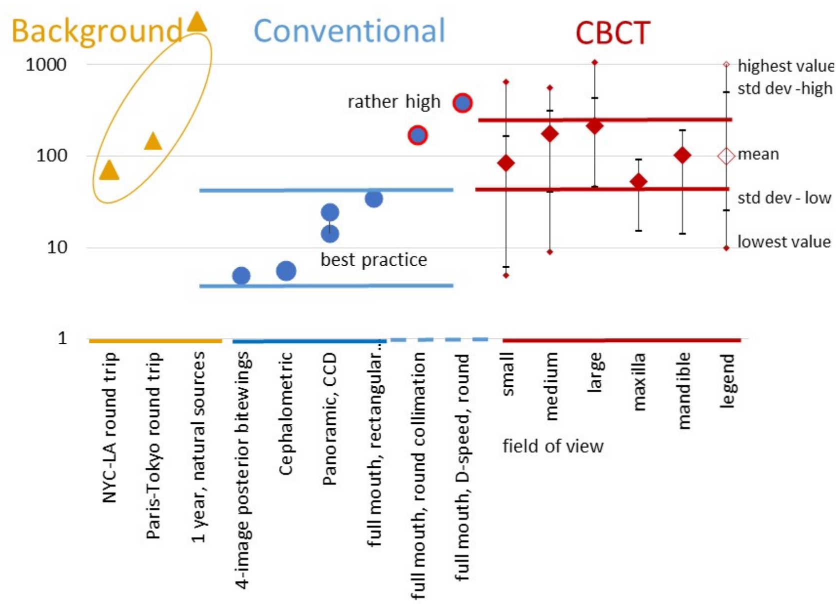
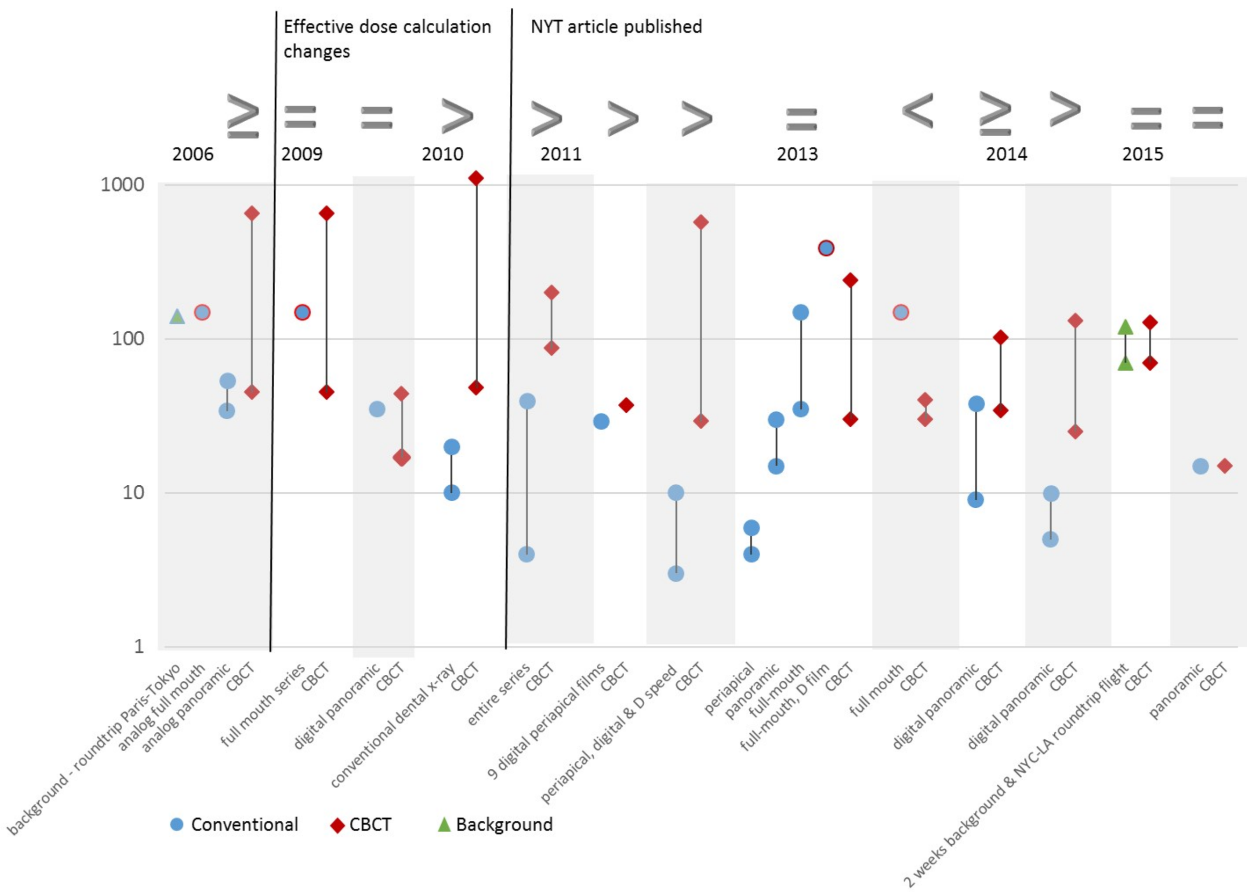
