CBCT Use in Orthodontic Residency Programs in USA

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CBCT Use in Orthodontic Residency Programs in USA

Su Min Han, D.M.D.

Thesis submitted
to the School of Dentistry
at West Virginia University
in partial fulfillment of the requirements for the degree of

Master of Science in
Orthodontics

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ABSTRACT
CBCT Use in Orthodontic Residency Programs in USA
Su Min Han, D.M.D.

Background and Objectives:
Cone beam computed tomography (CBCT) scans in dentistry have been up and coming forms of x-ray technology that allows cross-sectional images to form a comprehensive 3-dimensional representation of the mouth. While the typical use for CBCT imaging is reported to be for implant dentistry, there are many contexts in which it is indicated in orthodontics.

There are various schools of thought regarding when CBCT is indicated for specific diagnosis of problems or general use in the collection of initial, progress and post-treatment orthodontic records. There are programs that follow the Radiology guidelines for taking CBCT scans and others that prefer the use of 2D panoramic and lateral cephalogram for initial diagnostic records.

The purpose of this study is to survey how post-graduate orthodontic graduate programs across the United States are utilizing CBCT scans for initial, progress and post-treatment records. The null hypothesis is that not all orthodontic residency programs in North America are utilizing CBCT scans for initial, progress and post-treatment records.

Experimental Design and Methods (Survey):
An electronic survey (via Qualtrics) was emailed to 58 orthodontic residency programs across America. Contact information was obtained from the AAO (American Association of Orthodontists) member directory. Responses were divided into western and eastern states and analyzed for any patterns or trends.

Results: A total of 36 out of 58 orthodontic residency program directors or chairmen completed the survey (62.07%). The large majority of programs have access to an in-house CBCT machine. Only a small handful of programs are utilizing CBCT scans for regular use in initial, progress, and final records. Half of the surveyed American orthodontic residency programs extract 2D images from 3D scans. Western states are slightly more likely to have access to in-house CBCT machines than eastern states, but both regions each showed that the large majorities have access.

Conclusions: In this study, trends of access to, utilization of, and charging of CBCT scans were observed in American orthodontic residency programs. While many recent studies consistently support the notion that 3D CBCT imaging is better than conventional 2D imaging, there seems to be a disconnect with what is clinically being done in reality.
Dedication

This paper is dedicated to the love of my life and husband, James.
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Dr. Ngan – Thank you
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Jun Xiang – Thank you
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CHAPTER 1: INTRODUCTION

Background and Significance

Cone beam computed tomography (CBCT) development has led to a variety of uses in fields all across dentistry. Root canals and apical lesions can be better visualized for endodontists. CBCT is also great for evaluating bone width and height and positioning for implants for general dentists, oral surgeons, and periodontists. Orthodontists can benefit from CBCT because it helps analyze root resorption, bony recession, and specific 3-dimensional positions of any impacted teeth. Many orthodontists who are able to afford having an in-house CBCT machine may be moving away from taking 2D lateral cephalometric and panoramic x-rays as these images can be extracted from one CBCT scan.

Statement of Problem

CBCT currently has limited use in orthodontics for the diagnosis and treatment planning of specific localized issues but not so much for daily use in initial, progress, and final records. With the increased risk of radiation exposure and questionable improvement in case diagnosis compared to the conventional 2D radiographs, CBCT use on a regular basis is highly debatable.

Purpose of the Study

The purpose of the study is to evaluate the current uses of CBCT in orthodontic residency programs across the United States of America and assess how this can shed a light on future implications of CBCT use.
Null Hypothesis

1. Orthodontic residency programs in the United States do not take CBCT scans for initial records.
2. Orthodontic residency programs in the United States do not take CBCT scans for progress and post-treatment records.
3. Orthodontic residency programs in the United States do not extract 2D pan and lateral cephalogram from 3D CBCT scans for initial diagnostic records.
4. There is no difference in the use of CBCT scans between the orthodontic programs in the Western and Eastern states of USA.

