Orthodontists' Awareness of the Radiation Dose of Cone Beam CT Scans (CBCT) in Orthodontics and Its Influence on the Use of CBCT

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Abstract

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The purpose of this study was to evaluate the use of cone beam computed tomography (CBCT) by orthodontists in the USA and the orthodontists' awareness of the radiation dose of cone beam CT scans compared to 2D radiographs. A survey was developed using the Qualtrics platform and disseminated to orthodontists practicing in the US. A second survey was distributed amongst the orthodontics post graduate program directors to report the use and training on CBCT scans during orthodontic programs.

From the 161 orthodontists who responded to the first survey, almost half of them indicated that they use CBCT scans routinely. 47% reported that they believe that the CBCT scans have equal or lower radiation than a combination of the traditional 2D radiographs (panoramic plus cephalometric radiograph). Not providing additional information (42.2%) was the most common reason preventing orthodontists from prescribing CBCT scans followed by lack of access (34.8%), radiation (33.5%), cost (27.3%), never prevented (26.1%), insurance (13%), patient being child/adolescent (11.8%).

From the 15 program directors who responded to the second survey, 53.3% indicated that they have direct access to a CBCT scan in the graduate orthodontic clinic and 46.7% indicated that they refer their patients to another clinic. 13.3% indicated that they use a CBCT scan on 100% of

all their patients. The most common number of hours of training on radiation safety was 1-2 hours (46.2%) was followed by 3-5 hours (38.5%) and none (15.4%).

The lack of clinicians' knowledge of radiation exposure, as well as their reported limited training in CBCT use suggest that there is a pressing need for enhanced education regarding CBCT radiation safety.

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INTRODUCTION AND STATEMENT OF THE PROBLEM

Radiographic imaging is a vital part of dentistry. Traditionally, 2D imaging is used in dentistry. With the advances in technology, there has been an increase in use of 3D imaging. Cone beam CT scans (CBCT) were first built for angiography at the Mayo clinic. There are many uses for CBCT scans in medicine including radiation therapy planning, mammography, and otorhinolaryngological surgery. (1) Cone beam CT scans are 3D imaging using a single rotation with a cone shape beam to acquire images. (2) This is one of the main differences with medical CT scans which acquires the imaging volume using multiple rotation with a fan shape beam. (2) The first commercial CBCT scan was approved by the FDA for dentistry in 2001. (1)

The creation of CBCT images includes two steps: acquisition and reconstruction. During the acquisition of CBCT images, the C arm (an arm with x-ray source and a reciprocating x-ray detector) rotates around the patient's head. This rotation can be 180° or more. As a result of this rotation, a sequence of 2D images referred to as basis projections are acquired. During reconstruction, the basis images are processed by a workstation computer. (1, 3) Each CBCT machine has its own features. Some of these features include size of the field of view, voxel size, spatial resolution, number of basis images, and path of rotation.(1)

An important consideration in using imaging in dentistry is the radiation dose. ALARA (As Low As Reasonably Achievable), and more specifically ALADAIP (As Low As Diagnostically Acceptable being Indication-oriented and Patient-specific) is the main principle of use of diagnostic radiation. (4) This becomes more prominent when working with younger patients. The true risk of developing cancer, especially in children after cone beam CT is not yet

known. In-vitro research has shown that the effective dose of younger patients is higher than the older patients. (5) Also, in 25% of cancers including leukemia and thyroid, skin, breast and brain cancer, children are more radiosensitive than adult. (3) All these signify the importance of the use of radiographs in children which are the main part of the patient population in orthodontic practices.

To be able to make a meaningful comparison of the radiation dose of different types of radiographs, the effective dose is measured with consideration of the type of tissue and degree of radiation sensitivity of that tissue exposed during a certain radiograph. The effective radiation dose is usually reported in Sieverts or Micro- Sieverts(μSv). The sensitive organs that are exposed during the imaging of the head and neck area are bone marrow, thyroid, esophagus, skin, bone surface, salivary glands, and brain. The most sensitive tissue is thyroid followed by salivary glands. (6)

Imaging is an important part of orthodontic diagnostic records. Traditionally, panoramic and cephalometric images are the primary imaging used in orthodontics. In recent years, there has been an increase in the use of CBCT scans in orthodontics. The effective dose of panoramic and cephalometric imaging is 6–38 μSv and 2–10μSv, respectively, whereas the effective dose of CBCT scans varies between 5.3–498μSv.(7) Effective radiation doses are also affected by the age of the patient. Ludlow et al in a review of literature reported a mean adult effective dose of 212 μSv for large field of view, 177 μSv for medium field of view and 84 μSv for large field of view. They reported a mean child effective dose 175 μSv for medium and large fields of view and 103 μSv for small field of view. (4, 7) The ranges of effective doses of panoramic, lateral ceph and cone beam CT scans is reported in table 1. In an in-vitro study, Signorelli et al compared the radiation dose of CBCT scans in three modes of portrait, normal landscape, and

fast scan landscape to conventional orthodontics radiographs (consisted of conventional lateral and posteroanterior cephalograms and digital panoramic radiograph). They concluded that one CBCT scan has 2-4 times more radiation than conventional orthodontic radiographs. (8) There are multiple factors that determine the radiation dose of CBCT scans. Some of these factors are features of machine, while the others can be determined by the clinicians.(6)

Table 1: Radiation dose (μSv) of panoramic, lateral ceph and CBCT scans

TYPE OF RADIOGRAPH	RADIATION DOSE (μSV)
2D PANORAMIC	6–38 (4)
2D LATERAL CEPH	2–10(4)
CONE BEAM CT SCAN	
SMALL FIELD OF VIEW	5-388 (7)
MEDIUM FIELD OF VIEW	40-626 (7)
LARGE FIELD OF VIEW	46-498 (7)

One of the factors determining the cone beam CT dose is the size of field of view. CBCT scans are in different sizes of the field of view, including small, medium, and large. The small field of view usually includes a couple of teeth, medium includes one jaw and large field of view can cover from the skull to cervical vertebrae. The size of the field of view is usually associated with collimation of the x-ray beam. As a result of that the radiation dose of smaller fields of view CBCT scan is lower than the larger ones. Also, with smaller field of view CBCT scans, there are fewer sensitive tissues radiated during the scan acquisition. The smaller field of view CBCT

scans usually have smaller voxels. Voxels are the smallest element of CT scans detectors. The size of the voxels determines the spatial resolution of the CBCT scans. The smaller voxel size of a CBCT scan, the higher the spatial resolution is. (1, 6, 9)

Another important factor determining the radiation dose of a CBCT scan is the exposure settings of the machine. CBCT exposure can be continuous radiation exposure or pulsed exposure. Since the radiation is turned off between the basis images, the pulsed exposure usually results in a lower radiation to the patients. Some CBCT machines have fixed x-ray potential and current, whereas in some machines these factors can be changed. In these machines, it is possible to adjust the exposure settings based on patient's factors. The tube current can be between 1- 32 mA and the potential can vary between 40 - 120 kV. Another factor that can help limiting the CBCT radiation dose is the presence of an additional filtration in the x-ray source. (3) The scanning time also determines the radiation dose of the CBCT scans. The scanning time can be between 5-40 seconds. (1, 9)