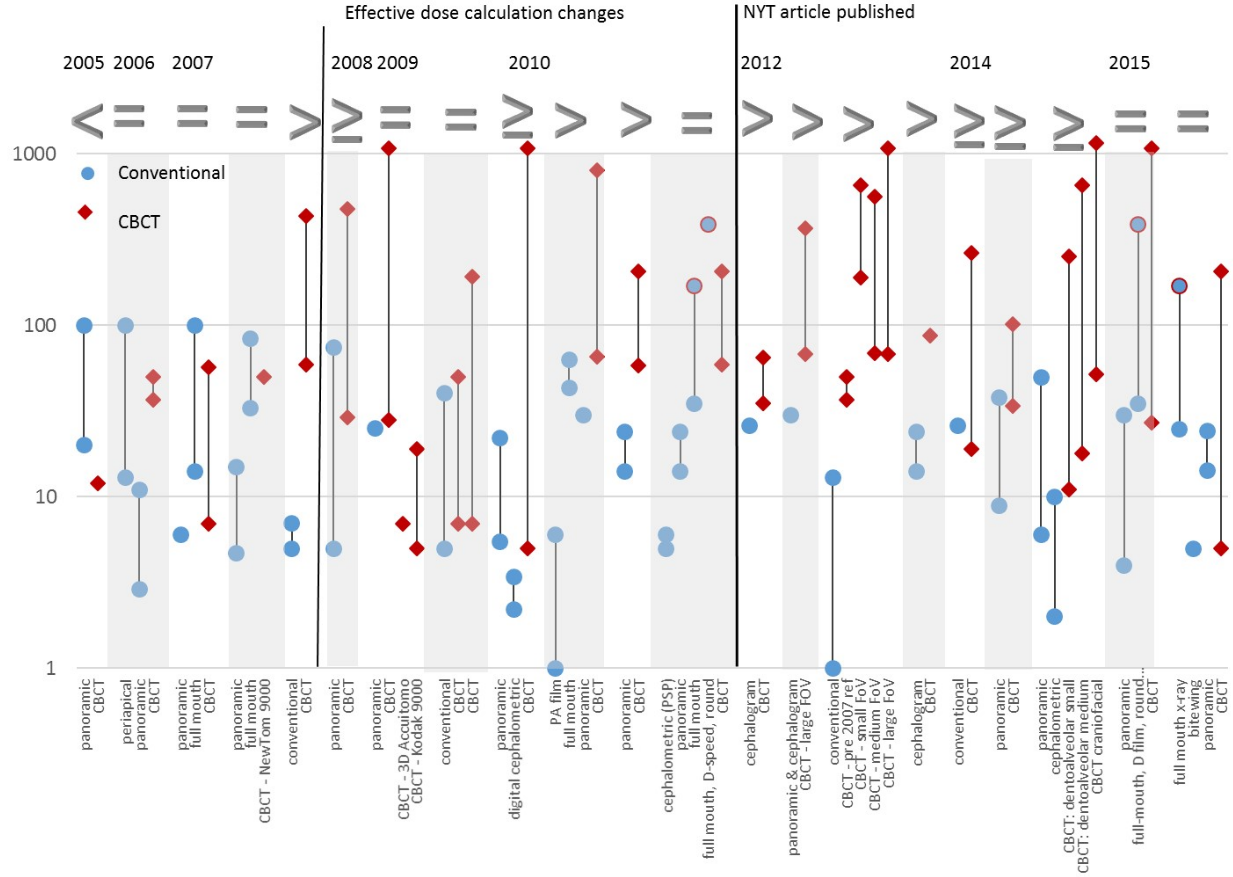