Alternative Hypothesis

1. Orthodontic residency programs in the United States do take CBCT scans for initial records.
2. Orthodontic residency programs in the United States do take CBCT scans for progress and post-treatment records.
3. Orthodontic residency programs in the United States do extract 2D pan and lateral cephalogram from 3D CBCT scans for initial diagnostic records.
4. There is a difference in the use of CBCT scans between the orthodontic programs in the Western and Eastern states of USA.

Assumptions

1. Survey participants will answer questions honestly
2. The survey questions are reliable
**Limitations**

1. Other factors not listed in the survey may influence respondents’ opinions of or participation in the study
2. Some respondents’ ability to participate in the survey may be affected due to lack of computer literacy

**Delimitations**

1. The study is limited to currently active program directors or department chairs of orthodontic residency programs in USA.
2. The study is limited to program directors or department chairs with an active email address listed in the American Association of Orthodontists member directory

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**CHAPTER 2: REVIEW OF THE LITERATURE**

**CBCT Compared to Conventional Radiographs**

Cone beam computed tomography uses a cone beam shaped x-ray tube to produce a single 360 degrees rotation of scanning, like a panoramic x-ray, but collects many 2D images to combine into a 3D volumetric image set. Therefore, there are likely to be fewer problems with anatomic superimposition, magnification, and distortion. However, Silva et al. found that CBCT has a higher effective dose compared to conventional 2D radiographs. Based off the ALARA
principle to keep radiation doses to patients As Low As Reasonably Achievable, “the use of a CBCT image is not recommended routinely in orthodontic practice”\textsuperscript{11}.

Some disadvantages of the conventional 2D lateral cephalometric radiograph are patient positioning errors, differentially magnified bilateral structures, superimposed craniofacial structures, asymmetry in craniofacial syndromic patients, and poor accuracy and precision of landmark reproduction\textsuperscript{5}. Especially when it comes to bilateral structures, they often show double images, with the structure farthest from the x-ray source showing greater magnification. In this case, the operator will often select the landmark that is the average of the two structures, thus resulting in room for error. However, the advantages of conventional radiographs keeps practitioners preferring it over CBCT, such as decreased cost of the machine, decreased radiation exposure, ease of use, and familiarity and comfortability.

\textit{Value of Extracting 2D Images from CBCT Scans}

When comparing the precision of cephalometric landmark identification, Ludlow et al.\textsuperscript{5} found that 3-dimensional (3D) CBCT scans were more precise than conventional 2D radiographs, “even when using traditional 2D definitions for these landmarks.” Thirteen out of 23 landmarks were more precisely identified (statistically significant) than conventional cephalometric radiographs. Bilateral landmarks of condylion, gonion, and orbitale were notably more precise and less variable to a statistically significant extent. The study discusses that this increased precision of these landmarks explains the notion that “increased variability is a function of structure noise from the superimposition of bilateral structures in conventional cephalograms.”\textsuperscript{5} When bilateral structures overlap in a conventional 2D radiograph, the operator
will choose the middle point between the two outlines and thus cause landmark localization errors.

When comparing conventional 2D cephalometric radiographs with 2D cephalometric radiographs extracted from 3D CBCT scans, they have been shown to be comparable in terms of measurements taken on both mediums\textsuperscript{4}. Both CBCT scans and conventional 2D cephalometric x-rays were taken on forty dry human skulls. The benefit of this study is that both radiographs are seen without soft tissue distortion so the bony landmarks can be accurately identified. After the 2D cephalometric images were extracted from CBCT scans, both radiographs were digitally traced and analyzed for 15 conventional hard tissue landmarks and 14 measurements (10 angular and 4 linear). The results showed that there was no difference of clinical relevance between measurements taken on conventional 2D cephalometric radiographs and measurements taken on 2D cephalometric radiographs extracted from 3D CBCT scans. However, the cephalometric radiographs extracted from CBCT scans showed better reproducibility than that of conventional cephalometric radiographs. Van Vlijmen et al.\textsuperscript{4} also states that “the contrast and transparency of the 2 types of cephalometric radiographs are not the same… [so] it can be hard to identify the structures and landmarks needed for a proper cephalometric analysis in CBCT-constructed cephalometric radiographs.”

