Predicting Adoption of Cone Beam Computed Tomography among Pediatric Dentists

BY

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B.D.S., King Saud University, 2013

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Oral Sciences
in the Graduate College of the
University of Illinois at Chicago, 2017

Chicago, Illinois

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ACKNOWLEDGMENTS

To Mom and Dad,

I cannot thank you enough for your endless sacrifices and unconditional love and support.

To my Wife,

Thank you for your endless support and encouragement throughout this residency.

Dr. David Avenetti, Dr. Charles Le Hew, Dr. Ian Marion, Dr. Johan Aps, and Dr. Anne Koerber,

Thank you for your insight and expertise that greatly assisted me with my project.

Dr. David Avenetti,

I would also like to show my gratitude to Dr. Avenetti for accepting me into the program that enabled me to have this experience. Thank you for sharing your pearls of wisdom with me during the course of my residency.

Dr. Anne Koerber and Dr. Le Hew,

Thank you for helping me throughout the course of this project, for your assistance with the methodology, and for teaching and helping with SPSS.

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LIST OF ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
AEGD	Advanced Education in General Dentistry Programs (AEGD)
AAOMR	American Academy of Oral and Maxillofacial Radiology
ADA	American Dental Association
AAPD	American Academy of Pediatric Dentistry
ALARA	As Low as Reasonably Achievable
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
GPR	General Practice Residency
U.S	United States

I. OBJECTIVES

- To examine why some pediatric dentists adopt Cone Beam Computed Tomography (CBCT) in their practice and others do not.
- To assess the extent and frequency of CBCT use by pediatric dentists.
- To compare characteristics of CBCT adopters versus non-adopters.

II. HYPOTHESES

1. Pediatric dentists who use CBCT will show characteristics typical of early adopters of technology compared to those who are not using CBCT.
2. Familiarity, Compatibility, and Access will predict which pediatric dentists have adopted the use of CBCT. These factors will be more strongly associated with the adoption of CBCT compared to demographics.
3. Pediatric dentists who work in hospital or academic institutions will adopt CBCT more readily than pediatric dentists who work in private offices, community health centers, or other institutions.
4. Pediatric dentists who are younger in age will adopt CBCT more readily than older pediatric dentists.

III. INTRODUCTION

III.A. Radiographic Imaging

Most radiographic diagnoses are made using two-dimensional (2D) images. However, there are several limitations associated with 2D radiographs, including the differentiation between surface characteristics of the lesion (smooth versus rough)[1-3], the localization and size of a lesion in the buccolingual dimension[2], and the changes that appear over time when comparing images to detect progression or healing.[3,4] Other inherent limitations include magnification, distortion, and superimposition that can enable misinterpretation of structures. Unlike these 2D images, CBCT is capable of producing three-dimensional (3D) images that can more specifically and accurately guide diagnosis, treatment, and follow-up.[1] When planning a surgical intervention, it is important to have a quality image to localize the lesion and to know its proximity to important anatomical structures in a 3D aspect. Unfortunately, traditional radiographs may not provide this information, which in turn may complicate or compromise the planned surgical intervention. Therefore, an imaging modality with 3D capability can be useful to enhance diagnosis and treatment planning.[2]

Since 1896, 2D radiographs (like periapicals and bitewings) have been used in dentistry and brought many advantages to dentistry. They facilitate diagnosis and improve treatment quality. Since then, dental imaging techniques have gradually advanced with the introduction of tomography and panoramic imaging.[1]

III.B. CBCT Background:

One of the greatest innovations in the field of radiology was the invention of computed tomography (CT) by Sir Godfrey Hounsfield in 1967. [1] CT technology is utilized widely in medicine. This includes evaluation and diagnosis of the head and neck regions[5] to help guide

oral surgical procedures; however, its use is limited. CT is difficult to integrate into dentistry and the dental office due to equipment size, equipment using hospital-based systems, higher radiation dose and cost. [6] In 1998, a new generation of computed tomography, the CBCT became available. Implications for use in dentistry became immediately apparent and CBCT systems were introduced in 1998 specifically for dento-alveolar imaging. Most of the units are comparable in size with a conventional panoramic radiographic machine, allowing easier integration into the dental office. CBCT has the potential to become the standard and state-of-the-art, non-invasive diagnostic instrument for various dental applications that require bony defect characterization.[1-4]

Compared to conventional CT, CBCT generates 3D data at a lower cost using a rapid scan time, and with lower absorbed doses of radiation. Some other advantages of CBCT are that it involves a smaller system, the X-ray beam is limited, accurate images are obtained, the display modes are exclusive to dento-facial imaging, and there are fewer imaging artifacts.[2,41] Also when compared to traditional 2D radiography, CBCT is superior by including a lack of superimposition, 1:1 measurement, the absence of geometric distortions, and 3D display. CBCT offers 3D representation of hard tissues with minimal soft tissue information, by utilizing relatively low ionizing radiation.[6]

Since CBCT was originally released, there have been many advancements in this technology including "a reduced cost of production for the sophisticated X-ray source, a quality detector, advancement in software design, and a more powerful computer system".[37] Other advantages of CBCT that they produce 3D images, although each manufacturer uses different exposure parameters and viewing software. They can share digital images from different CBCT manufacture units by Digital Imaging and Communications in Medicine (DICOM) data format, which render them convenient for image sharing.[7,8,9,10]

The advancements in reducing the size of CBCT machine, reduced its cost to purchase have allowed CBCT equipment to be more available to use in the dental office. CBCT images can be reconstructed into many formats that an oral care provider can navigate. A single CBCT image can be reconstructed to view as a panoramic, cephalometric, or bilateral multiple cross-sectional views for evaluation of a variety of oral and maxillofacial anomalies.[1,13,42] CBCT errors remain small and clinically insignificant. [3,4,41]With the large advancements in dentistry and the clinical applications of CBCT grow, it's predicted that the usefulness of cone-beam technology in dental and maxillofacial imaging over the next few decade will grow. [2]

III.C. Indications, Application, and Concern about CBCT Imaging in Dental Practice:

Radiographic imaging in dentistry is well-controlled and monitored by the American Academy of Oral and Maxillofacial Radiology (AAOMR) and the American Dental Association (ADA).[12] They have provided a rationale for image selection for areas of the head and neck region.[1,2] The use of 3D imaging is justified in certain cases, in which 2D images cannot provide the necessary information that is required for proper diagnosis and treatment.