Figure 4 Effective radiation dose ranges reported in peer-reviewed journal articles



Sources: see appendix table 1

Figure 5 Effective radiation dose ranges reported in professional media articles



Sources: See appendix table 2

Supporting Material - Appendix Tables for Comparison of the accuracy of CBCT radiation effective dose information in peer-reviewed journals, professional magazines, news sites and blogs

Appendix Table 1 Sources for Figure 2

Conclusion	Reference
>=	J. Martin Palomo, Chung How Kau BDScD, Leena Bahl Palomo, and Mark G. Hans. Three-Dimensional Cone Beam Computerized Tomography in Dentistry. Dentistry Today. 1/11/2006.
=	Allan G. Farman, Claudio M. Levato, William C. Scarfe. Maxillofacial Volumetric CT: An Update and the Importance of the Dicom Standard for Interoperability. Inside Dentistry. 3/2009.
=	Michael Tischler. Utilizing Digital Imaging to Enhance the Team Approach to Implant Treatment. Dentistry Today. 1/4/2009.
>	DrBicuspid Staff. UK agency releases guidelines for dental CBCT. Dr Bicuspid. 11/8/2010.
>	Jason J Hales. 3D Evaluation of Root Canal Morphology Cone Beam Computed Tomography. theendoblog.com. 5/28/2011.
>	Jason J Hales. Cone Beam Computed Tomography CBCT A Proper Introduction. theendoblog.com. 2/18/2011.
>	Dentistry Today. Three-Dimentional X-Rays for Kids: Ongoing Debate. Dentistry Today. 7/3/2011.
=	Catherine Paulhamus. The ALARA Principle in Practice. Inside Dentistry. 11/2013.
<	Renee Knight. Test your imaging IQ with our DPR Quiz. Modern Dental Network. 2/11/2013.
>=	Curtis E. Jansen. NA. Inside Dentistry. 8/2014.
>	Howard Farran. The Highest Margin Procedure in Dentistry with Dr. Dale Miles : Howard Speaks Podcast #16. dentaltown. 10/23/2014.
=	Strobel Dentistry. How Cone Beam Technology Works and What it Can Do for You. dentaltown. 12/2/2015.
=	Howard Farran. Oral Radiology: Past Present & Future with Anthony Mecham : Howard Speaks Podcast #123. dentaltown. 8/19/2015.

Appendix Table 2 Sources for Figure 3

Year	PMID	Conclusion
2005	16146304	<
2006	16480609	=
2007	17367457	=
2007	17931947	=
2007	17697108	>
2008	18805225	>=
2009	19715008	=
2009	19777550	=
2010	20379362	>=
2010	20683285	>
2010	20884935	>
2010	20884933	=
2012	22464520	>
2012	22981080	>
2012	23144478	>
2012	??	>
2014	24660190	>=
2014	24993927	>=
2014	25454528	>=
2015	24669832	=
2015	25951956	=

Appendix Table 3 Statements comparing effective dose from CBCT and conventional dental radiography in professional media