Variations in Voxel

Voxels are what compose volume. Each voxel represents the x-ray density of the structure in terms of brightness or gray scale color\textsuperscript{6}. Decreasing the voxel size/resolution results in a decrease in image quality, increase in noise/artifacts/scatter, and increase radiation exposure
to patients, decrease in the detail of anatomy, and decrease the effect of partial volume averaging$^6,7$.

According to Molen et al., “most common voxel sizes used for orthodontic scans are 0.3 and 0.4mm, which are not adequate to properly visualize bone”$^7$. Decreasing the voxel size and thus decreasing the effect of partial volume averaging can improve this. Because a voxel can only display 1 gray value at a time, a voxel that is larger than the object being measured will display an average of the surrounding densities. For example, “if a voxel represents an area of 75% lucent soft tissue and 25% opaque cortical bone, the voxel will appear more lucent than opaque”$^7$. This phenomenon is called partial volume averaging. Therefore, if small buccal bone measurements must be made, the voxel size can be decreased, which also decreases the partial volume averaging affect, but at the cost of increased radiation exposure to the patient.

When comparing the accuracy of linear measurements from CBCT scans of different voxel sizes, Damstra et al.$^6$ found no significant difference. They studied 10 dry skull mandibles and scanned each with 0.4 and 0.25 voxel sizes. The measurements from these scans were compared to “anatomic truth” values, which are 6 digital caliper measurements collected directly from the dry mandibles. The results showed that “the measurements on 3-dimensional surface models of 0.25 and 0.40 voxel size data sets… are accurate compared with direct caliper measurements” and “an increased voxel resolution did not result in greater accuracy.”$^6$.

Field of View Considerations

Full size FOV such as 17cm x 17cm cover “TMJ articulations and anatomic landmarks necessary for quantitative cephalometric and/or airway assessment”$^{13}$ and can be used for TMJ disorders, full head diagnosis, and skeletal asymmetries. Medium size FOV such as 17cm x
10cm includes the “dentition of at least one arch up to both dental arches”\textsuperscript{13} and can be used for bony evaluation and closer views at pathology. Small size FOV such as 10cm x 10cm includes “a few teeth, a quadrant, and up to two dental arches”\textsuperscript{13} and can be used for detailed diagnosis such as apical root evaluation and determining pulp canal locations.

Scatter/noise levels increase when field of view (FOV) increases. “Smaller FOVs may decrease noise from scatter… [but] as voxels decrease in size, they become more sensitive to noise”\textsuperscript{7}. This is why “large FOVs, such as those frequently used in orthodontic scans, are contraindicated for clinicians wishing to evaluate buccal bone thickness”\textsuperscript{7}.

\textbf{CHAPTER 3: MATERIALS AND METHODS}

\textit{IRB Approval}

Approval for exempt human subject research was obtained from West Virginia University Institutional Review Board prior to the start of this study (See Appendix A).

\textit{Survey Design}

The survey was designed to be a cross-sectional study to evaluate how American orthodontic residency programs are utilizing CBCT machines and to discover if any patterns exist when comparing western and eastern states. The survey consisted of 15 questions, with 14 being multiple choice and 1 having a pull-down list of answer choices. There was one question that allowed an “other” option that prompts the respondent to write a short answer if this option is chosen.
Survey Distribution

Program directors and/or chairmen of accredited orthodontic residency programs in USA were emailed a letter requesting participation in a survey. Email information of potential respondents was obtained from the American Association of Orthodontists directory. Out of 65 American orthodontic residency programs, 7 email addresses were not correct so the final survey distribution number was 58 potential participants. The email contained a cover letter describing the purpose of the study and potential legal uses of information provided, as well as a link directing the recipient to the survey platform, Qualtrics, where they can fill out the survey. Three follow up requests were emailed, each in 3-week intervals, to candidates who did not respond to the previous survey requests. The survey began collecting responses in November 2021 and stopped collecting responses in January 2022.