The path of trajectory (or degree of rotation of the CBCT gantry) is another factor determining the radiation dose. A scan arc of 180°results in 50% radiation when compared to 360°. However, a lower scan arc results in less number of basis projections and eventually loss of image quality and incomplete information. (10)

As previously mentioned, panoramic and lateral cephalometric images are the main diagnostic images used in orthodontics. These images are part of the initial, progress and final records. With the introduction of CBCT scans in dentistry, one of the questions that has arisen was the role of CBCT scans in orthodontics. There are multiple position papers from different European and American associations addressing the use of CBCT scans in orthodontics. The European commission on radiation protection in their report (SEDENTEXCT), does not

recommend using CBCT scans as the "standard method of diagnosis and treatment planning" for orthodontic patients and discourages the use of CBCT scan for serial monitoring evaluations. CBCT can be used for localized evaluations of impacted teeth where conventional imaging cannot provide adequate information. Large field of view CBCT scans can be used for evaluations of patients with clefts, complex craniofacial deformities requiring surgical or combined surgical/orthodontic intervention aged 16 years or over. For transverse expansion, the panel was not able to find universally accepted criteria. The panel concluded that CBCT should not be used for the reconstruction of conventional panoramic and cephalometric images. (11)

The American Association of Oral and Maxillofacial Radiology (AAOMR) position paper was published in 2013. The position paper recommends that the use of CBCT scans should be based on patient's history, clinical examination, available radiographic images and a condition that requires further evaluation by CBCT scans. Using CBCT scans for reconstruction of panoramic and cephalometric images should be avoided. The radiation dose risk of CBCT scans for the patients should be considered. (12)

The current evidence supports using CBCT scans for localization of impacted teeth, dentofacial abnormalities and deformities of craniofacial anatomy, maxillary transverse dimensions and pathologic evaluation. (4, 9)

Considering the increased use of CBCT scans in dental practices, it is important to determine the clinician's knowledge of radiation risks associated with CBCT scans as well as the specific guidelines on the use of CBCT scans. Stokes et al in a review of the literature reported that although there is a high awareness of existence of CBCT, the clinicians' knowledge of applications, indications, and radiation dose of CBCT scans is limited. (13) They reviewed 39 articles as a part of their literature review, in which only 2 focused on the awareness of

orthodontists: Cesur et al in 2016 evaluated the knowledge of orthodontics regarding the radiation of cone beam CT scans compared to medical CT scans amongst orthodontists in Turkey. Of 366 participants in their study, 85.6% indicated that they prefer CBCT scans over medical CT scans and 56.3% use CBCT scans for orthodontic diagnosis. From the university-based population 90.4% indicated that a CBCT machine is required for their clinic while only 40% of clinicians felt the need for a CBCT machine in their clinic. 49.4% of the respondents indicated they learnt CBCT from seminars. (14) Sugumaran et al in 2018 evaluated the knowledge and awareness of orthodontists of CBCT scans in India. The main focus of their study was the comparison of CBCT scans with medical CT scans. In this study, although 84% of participants reported that they are aware CBCT scans are not justified for all orthodontics patients, only 50% were aware of SEDENTEXCT guidelines. The participants were aware that CBCT scans have lower radiation compared to medical CT scans. They did not provide any information regarding the comparison of CBCT scans with plain films. (15)

Caiado et al in 2022 in a multi-country survey reported that among 1284 orthodontists 84.4% used CBCT scans for selected cases. However, only 45.2% followed a guideline using CBCT scans. Only 32.7% of the participants reported that they had a training course on CBCT. Their study include orthodontists from Belgium, Brazil, Canada, Romania, and the United States of America. (16)

Guberman et al in a study on evaluation of use of CBCT scans in postgraduate programs in North America and Europe reported North American programs have more access to CBCT scans in postgraduate clinics and use CBCT imaging more routinely. They also reported that 24.4% of the North American programs use CBCT scans for initial evaluations and 25.8% use CBCT scans routinely as part of progress/ final records. (17) In a recent survey published in

September 2024, AAO reported 42% of its American and Canadian members use CBCT scans. (18) The purpose of this study is to evaluate the awareness of orthodontist of the radiation dose of CBCT scans compared to conventional 2D images and how this influences their use of type of diagnostic imaging.

OBJECTIVES

1. Evaluate the use of CBCT by orthodontists in the USA
2. Describe the availability of CBCT equipment in orthodontists' offices in the USA
3. Evaluate the orthodontists' awareness of the radiation dose of cone beam CT scans compared to 2D radiographs
4. Describe clinicians' training on CBCT safety, their awareness of methods to reduce radiation dose and the use of radiation safety guidelines
5. Test the hypothesis that the orthodontists' belief in the radiation dose affects their usage of CBCT.

    Hypothesis 1: orthodontists who use CBCT on a regular basis underestimate the levels of radiation associated with CBCT.

6. Test the hypothesis that the availability of CBCT in the office influences the frequency of use.

    Hypothesis 2: orthodontists who have a CBCT in their offices are more likely to use CBCT machines for routine evaluations.

7. Test the effects of Clinician related factors (age, gender, use of CBCT during graduate training) on their use of CBCT

8. Report on the use and training of CBCT in graduate programs

RESEARCH DESIGN AND METHODS

Surveys

This study received approval from the Institutional Review Board (IRB) at the University of Washington (UW). In collaboration with a survey specialist, two surveys were designed to address the research objectives.

Survey #1 (Appendices 1 and 2)

The first survey aimed to assess orthodontists' use of CBCT and their awareness of radiation exposure associated with CBCT and to evaluate how this awareness influences their use of this technology.

The survey was developed using the Qualtrics platform and disseminated to members participating in the AAO Partners in Research Program, as well as to the members of relevant Facebook groups, including "Orthodontic Pearls," "Women in Orthodontics," and the Western Angle Society. The accompanying consent and recruitment form clearly indicated that the survey targeted orthodontists practicing within the United States.

To ensure the integrity of the data collected, specific inclusion and exclusion criteria were established. Inclusion criteria mandated that participants be currently practicing orthodontists in the United States. Practitioners who do not specialize in orthodontics and orthodontists who are not actively practicing in the United States were excluded from participation. This approach aimed to ensure that the insights gathered accurately reflect the perspectives of qualified professionals in the field.

This survey was designed in two distinct formats: the AAO format (Appendix 1) and the non-AAO format (Appendix 2). The primary difference between these formats lies in the question addressing the comparison of radiation doses between panoramic and cephalometric images and those associated with CBCT scans. In the initial questionnaire (non-AAO format), this comparison was posed directly. Conversely, in the AAO format, the question was framed indirectly through three separate questions. This modification was made in accordance with the guidelines set forth by the review committee of the AAO Partners in Research Program.

Survey #2 (Appendix 3)

A second survey was designed to investigate the utilization of CBCT and the education regarding radiation safety of cone beam CT scans in postgraduate orthodontic programs across the United States. This survey was also developed using the Qualtrics platform.

The survey was distributed directly to the directors of 68 orthodontic graduate programs nationwide. Each director received an initial email outlining the objectives and significance of the survey, along with a request for their participation. In order to encourage a higher response rate and enhance engagement, a follow-up reminder email was subsequently sent.