	Statement comparing effective dose from CBCT and conventional dental radiography
=	The NewTom 3G system also has an automatic exposure control device which selects the starting intensity of the x-ray beam, depending on the size of the patient, and modifies the anodic current according to the density of the transversed tissues (maximum value, 15 mA). This reduces the patient-absorbed dose to approximately that of a film-based periapical survey of the dentition or 1 to 7 times that of a single panoramic image.
	(Allan G. Farman, Claudio M. Levato, William C. Scarfe. A Primer on Cone Beam CT. Inside Dentistry. 1/2007.)
>	While the dose can be equal to or even less than a traditional panoramic exposure for small FOV systems it would take the combination of up to six such small FOV images to provide a full panorama of the teeth or three to six times the dose needed for the standard panoramic to say nothing of the time to stitch adjacent volumes and examine the full dataset.
	(Allan Farman. Should conebeam CT be used for caries detection. Dr Bicuspid. 5/12/2009.)
≥	Imaging Sciences Internationals iCAT is equivalent to approximately two panoramic images for standard exposure regimens.
	(Allan Farman . When it comes to dental imaging Luddites still exist. Dr Bicuspid. 5/12/2009.)
<	Small FOV systems can provide limited (ie, “focused field”) volume images of several teeth for approximately the same dose as two traditional intraoral radiographs. Given that multiple traditional images at different angles could be needed to evaluate an endodontic problem, small FOV CBCT might actually result in a dose savings to the patient.
	(Allan G. Farman. 3-D Imaging in Dentistry. Inside Dentistry. Jul/Aug 2010.)
>	Radiation doses to patients and potential doses to employees and other persons arising from the use of dental conebeam CT although lower than from medical CT equipment can be significantly higher than from conventional dental radiography equipment the HPA noted.
	(DrBicuspid Staff. UK agency releases guidelines for dental CBCT. Dr Bicuspid. 11/8/2010.)
>	In contrast the conebeam CT device used in our study results in only a threefold higher dose compared with digital panoramic tomography.
	(Kathy Kincade. Conebeam CT A better diagnostic tool for sialoliths. Dr Bicuspid. 7/6/2010.)
>	[With the] J Morita Veraviewepocs 3De the patient is exposed to the lowest radiation dose on the market. A single 40 x 40mm 3D scan exposes the patient to 0029mSv This is approximately the same amount of radiation a patient would receive with 9 digital periapical films 0003mSv.
	(Jason J Hales. 3D Evaluation of Root Canal Morphology Cone Beam Computed Tomography. Endo Blog. 5/28/2011.)
=	This means we can use it on a more routine basis without exposing patients to radiation beyond what they would typically get with a fullmouth radiographic exam using Dspeed film.
	(Kathy Kincade . Conebeam CT poised to play new role in periodontics. Dr Bicuspid. 10/31/2011.)
>	For instance the dose from a panoramic machine is much lower than that of a largevolume conebeam CT examination so a panoramic examination is preferable in most circumstances when an overview examination is needed with a new patient.
	(Kathy Kincade . Leaders in Dentistry A conversation with DrÂ Stuart White. Dr Bicuspid. 12/5/2011.)
>	The amount of radiation produced by 3-D CBCT imaging varies substantially depending on the machine used and the field of view exposed, and some clinicians may not realize how much higher that radiation is compared to conventional radiographs.

	(Dentistry Today. Three-Dimentional X-Rays for Kids: Ongoing Debate. DentistryToday. 3/7/2011.)
>	Although the radiation doses from dental CBCT exams are generally lower than other CT exams, dental CBCT exams typically deliver more radiation than conventional dental xray exams the FDA states on the new Web page.
	(DrBicuspid Staff. FDA issues guidance on dental CBCT. Dr Bicuspid. 8/14/2012.)
>	You cannot justify a CBCT examination, despite its low dose even when a suitable small field of view and suitable exposure factors are used, to examine a 9-year-old for the permanent successors to the primary dentition when a high-resolution, much lower-dose digital panoramic would do the job.
	(Martin Jablow, Dale A. Miles, Allen Ali Nasseh. Question: Is 3D imaging the new standard of care?. Inside Dentistry. 6/2012.)
>	. . . although patient radiation doses are still far higher than for traditional, non-computed radiographic techniques, a fact that should be taken into account when considering using CTs for dental implants.
	(Dr. Michael Tischler. 3D: Your baseline for success. Modern Dental Network. 3/21/2012.)
>	but do require more radiation exposure than 2D dental xrays
	(Dental Geek. Orthodontics and Conebeam Computed Tomography Improved Diagnosis and Treatment Outcomes. Dental Geek. 12/18/2013.)
<	In some cases a TMJ examination acquired with conebeam CT can be accomplished at one-half the effective dose of an intraoral fullmouth series radiographic examination the study authors wrote.
	(Kathy Kincade . 3D imaging improves orofacial pain diagnoses. Dr Bicuspid. 7/19/2013.)
=	Icat QuickScan+ technology that offers a lower dose when high resolution is not needed, at a dose comparable to 2D pan.
	(Michael Quirk. The best clinical x-ray products and practices for your dental practice. Modern Dental Network. 9/30/2014.)
<	i-CATÂ® FLX from Imaging Sciences International offers full-dentition 3D imaging at a dose lower than a 2D panoramic x-ray with QuickScan+.
	(Allan G. Farman. Digital Directions in Dentistry 2015. Inside Dentistry. 2/2015.)
≥	Small field-of-view CBCT technology largely obviates this need by providing an accurate, three-dimensional representation of endodontic pathology at a radiation dose comparable to several radiographs. [ref]
	(Rebekah Lucier Pryles. CBCT: A Three-Dimensional Look at Endodontic Diagnosis Endodontics Showcase. Inside Dentistry. 7/2015.)
>	Unfortunately CBCT scans are the radiation equivalent of at least a full series of dental Xrays and often expose patients to even greater exposure levels.
	(Lawrence Spindel. When do dentists recommend CBCT scans. Ask Dr. Spindel. 10/2/2016.)