Statistical Analysis

All tests in this current study were conducted using SAS (version 9.4, 2013, SAS Institute Inc. Cary, NC). The FREQ procedure was done on all survey questions to determine the frequency and percentage that an answer choice was chosen. Respondents were divided into western and eastern states, with western states ranging from the coast of the Pacific Ocean to include states bordering the Mississippi River. All states east of the states bordering the Mississippi River were considered eastern states in this study. Chi-square analysis was performed on the divided regions to determine any comparisons or similarities between them. P-values less than 0.05 were considered to be statistically significant.
CHAPTER 4: RESULTS

Data Collection

Thirty seven orthodontic program directors or program chairmen responded to the survey. One respondent did not complete the survey but emailed responses and thus was excluded from the data analysis. This results in an effective response rate of 36 out of 58 accredited orthodontic residency programs (62.07%).

Respondent Biographical Data

All respondents were residents of the United States of America (100%) (Figure 1). There was one respondent from each of the following states (2.78% each): Alabama, Arizona, Florida, Illinois, Indiana, Michigan, North Carolina, New Jersey, Ohio, South Carolina, Tennessee, Texas, Virginia, Washington, Wisconsin, and West Virginia. There were two respondents from each of the following states (5.56% each): California, Georgia, Louisiana, Maryland, Missouri, and Nevada. There were three respondents from Pennsylvania (8.33%). There were five respondents from New York (13.89%).

Access to In-House CBCT Machine

88.89% of surveyed programs have an in-house CBCT machine.

Western states are more likely to have CBCT machines in-house (90.91 %) than eastern states (88.00%). No statistically significant results were found.
**Brand of CBCT Machine**

In total, the iCAT machine is the most popular, with 30.56% of respondents using it. Second most commonly used is Planmeca and Carestream, both 27.78%.

Western states use iCAT the most (45.45%), then Carestream (27.27%), then Planmeca (18.18%). Eastern states use Planmeca the most (32.00%), then Carestream (28.00%), then iCAT (24.00%). No statistically significant results were found.

**Initial Records**

For initial records, most programs take conventional 2D pan and lateral cephs (77.78%). Seven programs take CBCT only for initial records (19.44%). One program takes full mouth series and 2D lateral ceph for initial records (2.78%).

Western and eastern states both prefer to take conventional 2D radiographs for initial records, with or without CBCT scans as needed. Western states are more likely to take CBCT scans only when collecting initial records (27.27%) than eastern states (16.00%). No statistically significant results were found.

**Extracting 2D Images from 3D CBCT Scans**

When it comes to extracting 2D pan and lateral ceph from 3D CBCT scans, 50% of programs extract and 50% do not extract.

Even within the two separate regions, the likelihood of extracting or not extracting is close to 50/50. 54.55% of western states do not extract and 45.45% of western states do extract. 48.00% of eastern states do not extract and 52.00% of eastern states do extract. No statistically significant results were found.
Fees for Initial Radiographs

If they do extract, 66.67% of programs only charge the one fee for the CBCT scan. 33.33% of programs will charge 2D pan and lateral cephalometric images when extracting these images from CBCT scans.

When extracting 2D images from the 3D CBCT scan, western states 100% of the time will charge just the CBCT scan fee. However, 57.14% of eastern states will charge the CBCT scan fee only and 42.86% of eastern states will charge 2D pan and lateral cephalometric images. No statistically significant results were found.

Progress and Final Records

63.89% of programs do not take CBCT scans for progress and final records. However, 36.11% of programs do.

54.55% of western states do not take CBCT scans for progress and final records but 45.45% do. 68.00% of eastern states do not take CBCT for progress and final records and 32.00% do take them. No statistically significant results were found.