This approach aimed to gather comprehensive insights into the current practices and educational standards related to CBCT and radiation safety within postgraduate orthodontic training. By focusing on the perspectives of program directors, the survey sought to elucidate the extent to which these crucial topics are integrated into the curricula and training of future orthodontic practitioners.

STATISTICAL ANALYSIS

Frequency and percentage were used to summarize all categorical variables, including CBCT use and perceived CBCT radiation, and the mean and standard deviation for quantitative variables (e.g., age). In addition, 95% confidence interval were computed to describe the rate of CBCT use and perceived CBCT radiation. The chi-square test and Fisher's exact test were used to test for associations between CBCT use, perceived CBCT radiation and other practitioner and practice characteristics. All analyses were performed using R statistical software Version 4.4.1 (R Core Team, 2024) with statistical significance level set at $\alpha = 0.05$.

RESULTS

Survey #1: Orthodontists practicing in the US

Demographics

There were 180 respondents to the surveys (135 using the AAO format and 45 using the non-AA0 format). 15 respondents were excluded because they were not orthodontists practicing in the United States. 4 respondents were omitted from the analysis due to incomplete surveys. The results are based on 161 orthodontists practicing in the United States and who completed the majority of the survey. The mean age of respondents is 48.8 with 46.3% female and 51.3% male responders. The majority of the respondents graduated more than 15 years ago. Only 3.8% of the respondents reported using CBCT scans on 100% of their patients during their orthodontics training, followed by 5% routinely, 38% occasionally, 51% never used CBCT scans during their orthodontics training. The demographics of the respondents are reported in table #2.

Table 2: Demographics (Race/ethnicity and Gender distribution, Years since graduation and Age distribution)

Variable	N (total)	Percentage
Race		
White	125	77.6%
American Indian or Alaska Native	1	0.6%
Asian	16	9.9%
Other	4	2.5%
Unknown	15	9.3%
Ethnicity		
Hispanic or Latino	6	3.7%
Not Hispanic or Latino	125	77.6%
Unknown	30	18.6%

Gender		
Female	74	46.3%
Male	82	51.3%
Prefer not to say	3	1.9%
Prefer to self-describe	1	0.6%
Unknown	1	0.6%
Years since graduation		
<1-5 years ago	36	22.5%
6-15 years ago	38	23.8%
More than 15 years ago	86	53.8%
Unknown	1	0.6%
Age		
Mean	48.8	
Median	48	
Range	30-85	
Unknown	14	

Use of CBCT, Frequency and Indications

CBCT use was defined in three different ways. The first method (CBCT use #1) was based on the response to the question "How often do you use cone beam CT (CBCT) scans in your practice?", often, sometimes, rarely or never. Reponses were grouped into three categories of use: often, sometimes and rarely or never. Never responses were grouped with the rarely response due to the small number of never responses. The second method (CBCT use #2) was based on the response to a question about the frequency of prescribing CBCT scans: every case or selected cases. The third method (CBCT use #3) was based on a combination of the questions used for the first and second methods. Only practitioners who often used CBCT scans used CBCT scans for every case or selected cases, and all other practitioners only used CBCT scans for selected cases. Responses were grouped into three categories of use: often used CBCT scans for every case, often or sometimes used CBCT scans for selected cases, and rarely or never used CBCT scans for selected cases. The three methods are reported in table #3.

Table 3:CBCT use by the 3 methods

CBCT use	**N = 161**	**95% CI**[1]
CBCT use method #1, n (%)		
Often	42 (26.1)	20%, 34%
Sometimes	38 (23.6)	17%, 31%
Rarely/Never	81 (50.3)	42%, 58%
CBCT use method #2, n (%)		
Every case	29 (18.0)	13%, 25%
Selected cases	132 (82.0)	75%, 87%
CBCT use method #3, n (%)		
Often/Every case	29 (18.0)	13%, 25%
Often/Sometimes/Selected cases	51 (31.7)	25%, 40%
Rarely/Never	81 (50.3)	42%, 58%

[1]CI = Confidence Interval

98.1% of the respondents indicated they use CBCT scans for diagnostic purposes, followed by progress evaluation (39.8%), final evaluation (21.7%) and other reasons (19.0%). Other reasons mentioned by the participants included evaluation of suspected pathology, specific dental location issues or pathology not adequately imaged, rare cases, and outcome of research.

From the orthodontists who responded to this survey 17.4% reported they use CBCT scan to reconstruct panoramic and lateral cepholametric images always or often, 16.1% sometimes, 66.5 % rarely/never.

Not providing additional information (42.2%) was the most common reason preventing orthodontists from prescribing CBCT scans followed by lack of access (34.8%), radiation

(33.5%), cost (27.3%), never prevented (26.1%), insurance (13%), patient being child/adolescent (11.8%).

Access to CBCT

From the respondants, 49.7% reported they refer patients to an office or facility other than their practice for CBCT scans. 45.9% reported they have CBCT scans in their office.

85.1% of the respondents reported they have panoramic and lateral cephalometric machines in their offices, 50.9% of respondents reported they have CBCT scans in their offices, and 28% reported they have multifunctional machines in their offices.

Perceived Radiation Exposure Associated with CBCT

Perceived radiation exposure associated with CBCT was asked differently between the non-AAO formatted survey and the AAO formatted survey. The non-AAO formatted survey asked a single question about how CBCT radiation compares to 2-D radiographs, higher, equal or lower. The AAO formatted survey asked three questions about how CBCT radiation compares to 2-D radiographs. Respondents were asked to rate their agreement (strongly agree, agree, neither agree or disagree, disagree or strongly disagree) to whether the CBCT radiation was higher, equal or lower than 2-D radiographs. To combine the responses from the two surveys, the agreement to the AAO formatted survey statement that CBCT radiation was higher than the 2-D radiographs was grouped into strongly agree/agree, neither agree nor disagree and strongly disagree/agree to indicate higher, equal or lower radiation as compared to CBCT radiation. Note, that there was high (inverse) agreement (90%) between the two AAO formatted survey statements that CBCT radiation was higher or lower than 2-D radiographs (Appendix 4). The combined responses to

questions regarding the perceived radiation of CBCT scans versus 2D radiographs is reported in table 4.

Table 4:CBCT radiation versus radiation of 2-D radiographs

	N = 161	**95% CI**[1]
CBCT radiation vs 2-D radiographs #2, n (%)		
Lower	28 (17.4)	12%, 24%
Equal	48 (29.8)	23%, 38%
Higher	85 (52.8)	45%, 61%
CBCT radiation vs 2-D radiographs #2, n (%)		
Lower/Equal	76 (47.2)	39%, 55%
Higher	85 (52.8)	45%, 61%

[1]CI = Confidence Interval

Other Clinician-Related Characteristics

Evaluation and Training

35% of the respondents reported they always/often conduct a full evaluation of CBCT scan while, 15% reported they sometimes evaluate the full scan and 50% reported they rarely or never evaluate the whole volume of the scan. 25.6 % of orthodontists reported they always/often submit CBCT scans for review by oral radiologists, 29.4% reported they sometimes submit CBCT scans for review by oral radiologists. 35% reported they never submit CBCT scans for oral radiologist review.