When dealing with any radiographic imaging system it is critical to respect the as low as reasonably achievable (ALARA) radiation dose concept. However, it should not be used as a reason to avoid using CBCT imaging with higher doses as it can provide crucial information.[6] Although CBCT radiation doses can be significantly higher than conventional dental radiography, its use is justified by its benefit over 2D radiograph in an indicated cases. However, it is extremely important that their use be justified over conventional techniques before they are carried out.[6]

CBCT has recently become very popular in dental specialties including orthodontics, periodontics, prosthodontics, endodontics, and oral surgery due to numerous advantages in

diagnosis over conventional 2D radiographs. Several studies carried out in the USA and around the world have indicated that the dental community needs and is willing to learn more about CBCT and that the current educational programs are moving towards training their graduate and post-graduate students on the advancing technology.[32-35] This highlights that dentistry in general is rapidly moving towards increased use of CBCT and that current practitioners, including the pediatric dentists, should look to keep themselves up-to-date.[33-35, 40]

If a CBCT scan is required in a pediatric patient (e.g. in case of a dento-alveolar trauma or a bony lesion), the pediatric dentist should be able to interpret the acquired 3D data correctly.[4] CBCT imaging is very versatile with uses in implant planning, surgical assessment of pathology and impacted teeth with relation to adjacent teeth, endodontics, TMJ assessment, and pre-and postoperative assessment of craniofacial fractures.[21-23] CBCT use has greatly increased in orthodontics allowing imaging to assess growth and development.[8,27-29]

When dealing with complex treatment plans, CBCT images are helpful.[30] However, interpreting these images requires extensive anatomical knowledge. Additionally, the benefit of CBCT use varies on a case-by-case basis and dentists must determine if CBCT increases the diagnostic knowledge and improves or changes that particular patient's dental care. This requires continuous training and education on the part of dentists.[4]

III.D. Education, Knowledge, and Attitude towards CBCT:

Recent survey studies indicate that most U.S. dental schools provide some form of teaching on CBCT for pre-doctoral as well as post-doctoral students. While many schools endorse the application of CBCT, they seem to vary tremendously regarding what exactly should be taught.[38,39] A study done in South India evaluated the knowledge and attitudes of a dental fraternity towards CBCT. After surveying the dental faculties, undergraduate and post

graduate students, the results indicated that 58% of postgraduates and 85% of dental faculty staff had knowledge about CBCT. However, the majority failed to explain the advantages of CBCT over CT in dentistry. The study showed that the majority (77%) of dentists preferred CBCT over conventional CT for their patients to undergo 3D imaging. It was concluded that 22% of dentists believed lower radiation dose of CBCT is an important advantage over CT. Also, results showed that 80% of the dentists were willing to have a CBCT unit in their dental institution and the majority of dentists contemplated that the information on CBCT should be included in the academic curriculum in both undergraduate and postgraduate programs. The results also revealed that the dental faculty believe that the faculty courses did not provide adequate information about CBCT. Furthermore, the majority of dentists in all groups were willing to obtain updated information regarding CBCT.[32]

A study conducted in Mangalore, India, questioned 200 dentists working in reputed institutes in the area. All the participants of the survey were familiar of CBCT and considered it to be a useful diagnostic tool in dentistry. Most of participant believed that CBCT had lower radiation dose compared to CT. Additionally, 27% of participant dentists felt CBCT will be the standard imaging tool in the future of dentistry. The majority of the participants also reported inadequate CBCT teaching in educational institutions and were willing to attend CBCT courses in the future. In this study, 98% of dentists reported that the reason for not using CBCT is expense.[33]

A survey study was completed in Istanbul, Turkey, among two dental institutions with the aim to evaluate dental students' (postgraduate and undergraduate) knowledge and attitudes regarding CBCT. Results showed that 63% of students had heard of CBCT. Of these, 60% said they had learned about CBCT in their dental classes, 31% in seminars and 21% from the internet. However, 77% felt that CBCT need more coverage in their courses. Most of

participants thought CBCT are essential be available at dental faculties. While looking into the future of dentistry, 54% believed that the CBCT use would become more common in the near future and 85% wished to use it in their career.[34]

A cross-sectional study in India targeted different dental specialties with an objective of describing the current status of knowledge, attitude, and perspective of dental practitioners toward CBCT imaging. The results indicated that there is a gap in knowledge of CBCT applications among the dental specialists. The dental specialists themselves are aware that there is lack of training in this field and strongly perceive the need for further education. Experts in the field of oral radiology strongly agree that new educational strategies must be developed for training in CBCT. Introduction of training in CBCT at undergraduate as well as postgraduate level, while developing well-structured training modules, will help improve accuracy and reliability of oral and maxillofacial diagnosis, treatment planning and imaging outcomes.[35]