Fees for Progress and Final Records

If they do take CBCT scans for progress and final records, 82.35% of programs will not charge the patient, but 17.65% do charge the patient.

100% of western states do not charge for progress and final CBCT scans and 75% of eastern states do not charge too. 25% of eastern states do charge for progress and final CBCT scans. No statistically significant results were found.
CBCT Fees for Medicaid Patients

11.11% of programs do not see Medicaid patients in the orthodontics department. Out of those who do see Medicaid patients, 61.11% do not charge for CBCT and 27.78% do.

54.55% of western states do not charge, 27.27% do charge, and 18.18% do not see medicaid patients. 64% of eastern states do not charge, 28% do charge, and 8% do not see medicaid patients. No statistically significant results were found.

CBCT Pathology Reading

61.11% of programs refer out for pathology reading of the CBCT volume. 38.89% of programs read the CBCT within the orthodontics department.

45.45% of western states read scans in-house and 54.55% refer out. 36% of eastern states read scans in-house and 64% refer out. No statistically significant results were found.

Fees for CBCT Pathology Reading

Majority of programs do not charge separately to read the CBCT and will incorporate the service into the CBCT scan fee (94.29%). Only 2 programs charge separately for reading the scan (5.71%).

100% of western states and 92% of eastern states incorporate reading charge into CBCT scan fee. None of the western states charge separately for reading but 8% of the eastern states charge separately. No statistically significant results were found.

Field of View
Most of programs use 17cm x 17cm field of view (FOV) when taking CBCT scans for initial records (58.06%). 29.03% of programs use 10cm x 17cm FOV. 12.90% of programs use 10cm x 10cm FOV.

66.67% of western states use 17cm x 17cm, 22.22% use 10cm x 17cm, and 11.11% use 10cm x 10cm. 54.55% of eastern states use 17cm x 17cm, 31.82% use 10cm x 17cm, and 13.64% use 10cm x 10cm. No statistically significant results were found.

**Voxel Size**

The most commonly used voxel size is 0.3mm, with 41.18% of programs using it. Voxel size 0.4mm is used by 20.59% of programs. Voxel size 0.2mm is used by 17.65% of programs. 20.59% of respondents did not know the voxel size of their CBCT machine.

30% of western states use voxel size 0.2mm, 40% use 0.3mm, and 10% use 0.4mm. 20% of western states did not know their voxel size. 12.50% of eastern states use 0.2mm, 41.67% use 0.3mm, and 25% use 0.4mm. 20.83% of eastern states did not know their voxel size. No statistically significant results were found.

**Image Quality 2D vs. 3D**

When it comes to practitioner opinion of the image quality/clarity of extracted images vs. conventional 2D images, only 8.57% of programs felt that the extracted pan and lateral ceph images were better. 45.71% of programs felt conventional 2D pan and lateral ceph x-rays were better. 45.71% of programs felt both images are comparable in quality and clarity.

9.09% of western states feel that extracted offers better image quality. 36.36% of western states feel that conventional 2D image quality is better. 54.55% of western states feel that image
qualities of both are comparably good. 8.33% of eastern states feel that extracted offers better image quality. 50% of eastern states feel that conventional 2D image quality is better. 41.67% of eastern states feel that image qualities of both are comparably good. No statistically significant results were found.

_Radiation Concerns_

85.71% of programs did not have patients who were concerned with excess radiation from CBCT scans. Only 14.29% of programs had patients with radiation concerns.

80% of western states had no patients with CBCT radiation concerns but 20% did. 88% of eastern states had no patients with CBCT radiation concerns but 12% did. No statistically significant results were found.

**CHAPTER 5: DISCUSSION**

_Initial Records_

While most orthodontic residency programs in America have access to an in-house CBCT machine (88.89%), only a handful of programs are taking CBCT scans for initial records (19.44%). Most programs are taking conventional 2D pan and lateral cephs for initial records (77.78%). With majority of patients unconcerned about excess radiation from CBCT scans (85.71%), it is curious that CBCT scans are not taken more regularly.