Appendix Table 4 Statements comparing effective dose from CBCT and conventional dental radiography in journal articles

PMID	year		Statement comparing effective dose from CBCT and conventional dental radiography
15067269	2004	=	The entire maxillofacial volume (13-cm-diameter field of view) is imaged, and the patient receives an absorbed dose similar to a periapical survey of the dentition
16448229	2005	=	The 3DX has a radiological dose effect that is 1/100 of the helical-CT and is comparable with a general dental X-ray unit. [ref]
17931947	2007	=	This indicates that the amount of radiation exposure to the patient is comparable to that received from routine diagnostic imaging and is much less as compared with a medical CT. [ref]
19777550	2009	=	It has been reported that the total radiation is approximately 20% of conventional CTs and equivalent to a full mouth radiographic exposure. [ref]
20884934	2010	<=	Although studies of radiation dosimetry are not directly comparable [ref], the exposure from CBCT is within the same range as traditional dental imaging [ref]. The combination of traditional dental radiographs, particularly in a complete series, can result in a radiation dose that is substantially higher than that of CBCT [ref]. Nevertheless, critics of CBCT seem to focus on the radiation dose to patients who undergo CBCT, although there has been little or no discussion on this topic as it relates to traditional dental imaging. [ref]
22464520	2012	<=	These rapid advances in CBCT technology have resulted in 3-dimensional images that have about 2% or less of annual background radiation, with only slightly more than conventional orthodontic imaging without any supplemental radiographs. [ref] If full-mouth intraoral radiographs are taken to assess the periodontal status of adults, CBCT imaging typically reduces the patient dose
23144478	2012	>	These researchers found that i-CAT CBCT delivered a higher dose to the patient than a typical panoramic radiography by a factor of 5–16.
14696833	2003	=	Patient radiation dose is lower than for conventional medical CT, but is similar to that for standard dental radiology
14696834	2005	=	CBCT provides high quality of diagnostic images that have an absorbed dose that is comparable to other dental surveys and less than a conventional CT. [ref]
17697108	2007	=	CBCT has a low effective dose in the same order of magnitude as conventional dental radiograph
18805231	2008	<	In the United States, the radiation risks from many CBCT systems would be below those for the most common intraoral full-mouth series examination [ref], which suggests that it may be possible, with the appropriate use of CBCT technology and selected intraoral images, to gain more information about dentoalveolar conditions and treatment with fewer risks and time, benefiting both the patient and the dentist. [ref]
18805235	2008	>	If the machine is capable of capturing both the panoramic image alone (low dose to patient) and CBVT data (higher dose to patient)

19715008	2009	=	With respect to CBCT, the amount of radiation for a full head and neck scan may be roughly equivalent to a full mouth set of radiographs, depending on the manufacturer and scan setting.
19810647	2009	=	The introduction of CBCT creates the opportunity for clinicians to acquire the highest quality diagnostic images with an absorbed dose that is comparable to other dental surveys and less than a conventional CT. [ref]
22376101	2012	>	A lateral cephalograph or panoramic radiograph does not require as much radiation as a CBCT scan[ref]
24993927	2014	>	However, compared with a conventional lateral cephalogram, a panoramic radiograph, and any supplemental films that are required, the radiation dose of CBCTs is still relatively higher.
24669832	2015	<	Therefore, the use of traditional radiographs like a complete radiographic series may result in a radiation dose that is higher than that of a CBCT imaging study.
26672697	2015	<	Several CBCT manufacturers, with a combination of partial rotation around the patient's head, low settings, and pulse technology where radiation only happens when taking images, created a CBCT scanner that takes a 3D image with less radiation to the patient than a panoramic radiograph.35 This resulted in the ideal combination of more information with less radiation, which by logic and historic perspective makes the choice obvious
24660190	2014	>	With the increased use of CBCT imaging in dental practice, clinicians must be made aware that patient radiation doses associated with CBCT imaging are higher than those of conventional radiographic techniques
18805224	2008	>	The effective dose from large-volume machines ranges widely, from 2.7 times to 25 times a conventioanl panoramic examination
17333969	2007	>	Patient radiation exposure The radiation dose absorbed by patient during CBCT is 3-7 times higher than that absorbed when acquiring a panoramic image.[ref]