63.4% of orthodontists reported they have no specific guidelines for prescribing CBCT scans, followed by using AAOMR position statement (23%), State/federal guidelines (18%), other (such as evidence-based literature) (3.7%) and SEDENTEXCT (1.2%).

Continuing education courses (46%) are the most common source of CBCT training amongst the respondents, followed by training from their graduate programs (44.7%), training provided by CBCT manufacturer (31.7%) and no training (14.9%).

Clinicians' Awareness of Methods to Reduce CBCT Radiation

Regarding ways to reduce radiation exposure, 54% reported they use smaller size of field of view, 38.5% reported they reduce exposure settings, 25.5 % reported they have no control over the exposure of radiation, and 7.5% reported they use other features such as reducing the rotation. 12.4% responded "other" and mostly commented they don't have a CBCT in their offices.

Use of CBCT and Perceptions of Radiation Dose

There was a statistically significant association between the percieved radiation of CBCT scans versus 2D radiographs and the use of CBCT scans ($p<0.001$). Clinicians who reported a lower perceived radiation dose of CBCT scans also tended to take them more frequently ($p<0.001$).

Table 5:CBCT use and CBCT radiation belief

	CBCT radiation vs 2-D radiographs		
CBCT use	Lower/Equal	Higher	**p-value**[1]
CBCT use #3, n (%)			<0.001
Often/Every case	21 (72.4)	8 (27.6)	
Often/Sometimes	23 (45.1)	28 (54.9)	
Rarely/Never	26 (32.1)	55 (67.9)	

[1]Chi-squared test

Clinicians who perceived radiation dose of CBCT to be lower or equal to that of 2D-radiography tended to use CBCT more frequently to reconstruct 2 D images from the CBCT ($p<0.001$).

There was no association between the perceived radiation dose of CBCT scans and reported CBCT training during post-graduate education ($p=0.881$), training from continuing educational courses($p=0.646$), training from CBCT manufacturer ($p=0.101$), or no training ($p=0.578$).

The use of CBCT was ignificantly higher between clinicians who reported they conduct a full review of incidental findings ($p<0.001$). There was no statistically significant correlation between clinicians reported review of incidental findings and their perceived level of radiation of CBCT ($p=0.822$).

Access to CBCT

Use of CBCT scans and having a CBCT machine in the office was significantly associated with clinicians reporting higher use of CBCT if they have a CBCT on site ($p<0.001$) (table 6).

There was no statistically significant correlation between perceived radiation dose and having a CBCT in the office ($p=0.061$). Use of CBCT scans to reconstruct 2D images was significantly associated with the presence of a CBCT in the office ($p<0.001$) (table 7).

Table 6:CBCT use and access to CBCT

	Access to CBCT		
CBCT use	CBCT in office	Refer for CBCT	**p-value**[1]
CBCT use #3, n (%)			<0.001
Often/Every case	29 (36.7)	0 (0.0)	
Often/Sometimes	36 (45.6)	13 (16.5)	
Rarely/Never	14 (17.7)	66 (83.5)	

[1]Chi-squared test

Table 7:CBCT machine in office vs CBCT use & perceived radiation

Characteristic	CBCT machine in office		p-value[1]
	Yes N = 82	No N = 76	
CBCT use #3, n (%)			<0.001
Often/Every case	29 (35.4)	0 (0.0)	
Often/Sometimes	37 (45.1)	13 (17.1)	
Rarely/Never	16 (19.5)	63 (82.9)	
CBCT radiation vs 2-D radiographs, n (%)			0.061
Lower	19 (23.2)	7 (9.2)	
Equal	20 (24.4)	22 (28.9)	
Higher	43 (52.4)	47 (61.8)	

[1]Pearson's Chi-squared test

Clinicians who report their source of training as continuing education courses and CBCT manufacturers are more likely to have a CBCT scan in their offices (p<0.001). Having a CBCT machine in the office was also associated with no training (p<0.001). There was no other association between other types of training and having CBCT in the office. P=0.449 for graduate program, P=0712 for others)

Clinician-Related Characteristics and CBCT Use

No statistically significant associations between CBCT use and years since graduation were noted (P=0.605). There is some evidence of an association between CBCT use and CBCT use during training, but the associations are not statistically significant (P=0.206). The biggest differences are between those who routinely used CBCT during training and others, but the number of orthodontists who routinely used CBCT during training is small. No statistically significant association was noted between use of CBCT scans and gender(P=0.893).

There is a statistically significant association between the use of CBCT scans as well as reconstructing 2Dimages from CBCT scans and training provided by manufacturers ($p<0.001$). No other statistical significant association is noted.

Clinician awareness of methods to reduce radiation exposure

There was a statistically significant association between the use of CBCT scans and reduce exposure settings ($p<0.001$). The only statistically significant association between the type of training and ways to reduce CBCT radiation was noted between the field of view and no training as well as reducing radiation exposure and training from CBCT manufacturer($p<0.001$).

Other correlations

There was a statistically significant association between the full evaluation of CBCT scans and the use of CBCT scans, CBCT availability in office, training received by continuing education and CBCT manufacturers courses ($p<0.001$). No statistical significance was noted between the full evaluation of CBCT scans and perceived radiation of CBCT scans ($p=0.062$) and training received from graduate programs ($p=0.802$) or no training ($p=0.003$).

No statistically significant differences were reported between the submitting CBCT scans to oral radiolgists for review versus CBCT use ($p=0.048$), percieved radiation ($p=0.062$), CBCT availiblity in office ($p=0.126$), type of training and the full evaluation of CBCT scans (Graduate program training $p=0.364$, Continuing education $p=0.363$, CBCT manufacturer training $p=0.386$, Other trainings $p=0.294$, No traning $p=0.630$.)

There is a statistically significant association between the use of CBCT scan and cost being a preventing factor for ordering CBCT scans ($p<0.001$). No statistically significant association reported for perceived radiation of the CBCT scans ($p=0.091$).

Statistical significance is noted between the use of CBCT scan and use of State/federal guidelines ($p<0.001$).

Survey#2: Program directors

There were 18 responses from the directors' survey. Three respondents indicated that either they are not a postgraduate program director, or they did not finish the survey. From the remaining 15 respondents, 53.3% indicated that they have direct access to a CBCT scan and 46.7% indicated that they refer their patients to another clinic. 13.3% indicated that they refer 100% of all patients for CBCT scans, 13.3% that they refer 75% of all patients for CBCT scans, 66.7% indicated that they occasionally refer their patients for CBCT scans, 6.7% indicated chose the "other" option but didn't provide further information. The most common reason for ordering CBCT scans amongst graduate programs was diagnostic imaging 93.3%, followed by progress evaluation 40%, final evaluation 33.3%, and other reasons (for specific cases) 6.7%.

From the 15 respondents, 46% indicated they don't have any guidelines and 53.3% indicated that they have guidelines for CBCT prescription. From this group, 100% indicated they use CBCT scans for evaluation of impacted teeth and evaluation of asymmetry, 87.5% indicated they use CBCT scans for orthognathic surgery and 25% indicated they use CBCT scans for airway evaluation.

From 8 respondents who indicated they use guidelines for their CBCT use, 1 used the basis of guidelines is AAOMR position statement, 1 used the SEDENTEXCT, 1 used State/federal guidelines, 4 use clinical judgement of faculty, 3 mentioned no specific guidelines and 1 indicated they have guidelines for the dose and field of view if they use CBCT scans on every patient.