A 2012 study was conducted to evaluate CBCT teaching in both undergraduate and postgraduate specialty training curricula in dental schools in the United States, the United Kingdom, and Australia. The study found that most of dental schools in all regions have CBCT technology or are in the process of acquiring a CBCT machine. Dental schools believe the benefits of acquiring CBCT and its application in dentistry. Most of dental school teach CBCT technology in their curriculum. There has been a large increase in dental schools that are preparing their students for CBCT image interpretation. Additionally, a higher number of postdoctoral dental residents compared to undergraduate students are receiving training to acquire, interpret, and apply software manipulation to CBCT images. [4]

III.E. Reasons for Not Using CBCT:

For most dental practitioners, the use of advanced imaging such as CBCT has been

limited because of cost, availability, and radiation dose considerations.[2] Depending on the manufacturer and model, a CBCT machine can range from $90,000 to $300,000.[2] Also, the dentist who orders or performs a CBCT for a patient is then legally responsible for interpreting the entire CBCT image, however, due to lack of education, some dentists may not feel comfortable reading the entire image.[44]

III.F. Reasons for Adopting New Technology:

For any innovation or new technology, there are key steps or elements that need to be in place. In 1962, Everett Rogers published his book, Diffusion of Innovations. Rogers produced his theory, "Adoption of New Innovation," from researching over 508 diffusion studies related to medical sociology, industrial sociology, early sociology, rural sociology, and education. His theory is among the most cited in adoption of new technology research. Rogers lists the key elements for adoption: "relative advantage (the perceived efficiencies gained by the innovation relative to current tools or procedures), compatibility with a pre-existing system, complexity and difficulty to adopt, availability or access to users, and familiarity or observability prior to adoption". Rogers theorizes that for any new technology to be adopted, it must be advantageous to the adopters and meet their needs, compatible and appropriate to their practice, not too complex, and available and familiar for trial so its usefulness can be witnessed prior to commitment. These elements usually judged all together since they are overlapping between them. For example, an innovation might be not familiar and complex to learn and use, reducing its likelihood to be used, but may be very compatible and advantageous relative to current tools. It is for this reason that innovations with a high learning curve may be adopted.[36,45]

Based on the literature, most CBCT applications are related to the specialties of oral and maxillofacial surgery, endodontics, implants, and orthodontics. Dentists' interest in CBCT in

recent years requires pediatric dentists to be familiar as well as trained to read and interpret CBCT images because it is important to make the final diagnosis for developmental diseases and trauma in pediatric patients. This study aims to assess the extent of CBCT use by pediatric dentists and examine why some pediatric dentists adopt CBCT and why non-adopters do not.

IV. METHODS

IV.A. Research Design

This study was a cross-sectional survey of pediatric dentists in the United States. A 20-item electronic questionnaire was used to obtain information about dentists' demographics, training program, and dental school. Questions were included to assess: their level of familiarity with CBCT, availability of CBCT, perceived relative advantages of CBCT, and perceived compatibility of CBCT to the pediatric dental profession. The primary outcome variable was adoption or non-adoption which is identified by whether the respondent said he or she is currently using CBCT in clinical practice. Adopters and non-adopters are compared for the four characteristics typical of early adopters: perceived advantages of CBCT, compatibility of the CBCT with their practice, familiarity with CBCT, and availability of CBCT. Additionally, information was collected on practice setting, years of experience, education, and practice location (See Figure 1). Data was self-reported by pediatric dentists using the questionnaire in Appendix A.

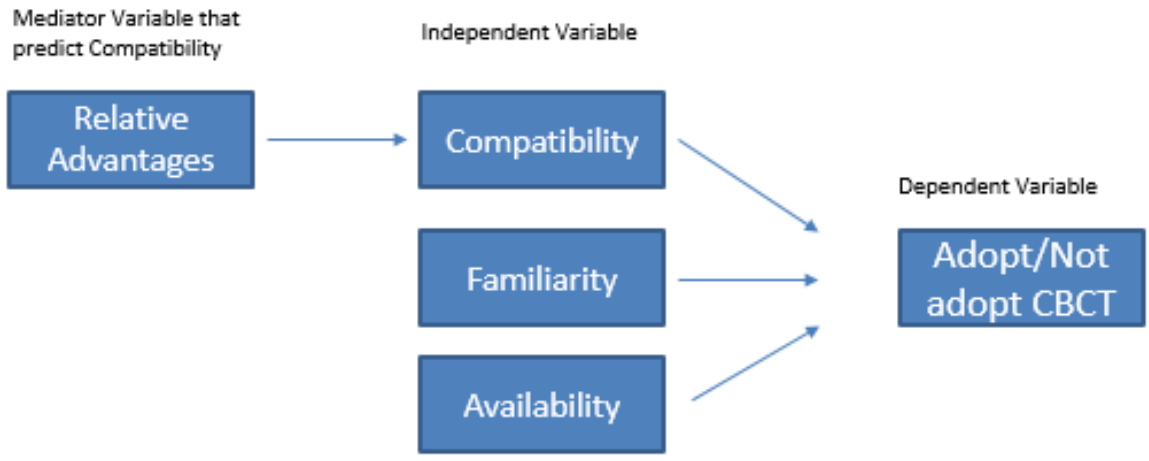

Figure 1. Model of variables that predict adoption of CBCT.

IV.B. Sample

This questionnaire was sent to the American Academy of Pediatric Dentistry (AAPD) member list. The inclusion criteria were pediatric dentists with active AAPD membership who currently were practicing pediatric dentistry in the United States. Subjects were excluded if they did not limit their scope of practice to pediatric dentistry, had additional specialty training outside of pediatric dentistry (including GPR or AEGD training), or did not answer if they were currently using CBCT (Appendix B).

IV.C. Description of Study Procedures

This study received expedited approval from the IRB at the University of Illinois at Chicago (Appendix C). The online survey was created using Qualtrics software (Qualtrics LLC, Dallas, Texas) and a link was provided in the email. With permission from the AAPD, the survey was e-mailed to all 7,174 active AAPD members. We predicted a 5-to-10% response rate for an estimated sample size of 300-600 subjects. A cover letter was included with the questionnaire email (Appendix D). The email was sent on October 7, 2016 and subjects' responses were maintained anonymously through Qualtrics. Two reminders were emailed on November 10, 2016 and December 7, 2016.