Current research states however that perhaps patients should not be totally unconcerned about excess radiation risk from CBCT scans. The effective dose for panoramic, lateral
cephalometric, and PA cephalometric radiographs is about 25-35 μSv, whereas a CBCT scan with a large field of view is 68-1073 μSv\(^5\). This excess radiation dose is “equivalent to a few days to several weeks of average per capita background dose in the United States”\(^5\). Unless the CBCT scan can provide enough benefit (such as better treatment results, treatment time, or treatment cost) to offset the extra radiation risk, it cannot be recommended per Ludlow et al\(^5\).

However, the radiation dose can be changed depending on CBCT machine settings of field of view and voxel size. If the FOV is decreased or the voxel size is increased, the radiation exposure is decreased, but at the expense of a less accurate and lower quality CBCT scan. This lower quality CBCT scan is likely to produce lower quality extracted images as well. Furthermore, if the voxel size were increased, it would increase the influence of partial volume averaging.

**Progress and Final Records**

More programs are taking CBCT scans for progress and final records than initial records (36.11%). This may be due to new findings in the middle of treatment, evaluating progress of an impacted tooth, or assessing post-treatment side effects on bone. However, bony assessment with CBCT is not recommended during active bone turnover and it is unknown how long after debond that these final CBCT records are being taken. “When teeth are being moved orthodontically, the alveolar bone in the direction of the applied force undergoes constant bone turnover… driven by the activity of osteoclasts, which decrease the density of the active bone.” This would cause the buccal bone undergoing bone turnover to appear less clear and more lucent on the CBCT. For this reason, “changes in alveolar bone should be assessed [via CBCT] only after orthodontic treatment and the rematuration of bone… [which] takes 6 to 24 months to fully subside after the
end of tooth movement”\textsuperscript{7}. This does not seem to be a large concern for conventional 2D radiographs as it is commonplace to take progress 2D radiographs during orthodontic treatment but more studies are required.

\textit{Extracting Images from 3D Scans}

When it comes to extracting 2D pan and lateral cephal images from 3D CBCT scans, half of the programs extract and the other half does not. This low extraction rate can be supported by the finding that only a small minority of programs feel that extracted pan and lateral cephal images were better in quality and clarity (8.57\%). The majority of eastern states feel that conventional 2D pan and lateral cephs are better (50\%) and the majority of western states feel that image qualities of both are comparably good (54.55\%).

Contrary to the survey results indicating that most programs do not prefer the image qualities of extracted images, Lamichaine et al. says a lateral image can be extracted from a CBCT scan to “replicate the inherent magnification of a conventional 2D lateral cephalogram with high accuracy” and that the extracted “image can be used in place of a 2D lateral cephalogram for comparison with either normative data or serial records”\textsuperscript{8}. However, De Vos et al. states that while high resolution is a noted benefit of CBCT imaging, “the most important disadvantage of CBCT imaging is the low contrast resolution and limited capability of visualizing the internal soft tissues”\textsuperscript{9}.

\textit{Field of View, Voxel Size}

Most programs chose the largest FOV option provided in the survey, 17cm x 17cm (58.06\%). It appears that the trend is to lean towards the larger field of view.
The majority of both regions prefer to use a 0.3mm voxel size. However, there was a difference in the second most often used voxel size, with western states using 0.2mm and eastern states using 0.4mm.

**Fees Overview**

If 2D images are extracted from CBCT scans, most programs only charge one CBCT scan fee (66.67%). However, a third of the programs will charge for conventional 2D pan and lateral cephalometric images even though these images were extracted from one CBCT scan (33.33%). When broken down into regions, western states are more likely to charge only one CBCT scan fee whereas half of eastern states are likely to charge 2D pan and lateral cephalometric fees for extracted images.

If CBCT scans are taken for progress and final records, most programs do not charge patients any fee (82.35%). Eastern states are more likely to charge for progress and final CBCT scans (25%) than western states (0%).