The most common number of hours of training on radiation safety was 1-2 hours (46.2%) was followed by 3-5 hours (38.5%) and none (15.4%). The highest number of hours for training

on reading CBCT scans was 3-5 hours (30.8%) followed by 6-8 hours (23.1%), and 1-2 hours and more than 8 hours (both 15.4%). 15.4% also indicated no training is provided on reading CBCT scans.

30.8% of the respondents indicated they don't use any means to reduce radiation, 69.2% indicated they reduce radiation. From these respondents,77.8% use smaller FOV size, 55.6% use lower radiation exposure settings, 11.1% use other factors such as reducing the rotation. 1 respondent indicated they use preset machine options that match the patient.

From the respondents, 38.5% never use CBCT scans to reconstruct 2D images, 23.1 % often, 23.1% rarely and 15.4 % sometimes use CBCT scans to reconstruct 2D images.

DISCUSSION

The aim of this study was to assess orthodontists' use of cone beam CT (CBCT) as well as their awareness of the radiation dose associated with CBCT scans compared to 2D radiographs. The frequency of use of CBCT was correlated with the orthodontists' belief of the radiation exposure, the availability of CBCT equipment in their office, as well as clinician and patient related factors. Information was gathered from orthodontists practicing in the United States of America using a survey distributed using several platforms. An additional survey was distributed to Graduate Orthodontic Program Directors in the United States, gathering information on current use of CBCT and training in postdoctoral programs.

A total of 180 orthodontists responded with 161 surveys being included in the study. Among the respondents, 18% indicated that they use CBCT scans frequently and in every case, 31.7% reported frequent use but not in every case, and 50.3% stated they rarely or never use CBCT scans. Caiado and coworkers in their multi country study showed that the CBCT scan use by the US orthodontists was the highest amongst the countries they evaluated. (16) In a recent survey published in September 2024, AAO reported 42% of its American and Canadian members use CBCT scans.(18) This finding is consistent with the results of our study concerning the use of CBCT scans by orthodontists in the United States. The lower usage of CBCT observed in the AAO survey may be attributed to differences in the regulations governing the use of CBCT scans in Canada and the United States. Additionally, another contributing factor could be related to the study participants. In our study, 53.8% of respondents reported having graduated more than 15 years ago, and 51% indicated that they did not utilize CBCT scans during their graduate training.

When evaluating the factors preventing the orthodontists from prescribing CBCT scans, not providing additional information was first, followed by lack of access, radiation, cost, insurance and patient's age. Almost one quarter of the respondents reported that no factors prevented them from prescribing CBCT scans. The primary reported reason of not providing additional information is interesting, as it suggests that the respondents believe CBCT scans, in most instances, do not provide supplementary insights beyond those afforded by traditional radiographs. Previous studies have shown that CBCT scans can be used for dental structural and position anomalies, dentofacial and craniofacial anomalies, airway and pathology evaluations. (9) Although these are common conditions observed and treated by orthodontists, they do not seem to indicate routine use of CBCT scans in orthodontics. One factor that can be related to the use of CBCT scans is the age of the clinicians that responded to the survey. Many of the orthodontists responded to this survey have over 15 years of experience, and their age (with a mean of 48 years old) suggests that they may have been trained and practiced before CBCT became widely available. This may lead them to feel less of a need for CBCT scans in their daily practice, as they might have relied on traditional diagnostic methods for most of their careers.

Lack of access was the second factor reported that prevents orthodontists from prescribing CBCT scans. In our survey, 45.9% of respondents indicated that they have a CBCT machine in their office. This is the first study to examine the availability of CBCT machines in orthodontic offices across the United States. In a previous study by Setzer et al., it was found that 50.69% of endodontists had a CBCT machine on-site in 2017 (20). This proportion may be higher if the study were conducted at the present time. Additionally, the application of CBCT scans has continued to evolve and expand in various dental specialties.

In our survey, 47.2% of respondents consider the radiation from CBCT scans to be either equivalent to or lower than that of the combination of conventional 2D images (a panorex and a lateral cephalogram). While the radiation dose of CBCT scans is influenced by multiple factors, in general, the radiation exposure from a combination of a panoramic radiograph and lateral cephalogram is lower than that from a CBCT scan. (8)

We investigated the correlation between the use of CBCT and clinician's belief of the CBCT radiation dose, the availability of CBCT equipment, as well as other clinician and patient related factors.

Our study found that orthodontists who perceive CBCT scans as having higher radiation exposure are more likely to use CBCT scans infrequently or never. Among the factors that influence orthodontists' decisions to refrain from prescribing CBCT scans, radiation concerns ranked third (33.5%).

The study further revealed that orthodontists without access to a CBCT machine in their office tend to use CBCT scans less frequently. Limited access to CBCT technology was identified as the second most common reason for not prescribing CBCT scans. A statistically significant correlation was observed between the presence of CBCT equipment in the practice and its frequency of use. This suggests that orthodontists who have CBCT technology available in their offices are more inclined to utilize it routinely. When comparing the perceived CBCT radiation dose versus 2D radiographs, the clinicians who believe radiation of CBCT is lower tend to have CBCT machine in their offices more often, but this was not statistically significant.

The mean age of the participants in our study was 48.8 years with relatively equal numbers of female and male participants. We didn't find any significant association between the

use of CBCT scans and either age or gender of the participants. This is similar to the results of the multi-country study by Caiado et al.

Regarding patient-related factors, 11.8% of respondents consider a young age to be a limiting factor when ordering a CBCT scan. Additionally, 13% of respondents reported that insurance coverage is one of the factors influencing their decision to use CBCT scans.

Cost was the fourth most commonly cited factor preventing orthodontists from prescribing CBCT scans. A statistically significant relationship was found between the use of CBCT scans and cost as a factor that inhibits practitioners from prescribing them. It is unclear if the respondents consider "cost" as a factor that applies to them, or to the patient. In either case, cost was reported as a significant barrier preventing practitioners from utilizing CBCT scans.

Among the orthodontists who participated in our survey, 63.4% reported that they do not follow any specific guidelines when exercising clinical judgment regarding the use of CBCT scans. Since the introduction of CBCT scans in dentistry, several guidelines have been established to govern their use. For instance, in the United States, certain states have developed specific guidelines for CBCT usage, while others lack such regulations. One of the most widely adopted guidelines among academic institutions is SEDENTEXCT. In a study by Caiado et al., it was found that 80% of U.S. orthodontists do not adhere to established guidelines for prescribing CBCT scans.(16) Our finding indicates an improvement in the use of guidelines; however, it remains unclear how the adoption of these guidelines influences the decision-making process of orthodontists.

In the current study, the continuing education programs (46%) were the primary source of training on CBCT radiation safety followed by graduate programs (44.7%) and CBCT

manufacturers (31.7%). Caiado et al reported only 27.2% of US orthodontist indicated that they had previous training on cone beam CT scans(16), however, the training mentioned in their study is on the use of cone beam CT scans and does not focus on the training for radiation safety, which is the question asked in our survey.