IV.D. Data Management

After closing the electronic questionnaire (Appendix c), the data were downloaded into SPSS (IBM Corp. in Armonk, NY) for analysis. The de-identified data were kept in a password-protected computer in a locked office at the Department of Pediatric Dentistry, University of Illinois at Chicago.

IV.E. Statistical Methods

The independent variable domains were the following:

- Familiarity with CBCT (questions #10, 11, 15 and 16).
- Availability of CBCT (question #13)
- Compatibility of CBCT to the subject's practice (questions# 17 and 18)
- Relative advantage Of CBCT (the mediator variable that predicts compatibility) (questions # 19 and 20)

The independent variables in each domain were examined to determine if they could be collapsed into scales. Some variables entered into the scales were reverse coded before inclusion. Cronbach's alpha was used to assess which items in a domain correlate with each other and could therefore be collapsed into a scaled score for that domain. If an item did not correlate with the other items in the domain, it was examined separately.

The binary logistic regression model was constructed in which the outcome variable (adoption) was regressed on the domain variables in the following manner:

1. Demographic variables were entered into the model, retaining only those which significantly ($p<.05$) related to the dependent variable.
2. Scaled scores for the domains, as well as any items that were not included in the scaled scores were entered into the model in a stepwise forward manner, retaining only those variables significantly related to the dependent variable.
3. The relationship between relative advantage and compatibility was examined. We predicted that relative advantage would not be significant when compatibility was entered into the model.

During analysis, certain variables were recoded or grouped to obtain the most meaningful results. Relative contributions of predictor variables were analyzed and the odds ratios and 95% confidence intervals were calculated.

V. RESULTS

V.A. Number of Participants and Response Rates

There were 533 responses (7%) following three rounds of distribution. The survey was inactivated on December 31, 2016. Of the 533 responses, only 396 met the inclusion criteria (74%); 137 responses were excluded due to additional specialty training (51 out of 137), not providing direct pediatric dental care (46 out of 137), or incomplete responses (40 out of 137). The final response rate was 5.6%.

V.B. Descriptive Characteristics of Participants

Table I describes the demographic characteristics of the participants. There were 216 males (55%) and 180 females (45%) that participated in the study (N=396). In our sample, there were 93 users of CBCT (23.5%). Two hundred and thirty five participants graduated from a university-based program with a hospital affiliation residency program (60%), 121 graduated from a hospital-based program (31%), and 37 participants from university residency program (9%). Board status of our sample was 272 board certified (69%), 65 board- eligible (16%), and 25 were either other or not pursuing board specialty (6%). The geographic distribution of the participants' practice location in the five AAPD regions showed that 53 participants were practicing in the north east (15%), 85 in the south east (23%), 82 in north central (22%), 53 in the south west (15%), and 90 in the western region (30%). The sample consisted of 254 participants (64%) that worked in a private practice setting or community health compared to 142 (36%) that worked either in a hospital or university setting.

Table I. Demographic Characteristics of Respondents, Categorized by Use of Cone Beam Computed Tomography (CBCT)

	N (%)	Use CBCT N (%)	Don't use CBCT N (%)
Total Sample (N)	396	93	303
Gender			
Male/Other	216 (55%)	52 (56%)	164 (54%)
Female	180 (45%)	41(44%)	115 (46%)
Age			
25 years old to 34 years old	112 (28%)	25 (27%)	87 (29%)
35 years old to 44 years old	92 (23%)	24 (26%)	68 (22%)
45 years old to 54 years old	67 (17%)	14 (15%)	53 (18%)
55 years and older	125 (32%)	30 (32%)	95 (31%)
Year of Specialty Graduation			
2011 to 2016	148 (37%)	33 (35%)	115 (38%)
2001 to 2010	66 (17%)	18 (19%)	48 (16%)
1991 to 2000	67 (17%)	14 (15%)	53 (17%)
< 1990	115 (29%)	28 (31%)	87 (29%)
Type of Residency Program Attended*			
Hospital-Based	121 (31%)	24 (26%)	97 (32%)
University-Based	37 (9%)	9 (10%)	28 (9%)
University-Based with Hospital Affiliation	235 (60%)	60 (64%)	175 (59%)
American Board of Pediatric Dentistry Status			
Board-certified	272 (69%)	67 (72%)	205 (68%)
Board-eligible	65 (16%)	9 (10%)	56 (18%)
Still in pediatric residency program	34 (9%)	12 (14%)	22 (8%)
Other/not pursuing board specialty	25 (6%)	5 (6%)	20 (6%)
Primary Practice Type			
Hospital or Academic institution	142(36%)	44 (47%)	98 (32%)
Private Practice or Community Health	254(64%)	49 (53%)	205 (68%)
Practice Location*			
Northeastern	53(15%)	15 (16%)	64 (21%)
Southeastern	85(23%)	20 (22%)	65 (21%)
Northcentral	82(22%)	18 (20%)	64 (21%)
Southwestern	53(15%)	15 (16%)	38 (16%)
Western	90(30%)	24 (26%)	66 (21%)

*Totals do not equal 396 due to missing responses

V.C. Familiarity of Pediatric Dentists with Cone Beam Computed Tomography (CBCT)

The respondents' familiarity with CBCT is reported in Table II. Two hundred and thirteen participants (54%) had no CBCT training. In addition, 304 participants (77%) felt they were not competent in using CBCT. On the other hand, 318 participants (80%) were somewhat or very familiar with the clinical indications for CBCT, and 247 participants (63%) felt highly skilled in interpreting CBCT images.