If it is a Medicaid patient, most programs do not have a code to charge for a CBCT (61.11%). It is unknown how they charge for Medicaid patients or if they avoid prescribing CBCT scans for Medicaid patients altogether. Eastern states (92%) are more likely to see Medicaid patients than western states (81.82%).

Majority of programs do not charge separately to read the CBCT and will incorporate the service into the CBCT scan fee (94.29%). Eastern states are more likely to charge a separate CBCT scan reading fee (8%) than western states (0%).
Clinical Implications

Many recent studies consistently support the notion that CBCT imaging is better than conventional 2D imaging. Lamichaine et al. says that the process of extracting 2D images from 3D CBCT scans can eliminate the need to take a separate lateral cephalometric radiograph, thus “increasing efficiency and reducing ionizing radiation to the patient”8. Van Vlijmen et al. says “the reproducibility of measurements on cephalometric radiographs obtained from CBCT scans was better, compared with the reproducibility of those on conventional cephalometric radiographs”4. Ludlow et al. says that CBCT images “provide generally more precise identification of traditional cephalometric landmarks”5. So if CBCT imaging truly is better as these studies imply, why is it not clinically utilized more often?

One of the leading factors could be due to price considerations. It seems that there is currently a lack of a rigid fee schedule, as evident in the survey results of inconsistent charging of extracted versus non-extracted conventional images and absence of a CBCT charge code for Medicaid patients in more than half the programs surveyed.

Another factor is operator preference, which may be influenced by any of the above-mentioned factors (fee schedule, radiation concerns, image quality considerations) in addition to familiarity of taking and reading conventional 2D radiographs.

Null Hypothesis Testing

1. ACCEPTED: Orthodontic residency programs in the United States do not take CBCT scans for initial records.

2. ACCEPTED: Orthodontic residency programs in the United States do not take CBCT scans for progress and post-treatment records.
3. **REJECTED:** Orthodontic residency programs in the United States do not extract 2D pan and lateral cephalogram from 3D CBCT scans for initial diagnostic records.

4. **REJECTED:** There is no difference in the use of CBCT scans between the orthodontic programs in the Western and Eastern states of USA.

**CHAPTER 6: SUMMARY AND CONCLUSIONS**

In this study, trends of access to, utilization of, and charging of CBCT scans were observed in American orthodontic residency programs. While many recent studies consistently support the notion that 3D CBCT imaging is better than conventional 2D imaging, there seems to be a disconnect with what is clinically being done in reality.

Within the limits of this study, the following can be concluded:

1. The large majority of programs have access to an in-house CBCT machine.
2. Only a small handful of programs are utilizing CBCT scans for regular use in initial, progress, and final records.
3. Half of the surveyed American orthodontic residency programs extract 2D images from 3D scans.
4. Western states are slightly more likely to have access to in-house CBCT machines than eastern states, but both regions each showed that the large majorities have access.

*Limitations*
Limitations of this study include small sample size, low participation, and potentially imperfectly worded survey questions. This study could have been more statistically relevant if the sample size and number of participants were increased. It is difficult to make any general assumptions with a small sample size. The survey questions were not pilot-tested to gauge interpretive range and thus some of the questions may have been worded in a way that incites confusion and incorrect responses.

CHAPTER 7: RECOMMENDATIONS FOR FUTURE RESEARCH

This study can be improved by surveying practicing orthodontists instead of residency programs. Even better, a study can be done surveying both practicing orthodontists and residency programs to compare how they both differ. Additionally, a pilot survey may be useful for future surveys in order to test out questions and ensure there is little to no room for participant interpretation of what questions are asking.
REFERENCES


APPENDIX A – IRB APPROVAL LETTER

West Virginia University
Office of Human Research Protections

Acknowledgement of Exemption

10/18/2021

To: Peter Ngan
From: WVU Office of Research Integrity & Compliance

Protocol Type: Exempt
Submission Type: Initial
Approval Date: 10/18/2021
Expiration Date: 10/17/2026
Funding: N/A