A CBCT scan that encompasses the same region as a lateral cephalometric and panoramic radiograph includes areas that may be unfamiliar to dentists. Previous studies have indicated that the prevalence of incidental findings ranges from 24.6% to 94.3%.(19) This underscores the importance of conducting a thorough review of CBCT scans. However, only approximately one-third of respondents reported that they consistently or frequently perform a comprehensive review of these scans, while 50% indicated that they rarely or never conduct a full review. Furthermore, only one-quarter of the respondents stated that they consistently or frequently have an oral radiologist evaluate the scans, while one-third reported that they never involve a radiologist in the review of CBCT scans.

Our survey found that nearly half of the orthodontists utilize a smaller field of view to reduce radiation exposure. In contrast, other techniques—such as reducing exposure settings (38.5%), adjusting the path of rotation, and utilizing less basis images (7.5%)—were less commonly employed to mitigate radiation dose to patients. The group that used reduced exposure settings to lower radiation dose also perceived the radiation dose of the CBCT scan to be higher than that of 2D radiographs. Palomo et al reported a radiation dose reduction of about 62% by reducing the kVp from 120 to 100. (20) Interestingly, one-quarter of orthodontists did not report using any methods to reduce radiation.

Regarding our second survey, the response rate was unfortunately low, with only 15 out of 69 programs providing responses. Similar to the findings of Guberman et al., respondents

reported that their residents or graduate students have access to CBCT scans either in a separate clinic or within the orthodontic clinic itself.(17) Despite working in an academic environment, 46.7% of respondents indicated that they do not follow any established guidelines for CBCT usage. The lack of adherence to guidelines in orthodontic programs is concerning, particularly since graduate students are expected to learn about radiation safety protocols during their training. Our study revealed that only 5 programs (38.5%) offer more than 3 hours of training on radiation safety, while 2 programs (15.4%) reported no training on CBCT radiation safety. Furthermore, 69% of program directors indicated that they employ at least one method, such as utilizing a smaller FOV, adjusting exposure settings, or other strategies, to minimize radiation exposure to patients.

This study is one of the few to examine orthodontists' awareness of radiation concerning cone beam CT scans. However, it has several limitations. The most significant is that the study was based on a survey. One limitation which is inherently associated with a survey is the potential for differences between respondents who chose to participate and those who did not. Surveys are also susceptible to response bias, as respondents may provide socially desirable answers or choose not to respond to questions they feel may reflect poorly on their knowledge. It is therefore difficult to determine whether the respondents are truly representative of the broader population of orthodontists. Additionally, the response rate from the AAO Partners in Research program was low. As a result, we expanded our outreach by utilizing other platforms, such as Facebook groups and the Angle Society, to distribute the survey.

CONCLUSIONS

Nearly half of the respondents in this survey of orthodontists practicing in the United States routinely take CBCT scans, have a CBCT in their office, and incorrectly believe that CBCT scans have equal or lower radiation than a combination of the traditional 2D radiographs (panoramic plus cephalometric radiograph). Considering the high use of CBCT scans, most orthodontists don't evaluate them for incidental findings.

The belief of low radiation dose of CBCT is associated with higher use of CBCT which is also correlated with greater availability of CBCT equipment in the clinicians' office.

The lack of clinicians' knowledge of radiation exposure, as well as their reported limited training in CBCT use suggest that there is a pressing need for enhanced education regarding CBCT radiation safety.

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APPENDICES

APPENDIX 1: Survey #1 (Non- AAO Format)

Dear participants,

Thank you for agreeing to participate in my project. The title of my research is " Orthodontists' awareness of the radiation dose of cone beam CT scans (CBCT) in orthodontics and its influence on the use of CBCT". The survey contains questions about CBCT scans and their radiation dosage. Some demographic information about you will also be collected in the survey. Human subjects' approval was obtained from the UW Institutional Review Board. The following questionnaire will take approximately 5-7 minutes to complete. There is no compensation for responding nor is there any known risk or benefit. All participant responses will be anonymous and no identifiable information is collected. Participation is strictly voluntary, and you may refuse to participate at any time. Your decision to participate will not affect your relationship to the UW or AAO. If you choose to participate in this project, please answer all questions as honestly as possible. To protect your identity as a research subject, no identifiable information will be collected, the research data will not be stored with your name, and we will not share your information with anyone. In any publication about this research, your name or other private information will not be used.

If you need more information or have any questions, please don't hesitate to contact me, Niloufar Amintavakoli, via my email address na07@uw.edu.

Thank you for your time and consideration,

Niloufar Amintavakoli

I confirm that I have carefully read the invitation email, and voluntarily agree to participate in the survey.

- o Yes
- o No

I confirm that I am an orthodontist currently practicing in the United States.

- o Yes
- o No

Survey (only accessible if the answer in the previous two questions is yes)

Question 1:

How often do you use cone beam CT (CBCT) scans in your practice?

- Often
- Sometimes
- Rarely
- Never

Question 2:

For which of the following reasons have you prescribed CBCT scans? (Select all that apply)

- Diagnostic imaging for treatment planning
  - Every case
  - Selected cases
- For progress evaluation
  - Every case
  - Selected cases
- For final evaluation
  - Every case
  - Selected cases
- Other (please describe: _____)
- None

<u>If the answer is option 2 (selected cases), the next question will be:</u>

For which of the following reasons do you use CBCT scans for diagnostic imaging? (Select all that apply)

- Pre-surgical evaluation
- Assessment of impacted teeth
- Airway evaluation
- Asymmetry assessment
- Others (please describe: _____)

Question 3:

How often do you acquire CBCT scans in order to reconstruct panoramic and lateral cephalometric images?

- Always
- Often
- Sometimes
- Rarely
- Never

Question 4:

How often have you completed a full evaluation of the CBCT scan for incidental radiographic findings?

- Always
- Often
- Sometimes
- Rarely
- Never

Question 5:

How often does an oral radiologist review and/or provide reports for your CBCT scans?

- Always
- Often
- Sometimes
- Never
- Others

Question 6:

Which of the following, if any, has prevented you from prescribing a CBCT scan? (Select all that apply)

- Cost
- A lack of access to a CBCT machine in my office
- The patient's insurance did not cover the CBCT
- Concerns about radiation dose
- A CBCT scan would not provide additional information than existing radiographs
- The patient was a child or adolescent
- The patient was an adult
- I have never been prevented from prescribing a CBCT
- Other (please describe: _____)

Question 7:

Which of the following guidelines do you follow when writing CBCT prescriptions? (select all that apply)

- American Academy of Oral and Maxillofacial Radiology position statement

- SEDENTEXCT principles (From the European Academy of Dentomaxillofacial Radiology)
- State or federal guidelines
- Other (please describe: _____)
- I do not use specific guidelines when writing CBCT prescriptions

Question 8:

Which of the following types of radiographic machines do you use in your office (select all that apply)?

- 2D Panoramic machine
- 2D cephalometric machine
- CBCT machine
- Multifunctional machine (CBCT, Panoramic and cephalometric machines)
- Other (please describe: _____)
- None of the above

If the choices 3 or 4 selected

Please provide the name of your CBCT machine

Question 9:

Which of the following best describes your access to a CBCT machine?