Table II. Respondents' Familiarity with Cone Beam Computed Tomography (CBCT)

	N (%)	Use CBCT (%)	Don't use CBCT (%)
Training in CBCT			
No Training	213(54%)	28 (3%)	185 (61%)
Less Than Two Hours Training	87(22%)	22 (24%)	65 (21%)
Two to Five Hours Training	64(16%)	27 (29%)	37 (12%)
More Than Five Hours Training	32(8%)	16 (17%)	16 (6%)
Competence Using CBCT in Practice*			
Not Competent	304(77%)	33 (38%)	271 (89%)
Somewhat Competent	83(21%)	54 (58%)	29 (10%)
Very Competent	8(2%)	6 (4%)	2 (<1%)
Knowledge of Clinical Indications for CBCT (CBCT)*			
Not Familiar	78(20%)	35 (38%)	43 (14%)
Somewhat Familiar	238(60%)	55 (60%)	183 (61%)
Very Familiar	77(20%)	2 (2%)	75 (25%)
Skills Interpreting Cone Beam Compute Tomography Images*			
Total	394	92	302
Not Skilled	7(2%)	5 (15%)	2 (<1%)
Somewhat Skilled	140(35%)	57 (62%)	83 (27%)
Highly Skilled	247(63%)	30 (33%)	217 (72%)

*Totals do not equal 396 due to missing responses

V.D. Availability of Cone Beam Computed Tomography (CBCT) to Pediatric Dentists

Table III shows the distribution of responses to the question pertaining to the respondents' access to CBCT. Three hundred and fifty six of the participants (90%) had access to CBCT either through a referral or available on the premises.

Table III. Respondents' Access to Cone Beam Computed Tomography (CBCT)

	N (%)	Use CBCT (%)	Don't use CBCT (%)
Access to CBCT *			
No	40 (10%)	0 (0%)	40 (13%)
Yes, through referral	292 (74%)	56 (60%)	236 (78%)
Yes, available on the premises	62 (16%)	37 (40%)	26 (9%)

*Totals do not equal 396 due to missing responses

V.E. Pediatric Dentists' Ratings of Compatibility with CBCT

The respondents' perceived compatibility of CBCT with pediatric dentists' practice is shown in Table IV. Three hundred and fifty eight participants (91%) feel CBCT is important to their practice. On the other hand, only 107 participants (27%) think that CBCT will become the standard practice in pediatric dentistry.

Table IV. Perceived Compatibility of CBCT

	N (%)	Use CBCT (%)	Don't use CBCT (%)
Importance of Cone Beam Computed Tomography (CBCT) imaging for pediatric practice *			
Not Important	36 (9%)	20 (22%)	16 (6%)
Somewhat Important	194 (49%)	61 (66%)	133 (44%)
Very Important	164 (42%)	11 (12%)	153 (50%)
Likelihood that Cone Beam Computed Tomography (CBCT) in Practice will become standard practice *			
Not Likely	287 (73%)	58 (63%)	229 (76%)
Somewhat Likely	84 (21%)	24 (26%)	60 (20%)
Very Likely	23 (6%)	10 (11%)	13 (4%)

*Totals do not equal 396 due to missing responses

V.F. Relative Advantages of CBCT

Perceptions of relative advantages and concerns are shown in Table V. Three hundred and fifty one participants (90%) believe that CBCT is a very useful imaging technology for pediatric dentistry. Two hundred and eight participants (53%) are concerned about the CBCT radiation dose, 144 participants (37%) had concerns about the cost to patients, and 162 participants (41%) had concerns about the equipment costs for the provider using CBCT. Two hundred and seventy three participants (69%) had concerns about the difficulty of image interpretation, and 253 (64%) had concerns about medico-legal issues.

Table V. Relative Advantages of Cone Beam Computed Tomography (CBCT)

	N (%)	Use CBCT (%)	Don't use CBCT (%)
Cone Beam Computed Tomography (CBCT) Usefulness in Pediatric Dental Practice*			
Not Useful	41 (10%)	23 (25%)	18 (6%)
Somewhat Useful	240 (61%)	62 (68%)	178 (59%)
Very Useful	111 (29%)	6 (7%)	105 (36%)
Concern about Radiation Dose*			
Not a Concern	187 (47%)	48 (52%)	139 (46%)
Somewhat of a Concern	145 (37%)	34 (37)	111 (37%)
A Great Concern	63 (16%)	11 (11%)	52 (17%)
Concern about Cost to Patient *			
Not a Concern	250 (63%)	55 (59%)	195 (65%)
Somewhat of a Concern	121 (30%)	31 (33%)	90 (30%)
A Great Concern	23 (7%)	7 (8%)	16 (5%)
Concern about Cost to Provider *			
Not a Concern	233 (59%)	44 (47%)	189 (63%)
Somewhat of a Concern	120 (30%)	37 (40%)	83 (27%)
A Great Concern	42 (11%)	12 (13%)	30 (10%)
Concern about Difficulty of Interpretation *			
Not a Concern	122 (31%)	18 (19%)	104 (34%)
Somewhat of a Concern	200 (51%)	54 (58%)	146 (48%)
A Great Concern	73 (18%)	21 (23%)	52 (18%)
Concern about Medico-Legal Issues *			
Not a Concern	141 (36%)	25 (27%)	116 (39%)
Somewhat of a Concern	172 (44%)	44 (47%)	128 (42%)
A Great Concern	81 (20%)	24 (26%)	57 (19%)

*Totals do not equal 396 due to missing responses

V.G. Reliability of Familiarity, Compatibility, and Relative Advantages Scales.