- I have a CBCT machine in my office.
- I refer to an office or facility other than my practice that has a CBCT machine.
- I don't have access to a CBCT machine in my office or other providers' offices.
- Others (please describe: _____)

Question 10:

Compared to the radiation dose provided by a 2-D panoramic radiograph plus a 2-D cephalometric radiograph, which of the following statements do you feel is most accurate regarding the radiation dose provided by a CBCT?

- A CBCT scan provides a lower radiation dose than the combined 2-D radiographs.
- A CBCT scan provides an equal radiation dose to that of the combined 2-D radiographs.
- A CBCT scan provides a higher radiation dose than the combined 2-D radiographs.

Question 11:

In what of the following ways do you reduce your patients' radiation exposure? (select all that apply)?

- Using a smaller size of field of view
- Reducing exposure settings (mAs, kVP)
- Reducing path of rotation (path of trajectory) (e.g., reducing 360-degree rotation exposure to 180-degree rotation exposure) and number of basis images
- I do not have control over changing the exposure settings.
- Other (please describe: _____)

Question 12:

How often did you use CBCT scans during your orthodontic training?

- Never
- Occasionally, for specific cases
- Routinely (for more than 75% of my patients)
- For all of my patients (100% of my patients)
- Other (please describe: _____)

Question 13:

What was your primary source of training on **radiation safety** of CBCT scans? (select all that apply)

- Orthodontic graduate program
- Continuing education course taught by an oral radiologist, orthodontist, or other subject matter expert
- Training or information provided by a CBCT manufacturer
- Other (please describe: _____)
- I have not received training on the radiation safety of CBCT scans

Question 14:

How long ago did you graduate from your orthodontic training program?

- Within the last year
- 1-5 years ago
- 6-10 years ago
- 11-15 years ago
- More than 15 years ago

Question 15:

From which orthodontic training program did you graduate?

Question 16:

Which of the following best describes your gender?

- Female
- Male
- Transgender
- Non-binary/non-conforming
- Prefer not to respond
- Prefer to self-describe: _____

Question 17:

What is your age in years?

Question 18:

Which of the following represents you better?

- American Indian or Alaska Native
- Asian
- African American
- Native Hawaiian or Other Pacific Islander
- White
- Other
- Prefer not to respond

Question 19:

What is your ethnicity?

- Hispanic or Latino
- Not Hispanic or Latino
- Prefer not to respond

APPENDIX 2: Survey #1 (AAO Format)
Dear participants,

Thank you for agreeing to participate in my project. The title of my research is " Orthodontists' awareness of the radiation dose of cone beam CT scans (CBCT) in orthodontics and its influence on the use of CBCT."The survey contains questions about CBCT scans and their radiation dosage. Some demographic information about you will also be collected in the survey. Human subjects' approval was obtained from the UW Institutional Review Board. The following questionnaire will take approximately 5-7 minutes to complete. There is no compensation for responding nor is there any known risk or benefit. All participant responses will be anonymous and no identifiable information is collected. Participation is strictly voluntary, and you may refuse to participate at any time. Your decision to participate will not affect your relationship to the UW or AAO. If you choose to participate in this project, please answer all questions as honestly as possible. To protect your identity as a research subject, no identifiable information will be collected, the research data will not be stored with your name, and we will not share your information with anyone. In any publication about this research, your name or other private information will not be used.

If you need more information or have any questions, please don't hesitate to contact me, Niloufar Amintavakoli, via my email address na07@uw.edu.

Thank you for your time and consideration,

Niloufar Amintavakoli

I confirm that I have carefully read the invitation email, and voluntarily agree to participate in the survey.

- o Yes
- o No

I confirm that I am an orthodontist currently practicing in the United States.

- o Yes
- o No

Survey (only accessible if the answer in the previous two questions is yes)

Question 1:

How often do you use cone beam CT (CBCT) scans in your practice?

- Often
- Sometimes
- Rarely
- Never

Question 2:

For which of the following reasons have you prescribed CBCT scans? (Select all that apply)

- Diagnostic imaging for treatment planning
  - Every case
  - Selected cases
- For progress evaluation
  - Every case
  - Selected cases
- For final evaluation
  - Every case
  - Selected cases
- Other (please describe: _____)
- None

<u>If the answer is option 2 (selected cases), the next question will be:</u>

For which of the following reasons do you use CBCT scans for diagnostic imaging? (Select all that apply)

- Pre-surgical evaluation
- Assessment of impacted teeth
- Airway evaluation
- Asymmetry assessment
- Others (please describe: _____)

Question 3:

How often do you acquire CBCT scans in order to reconstruct panoramic and lateral cephalometric images?

- Always
- Often
- Sometimes
- Rarely
- Never

Question 4:

How often have you completed a full evaluation of the CBCT scan for incidental radiographic findings?

- Always
- Often
- Sometimes
- Rarely
- Never

Question 5:

How often does an oral radiologist review and/or provide reports for your CBCT scans?

- Always
- Often
- Sometimes
- Never
- Others

Question 6:

Which of the following, if any, has prevented you from prescribing a CBCT scan? (Select all that apply)

- Cost
- A lack of access to a CBCT machine in my office
- The patient's insurance did not cover the CBCT
- Concerns about radiation dose
- A CBCT scan would not provide additional information than existing radiographs
- The patient was a child or adolescent
- The patient was an adult
- I have never been prevented from prescribing a CBCT
- Other (please describe: _____)

Question 7:

Which of the following guidelines do you follow when writing CBCT prescriptions? (select all that apply)

- American Academy of Oral and Maxillofacial Radiology position statement
- SEDENTEXCT principles (From the European Academy of Dentomaxillofacial Radiology)

- State or federal guidelines
- Other (please describe: _____)
- I do not use specific guidelines when writing CBCT prescriptions

Question 8:

Which of the following types of radiographic machines do you use in your office (select all that apply)?

- 2D Panoramic machine
- 2D cephalometric machine
- CBCT machine
- Multifunctional machine (CBCT, Panoramic and cephalometric machines)
- Other (please describe: _____)
- None of the above

If the choices 3 or 4 selected

Please provide the name of your CBCT machine

Question 9:

Which of the following best describes your access to a CBCT machine?

- I have a CBCT machine in my office.
- I refer to an office or facility other than my practice that has a CBCT machine.
- I don't have access to a CBCT machine in my office or other providers' offices.
- Others (please describe: _____)

Question 10:

In my professional opinion, a CBCT scan generally provides a **lower** radiation dose than the combined panoramic image and lateral ceph.?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Question 11:

In my professional opinion, a CBCT scan generally provides a **higher** radiation dose than the combined panoramic image and lateral ceph.?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Question 12:

In my professional opinion, a CBCT scan generally provides radiation dose **equal to** the combined panoramic image and lateral ceph.?

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Question 13:

In what of the following ways do you reduce your patients' radiation exposure? (select all that apply)?

- Using a smaller size of field of view
- Reducing exposure settings (mAs, kVP)
- Reducing path of rotation (path of trajectory) (e.g., reducing 360-degree rotation exposure to 180-degree rotation exposure) and number of basis images
- I do not have control over changing the exposure settings.
- Other (please describe: _____)

Question 14:

How often did you use CBCT scans during your orthodontic training?

- Never
- Occasionally, for specific cases

- Routinely (for more than 75% of my patients)
- For all of my patients (100% of my patients)
- Other (please describe: _____)

Question 15:

What was your primary source of training on **radiation safety** of CBCT scans? (select all that apply)

- Orthodontic graduate program
- Continuing education course taught by an oral radiologist, orthodontist, or other subject matter expert
- Training or information provided by a CBCT manufacturer
- Other (please describe: _____)
- I have not received training on the radiation safety of CBCT scans

Question 16:

How long ago did you graduate from your orthodontic training program?

- Within the last year
- 1-5 years ago
- 6-10 years ago
- 11-15 years ago
- More than 15 years ago

Question 17:

From which orthodontic training program did you graduate?

Question 18:

Which of the following best describes your gender?

- Female
- Male
- Transgender
- Non-binary/non-conforming
- Prefer not to respond
- Prefer to self-describe: _____

Question 19:

What is your age in years?

Question 20:

Which of the following represents you better?

- American Indian or Alaska Native
- Asian
- African American
- Native Hawaiian or Other Pacific Islander
- White
- Other
- Prefer not to respond

Question 21:

What is your ethnicity?

- Hispanic or Latino
- Not Hispanic or Latino
- Prefer not to respond

APPENDIX 3: Survey #2

Dear Program Directors,

Thank you for agreeing to participate in my project. The title of my research is " Orthodontists' awareness of the radiation dose of cone beam CT scans (CBCT) in orthodontics and its influence on the use of CBCT."The survey contains questions about CBCT scans and their radiation dosage. Some demographic information about you will also be collected in the survey. Human subjects' approval was obtained from the UW Institutional Review Board. The following questionnaire will take approximately 5-7 minutes to complete. There is no compensation for responding nor is there any known risk or benefit. All participant responses will be anonymous and no identifiable information is collected. Participation is strictly voluntary, and you may refuse to participate at any time. Your decision to participate will not affect your relationship to the UW or AAO. If you choose to participate in this project, please answer all questions as honestly as possible. To protect your identity as a research subject, no identifiable information will be collected, the research data will not be stored with your name, and we will not share your information with anyone. In any publication about this research, your name or other private

information will not be used. If you need more information or have any questions, please don't hesitate to contact me, Niloufar Amintavakoli, via my email address na07@uw.edu.

Thank you for your time and consideration,

Niloufar Amintavakoli

I confirm that I have carefully read the invitation email, and voluntarily agree to participate in the survey.

- Yes
- No

I confirm that I am a director of an orthodontic post-graduate program in the United States.

- Yes
- No

Question 1

What kind of access do your orthodontic residents/ graduate students have to a cone beam CT (CBCT) machine?

- There is a CBCT machine in the orthodontic clinic where the residents/ graduate students train.
- We refer patients to another clinic (e.g., oral radiology) that has a CBCT machine.
- We don't have access to a CBCT machine at our dental school.
- Other (please describe: _____)

Question 2

How often do your residents/ graduate students use CBCT?

- Never
- Occasionally, for specific cases
- Routinely (for more than 75% of their patients)
- For all of their patients (100% of their patients)
- Other (please describe: _____)

Question 3

For which of the following steps do your residents/ graduate students prescribe CBCT scans (Select all that apply)?

- Diagnostic imaging for treatment planning
    - Every case
    - Selected cases
- For progress evaluation
    - Every case
    - Selected cases
- For final evaluation
    - Every case
    - Selected cases
- Other (please describe: _____)
- None

Question 4

Does your clinic have specific guidelines for prescribing CBCT scans?

- Yes
- No

<u>If the answer to Question 4 is Yes, question 5 will be asked.</u>

Question 5

Based on the guidelines used in your clinic, for which of the following reasons do your residents/ graduate students use CBCT scans for diagnostic imaging? (select all that apply)

- Evaluation of impacted teeth
- Orthognathic surgery
- Airway evaluations
- Evaluation of asymmetry
- TAD placement
- Other (please describe: _____)

Question 6

If you have specific guidelines for CBCT prescription, what are those guidelines based on?

- American Academy of Oral and Maxillofacial Radiology and American Association of Orthodontics position statement

- SEDENTEXCT principles (From the European Academy of Dentomaxillofacial Radiology)
- State or Federal guidelines
- It is based on clinical judgement of faculty.
- Our clinic doesn't have guidelines on using CBCT scans because we take CBCT scans on every patient.
- Other (please describe: _____)

Question 7

How many hours of radiation safety training do your orthodontic residents/ graduate students receive during their training?

- None
- 1-2 hours
- 3-5 hours
- 6-8 hours
- More than 8 hours

Question 8

How many hours of training in reading CBCT scans do your orthodontic residents/ graduate students receive during their training?

- None
- 1-2 hours
- 3-5 hours
- 6-8 hours
- More than 8 hours

Question 9

Do you and /or residents/graduate students in your program make adjustments to reduce the radiation dose to the patient when prescribing CBCT?

- Yes
- No

If the answer to Question 9 is Yes, question 10 will be asked.

Question 10

From the following in what ways do you and/or residents/graduate students in your program reduce the radiation to your patients? (select all that apply)?

- Using smaller size of field of view
- Reducing exposure settings (mAs, kVP)
- Reducing path of rotation (path of trajectory) (e.g., reducing 360-degree rotation exposure to 180-degree rotation exposure) and number of basis images
- Other (please describe: _____)

Question 11

How often do your orthodontics residents/graduate students acquire CBCT scans in order to reconstruct panoramic and lateral cephalometric images?

- Often
- Sometimes
- Rarely
- Never

APPENDIX 4: Tables

Table 8:CBCT perceived radiation dose collapsed into 3 categories

CBCT radiation	**N = 118**
CBCT radiation lower, n (%)	
Strongly disagree/disagree	61 (51.7)
Neither agree nor disagree	39 (33.1)
Strongly agree/agree	18 (15.3)
CBCT radiation higher, n (%)	
Strongly disagree/disagree	17 (14.4)
Neither agree nor disagree	34 (28.8)
Strongly agree/agree	67 (56.8)
CBCT radiation equal, n (%)	
Strongly disagree/disagree	61 (52.1)
Neither agree nor disagree	39 (33.3)
Strongly agree/agree	17 (14.5)
Unknown	1

Table 9:Agreement between responses to higher and lower radiation

	CBCT radiation higher		
	Strongly disagree/disagree	Neither agree nor disagree	Strongly agree/agree
CBCT radiation lower, n (%)			
Strongly disagree/disagree	1 (0.8%)	1 (0.8%)	59 (50.0%)
Neither agree nor disagree	1 (0.8%)	32 (27.1%)	6 (5.1%)
Strongly agree/agree	15 (12.7%)	1 (0.8%)	2 (1.7%)

The percentage agreement is 50.0% + 27.1% + 12.7% = 89.8%

Table 10:Non-AAO formatted perceived radiation question

CBCT radiation	**N = 43**	**95% CI**[1]
Q15_nonaao, n (%)		
A CBCT scan provides a higher radiation dose than the combined 2-D radiographs.	24 (55.8)	40%, 71%
A CBCT scan provides a lower radiation dose than the combined 2-D radiographs.	10 (23.3)	12%, 39%
A CBCT scan provides an equal radiation dose to that of the combined 2-D radiographs.	9 (20.9)	11%, 36%

[1]CI = Confidence Interval