Table VI shows the Cronbach's alpha scale reliability test for Familiarity (correlation of 4 questions in Table II), Compatibility (correlation of two questions in Table IV), and Relative Advantages (correlation of two questions in Table V).

Table VI. Scale reliability for Familiarity, Compatibility, and Relative Advantages

Scale	Cronbach's Alpha
Familiarity	0.73
Compatibility	0.60
Relative Advantages	0.63

V.H. Adoption Prediction of CBCT among Pediatric Dentists.

Binary logistic regression was used to predict adoption from demographics as shown in Table VII. Practice type (P< .05) was the only demographic variable associated with use of CBCT in the preliminary regression analysis. In Table VIII, practice type and domains are significantly independently associated with the adoption of CBCT (P<.05). The preliminary tables are in Appendix E.

Table VII. Association between Demographic variables and Use of Cone-Beam Computed Tomography (CBCT)

	P-value	OR (95% CI)
Practice Type	.002^	2.4 (1.30-3.50)
Age	NS +	1.0 (0.99-1.01)
Pediatric Dentistry Experience	NS +	1.0 (0.98-1.10)
Type of Residency Program	NS +	1.1 (0.90-1.50)
Status of American Board of Pediatric Dentistry	NS +	0.9 (0.70-1.20)
Practice Location (Northeastern)	NS +	
Practice Location (Southeastern)	NS +	0.6 (0.30-1.40)
Practice Location (North central)	NS +	0.8 (0.40-1.60)
Practice Location (South Western)	NS +	0.7 (0.30-1.40)
Practice Location (Western)	NS +	1.0 (0.50-2.10)
Gender	NS +	0.9 (0.50-1.40)

*Binary logistic regression with Odds Ratios (OR) presented with 95% confidence interval (CI)
^ Significantly related to CBCT use at the alpha < 0.05 level
+ (NS = not significant)

Table VIII. Independent Association between Practice Type, Domains and Use of Cone-Beam Computed Tomography (CBCT)

	P-value
Practice Type	0.01^
Domain	
Familiarity	<.001^
Availability	<.001^
Compatibility	<.001^
Relative Advantage	<.001^

^ Significantly related to CBCT use at the alpha < 0.05 level

Table IX shows the results when domains and practice type are all entered into the model. Familiarity, Availability and Compatibility were the only domains in Rogers's model that predicted use/adoption of CBCT. Relative Advantage and Demographics were not predictive of CBCT use/adoption. The regression model explained 41% of the variance in the outcome variable (Nagelkerke R Square).

Table IX. Association between Practice Type, Domains and Use of Cone-Beam Computed Tomography (CBCT)

	P-Value	**OR (95% CI)**
Practice Type	NS	0.8 (.4-1.4)
Domains		
Familiarity	<.001^	1.7 (1.4-1.9)
Availability	<.001^	3.7 (1.9-7.2)
Compatibility	.001^	1.7 (1.2-2.3)
Relative Advantage	NS +	1.0 (0.9-1.2)

*Binary logistic regression with Odds Ratio (OR) and 95% confidence interval (CI)

^ Significantly related to CBCT use at the alpha < 0.05 level

+ (NS = not significant)

VI. DISCUSSION

In our study, we assessed the extent of CBCT use by pediatric dentists and what factors affect a pediatric dentist's decision to adopt a new technology. We used Rogers's model of Diffusion of Innovation to guide this investigation. The factors that affect pediatric dentists' adoption of CBCT were familiarity with CBCT, availability of CBCT, and compatibility of CBCT to their practice.

The results of this study show that less than one quarter of our sample are using CBCT (23%) currently. Most of our sample lack familiarity with, do not have availability to CBCT, and do not find it compatible with their practice. Also our study indicates that familiarity, availability, and compatibility of CBCT in pediatric dentists are significantly related to adoption of CBCT whereas relative advantages and demographics are not. That supports our first and second hypotheses. In regard to our study's third hypotheses that "pediatric dentists who work in hospital or academic institutions will adopt CBCT more readily than pediatric dentists who work in private offices, community health centers, or other institutions" we found that practice types was not related to CBCT adoption. Additionally, the hypothesis that "Pediatric dentists who are younger in age will adopt CBCT more readily than older pediatric dentists" was not supported, as we found out that age is not related to CBCT adoption. Age is not consistently found to be related to early adoption in other studies. [32]

In Rogers's Diffusion of Innovation theory and studies, he found that the younger generations tend to adopt new technology. However, in our study there was no significant difference in adoption of CBCT between different age groups. This may be due to the fact that in dentistry, one has to be able to adopt new technology quickly not only in order to keep up to date with other dentists but also because the standard of care may incorporate these new technologies,

including CBCT. Another reason may be the mandatory continuing education courses received by older groups which can introduce these groups to new technology which will help increase familiarity, and may alter perceptions of compatibility, and provide some availability of CBCT for consideration.

There are many factors that can affect a dentist's willingness to adopt new technology, some of which derive from the environment with which they were trained. We predicted the individuals who attended a hospital program or university program with hospital affiliation or who work in a hospital or academic institution would theoretically have more exposure, hence more likely to use CBCT. But, there was no difference in type of residency program attended (hospital-based, university-based, and university based with hospital affiliation) and practice type (hospital or academic institution, and private practice or community health) once the domains were put in the model. Practice type became irrelevant because the domains explained the use of CBCT better than practice type did. Also, this result may be explained by accessibility to CBCT by the dentist who may be referring the patient to be treated under other providers from a different specialty such as Endodontist, Prosthodontist, Orthodontists, and Oral Surgery who then may have access to CBCT.

Another factor that affects a dentist's willingness to adopt a new technology is how educated and familiar that dentist is to new technology in general. Rogers's model states that the better educated and more familiar people are about new technology the more adopters there will be. In our study we found this to be true, in that there was significant association between familiarity of CBCT and adoption/non-adoption of CBCT among pediatric dentists. To illustrate familiarity further, the questionnaire contained 4 questions about familiarity covering training in CBCT, competence using CBCT in practice, knowledge of clinical indications in the pediatric

population for CBCT, and skills interpreting CBCT images. We found that less than half of our total sample had some kind of training in CBCT (Clinical indications, knowledge of CBCT, and interpreting CBCT images). Most of the CBCT users reported having some kind of CBCT training. That provides insight as to how familiarity about CBCT is important to for pediatric dentist to adopt CBCT.

Being familiar and comfortable with CBCT is important in willingness to adopt the new technology. However, for a new technology to be fully adopted in clinical practice, Rogers indicates that it must be widely available to users. The results from this study demonstrated that there is significant association in adoption of CBCT and availability of and access to CBCT. Interestingly, all users in our sample have access to CBCT either by referral or availability of CBCT on the premises. So, the most important variable determining the adoption of CBCT in our study is CBCT availability. The logical explanation for this is that a provider is more likely to adopt a new technology that is readily available to them. As such, having access to a new technology makes it more practical for someone who is willing to adopt it in the first place. The technology must also be compatible for practical use.

In regards to compatibility of new technology, Rogers stated that in order for people to adopt a new technology it must be compatible with their life and practice. Once again, the results from this study fall in line, as there was an association between compatibility of CBCT and adoption of it. Most of our sample (users/non-users of CBCT) feel that CBCT is "somewhat" or "very compatible" to their pediatric practice. But most of our study sample didn't use CBCT, evidently due to lack of familiarity and availability of CBCT.

In our study, this lack of familiarity plays a role because less than one-third of respondents felt that CBCT will "somewhat" or "very likely" become the standard practice in

pediatric dentistry. This is not surprising because the clinical indications of CBCT use are not commonly encountered. In most instances, the use of 2D radiography is sufficient, at least to determine if further imaging or intervention is needed. For a new technology to be even considered for use, prospective users must find benefits for its use in their practice. In our study, relative advantage and adoption/non adoption were associated with CBCT use. However, once Compatibility was entered into the model, relative advantage was no longer a significant predictor of adoption. Its effect on adoption is subsumed by Compatibility.

Contrary to expectations, radiation dose, medico-legal issues, cost to provider, and cost to patient were not high concerns to potential users of CBCT. We believe this result can be explained by the fact that the most of pediatric dentists in our sample may not have adequate knowledge about the CBCT system details.

The main findings from our study are that familiarity, compatibility, and availability are associated with the use of CBCT. Also, there are no significant concerns (i.e. radiation dose, cost to patient and provider, difficulty of CBCT interpretation, and medico-legal concerns) that affect the use of CBCT by pediatric dentists.

If a CBCT scan is required in a pediatric patient (e.g. in case of a dento-alveolar trauma or a bone lesion), the pediatric dentist should be able to interpret the acquired 3D data correctly.[43] Consider how important it is for pediatric dentists to use CBCT. This study is helpful by suggesting how that number could be increased.

There are some limitations in this study. The sample was small and only represents pediatric dentists with active membership in AAPD, and therefore does not represent all pediatric dentists in US. A selection bias may be present. On the other hand, the sample showed a wide distribution within the United States, and wide ranges in age, experience, practice type, and

gender suggesting that a response bias is unlikely a higher response rate would make this study even more representative for the pediatric dentist population in the USA. Furthermore, this study has all the potential issues associated with self-reported data. Validity is also a potential limitation. The questions used in this study were used for the first time here, and we cannot entirely verify the validity of the responses. In addition, we have multiple independent variables that correlate with each other, potentially lowering the internal validity.

Future studies could compare the extent of use of CBCT between the US and other countries, and could ask about whether new guidelines would change their behavior. Additionally, although this study demonstrated which variables affect the use of CBCT by pediatric dentists, this study did not cover ways to improve these variables to influence CBCT use. These points discussed are all things to consider in future research in this field.

In conclusion, only one quarter of pediatric dentists in our sample currently use CBCT, and none of the demographic variables was associated with the use of CBCT. Consistent with Rogers's model, pediatric dentists who adopt CBCT have more familiarity, have more access, and view CBCT as compatible with their practice, thus showing the characteristics of new adopters, with the noted exception of age. This study also allowed us to come to the conclusion that if we want a group of people to adopt new things or technology, they must be familiar, perceive compatibility, and have access to the new technology, which is consistent with Rogers's research as well.

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VIII. APPENDICES

APPENDIX A

Study Questionnaire

Q1 What is your gender?
- ❍ Male
- ❍ Female
- ❍ Other/Prefer not to answer

Q2 What year did you graduate from your pediatric dentistry residency?

Q3 In what year were you born?

Q4 Do you provide direct pediatric patient care?
- ❍ Yes
- ❍ No

Q5 What type of residency program did you graduate from?
- ❍ Hospital-based program
- ❍ University-based program
- ❍ University-based with hospital affiliated training

Q6 Do you have any other specialty training besides pediatric dentistry including AEGD or GPR?
- ❍ Yes
- ❍ No

Q7 Which of the following best describes your status with the American Board of Pediatric Dentistry?
- ❍ Board certified
- ❍ Board eligible
- ❍ Still in Pediatric Residency Program
- ❍ Other/not pursuing board specialty

Q8 Which of the following describe locations where you practice? (please select all that apply.)
- ☐ Hospital
- ☐ Private office
- ☐ Academic Institution
- ☐ Other (Please specify) _____

Q9 In what state do you have your primary practice location?

Q10 Which would you say best describes the training you received about CBCT?
- ❍ No training
- ❍ Less than two hours
- ❍ 2-5 hours
- ❍ More than 5 hours

Q11 How do you rate your competence using CBCT in practice?
- ❍ Not competent
- ❍ Somewhat competent
- ❍ Very competent

Q12 Are you currently using CBCT in your clinical practice?
- ❍ Never
- ❍ 1-3 times a year
- ❍ More than 3 times a year

Q13 If CBCT were definitely indicated, would you have access to it?
- ❍ No
- ❍ Yes, through referral
- ❍ Yes, available on the premises

Q14 How likely do you think it is that you will gain access to CBCT in the next three years?
- ❍ Not likely
- ❍ Somewhat likely
- ❍ Very likely

Q15 Which of the following best describes your knowledge of clinical indications for CBCT use?
- ❍ I am very familiar with clinical indications for CBCT use
- ❍ I am somewhat familiar with clinical indications for CBCT use
- ❍ I am not familiar with clinical indications for CBCT use

Q16 Which of the following best describes your skills in interpreting CBCT images?
- ❍ I am highly skilled in interpreting CBCT images.
- ❍ I am somewhat skilled in interpreting CBCT images.
- ❍ I am not skilled in interpreting CBCT images.

Q17 How important is it to have CBCT imaging available for a pediatric practice?

- ❍ Very important
- ❍ Somewhat important
- ❍ Not important

Q18 How likely do you think it is that CBCT imaging will become standard practice in pediatric dentistry over in the next five years?

- ❍ Not likely
- ❍ Somewhat likely
- ❍ Very likely

Q19 How useful do you think CBCT is in pediatric dental practice?

- ❍ Very useful
- ❍ Somewhat useful
- ❍ Not useful

Q20 How much of a concern is each of the following regarding use CBCT?

	Not a concern	Somewhat of a concern	A great concern
Radiation dose	❍	❍	❍
Cost to patient	❍	❍	❍
Cost to provider	❍	❍	❍
Difficulties with interpretation	❍	❍	❍
Medico-legal reasons ("Legal risks")	❍	❍	❍

APPENDIX B

Exclusion Methods

The first step was to exclude all participants who responded, "No" or did not answer question (4), asking: "Do you provide direct pediatric patient care?" Also excluded were those who answered "Yes" or who did not answer question (6): "Do you have any other specialty training besides pediatric dentistry including AEGD or GPR?" Finally, any participant who did not answer question (12) "Are you currently using CBCT in your clinical practice?" was excluded.

Missing data. To address possible problems that may arise due to missing data, we used multiple imputation. Missing data for age (question#3) and pediatric dental experience (question#2) replaced with the mean value for those variables. Gender was recoded so that female is coded as 1, male coded as -1, and missing data/other coded as 0.

Practice location. Question (9), "In what state do you have your primary practice location?" was collapsed into five AAPD districts (http://www.aapd.org/about/affiliated/): Northeastern, Southeastern, North Central, South Western, and Western society(Appendix D).

The dependent variable, Question (12), "Are you currently using CBCT in your clinical practice?" was also recoded from: Never, 1-3 times a year, and more than 3 times a year, to: Never, and Yes.

APPENDIX C

IRB Study Certification

UNIVERSITY OF ILLINOIS
AT CHICAGO

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

Exemption Granted

September 20, 2016

Saad S. Binsaleh, BDS
Pediatric Dentistry
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M/C 850
Chicago, IL 60612
Phone: (312) 998-8343 / Fax: (312) 413-8006

RE: Research Protocol # 2016-0922
"Predicting adoption of Cone Beam Computed Tomography Among Pediatric Dentists"

Sponsors: None

Dear Dr. Binsaleh:

Your Claim of Exemption was reviewed on September 20, 2016 and it was determined that your research protocol meets the criteria for exemption as defined in the U. S. Department of Health and Human Services Regulations for the Protection of Human Subjects [(45 CFR 46.101(b)]. You may now begin your research.

Exemption Period:	**September 20, 2016 – September 20, 2019**
Performance Site:	UIC
Subject Population:	Adult (18+ years) subjects only
Number of Subjects:	600

APPENDIX D

Cover Letter

Dear AAPD members,

You are invited to participate in a web-based online survey on **Predicting adoption of Cone Beam Computed Tomography among Pediatric Dentists**. We are interested in learning why some pediatric dentists have chosen to use CBCTwhile others have not.

This is a research project being conducted by Saad Binsaleh, a pediatric resident at University of Illinois at Chicago. It should take approximately 5 minutes of your time and will indicate your consent to participate in the study.

Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. You are free to decline to answer any particular question you do not wish to answer for any reason.
You will receive no direct benefits from participating in this research study. However, your responses may help us learn more about CBCT uses in pediatric population.

There are no foreseeable risks involved in participating in this study. Your survey answers will be sent to a link at Qualtrics.com where data will be stored in a password protected electronic format. Qualtrics does not collect identifying information such as your name, email address, or IP address. Therefore, your responses will remain anonymous. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study.

You may open the survey in your web browser by clicking the link below:
https://uic.qualtrics.com/SE/?SID=SV_2fBGRyzGco45FrL
If you have questions at any time about the study or the procedures, you may contact me via email at sbinsa2@uic.edu or my research supervisor, Dr. Avenetti via email at Avenetti@uic.edu.

Thank you,
Saad Binsaleh

APPENDIX E

Preliminary Table

Table 6. Independent Association between Demographic Characteristics and Use Cone Beam Computed Tomography (CBCT)	
	P-value*
Practice Type	0.005^
Age	NS
Pediatric Dentistry Experience	NS
Type of Residency Program	NS
American Board of Pediatric Dentistry Status	NS
Practice Location	NS
Gender	NS

*Binary logistic regression

^ Significantly related to CBCT use at the alpha < 0.05 level

IX. VITA

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