WVU Protocol #: 2109420741
Protocol Title: CBCT in Orthodontic Records

The West Virginia University Institutional Review Board has reviewed your submission of Exempt protocol 2109420741. Additional details regarding the review are below:

- This research study was granted an exemption because the research involves educational tests, survey procedures, interview procedures or observation of public behavior and (i) information obtained is recorded in such a manner that human subjects cannot be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects responses outside the research could not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects financial standing, employability, or reputation [45 CFR 46.101(2)]. All exemptions are only good for three years. If this research extends more than three years beyond the approved date, then the researcher will have to request another exemption. The following documents have been acknowledged for use in this study and are available in the WVU+kc system:

The following documents were reviewed and approved for use as part of this submission. Only the documents listed below may be used in the research. Please access and print the files in the Notes & Attachments section of your approved protocol.

- Data Protection Certificate - Peter Ngan.pdf
- Survey Cover Letter_Letterhead.docx

Protocol #: 2109420741
Phone: 304-293-7073
FWA: 00005078
Fax: 304-293-3098
IORG: 0000194
Email: IRB@mail.wvu.edu
WVU IRB acknowledgement of protocol 2109420741 will expire on 10/17/2026.

1. There is no continuing review option for Exempt studies. If this study is still active after five (5) years and you intend to continue, you will need to resubmit a new protocol for approval no less than three (3) weeks prior to the expiration date in order to ensure compliance.

2. Amendments are not accepted on Exempt studies and are not required as long as there is no increase to risk to participants and changes do not exclude the study from Exempt status.

3. The IRB must be notified if there is an increase in risk to participants or if changes to the study exclude the study from Exempt status. In any of these cases, this protocol must be submitted as a new submission in WVU+kc.

4. Unanticipated, serious adverse events and/or side effect(s) encountered at WVU or an affiliate site that are related to the research must be reported to the WVU IRB within five (5) days using the Notify IRB action in WVU+kc.

5. Any Unanticipated Problem or UPIRTSO or other research related event resulting in new or increased risk of harm to study subjects, occurring at WVU or an affiliate site, must be reported to the WVU IRB within five (5) days using the Notify IRB action in WVU+kc.

6. All research personnel performing tasks related to the research must complete and remain current for the required training as applicable to the protocol reference above.

The WVU Office of Human Research Protections will be glad to provide assistance to you throughout the research process. Please feel free to contact us by phone, at 304.293.7073 or by email at IRB@mail.wvu.edu.

Sincerely,

[Signature]

Jane Channel, BSN, LNCC, CCRC, CCRN, TNCC
Senior IRB Coordinator
APPENDIX B – RAW STATISTICS

*Figure 1: Respondent Location*

<table>
<thead>
<tr>
<th>State</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>AZ</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>CA</td>
<td>2</td>
<td>5.56</td>
</tr>
<tr>
<td>FL</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>GA</td>
<td>2</td>
<td>5.56</td>
</tr>
<tr>
<td>IL</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>IN</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>LA</td>
<td>2</td>
<td>5.56</td>
</tr>
<tr>
<td>MD</td>
<td>2</td>
<td>5.56</td>
</tr>
<tr>
<td>MI</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>MO</td>
<td>2</td>
<td>5.56</td>
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<tr>
<td>NC</td>
<td>1</td>
<td>2.78</td>
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<tr>
<td>NJ</td>
<td>1</td>
<td>2.78</td>
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<tr>
<td>NV</td>
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<td>5.56</td>
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<tr>
<td>NY</td>
<td>5</td>
<td>13.89</td>
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<tr>
<td>OH</td>
<td>1</td>
<td>2.78</td>
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<tr>
<td>PA</td>
<td>3</td>
<td>8.33</td>
</tr>
<tr>
<td>SC</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>TN</td>
<td>1</td>
<td>2.78</td>
</tr>
<tr>
<td>TX</td>
<td>1</td>
<td>2.78</td>
</tr>
</tbody>
</table>
Figure 2: Frequency of In-House CBCT Machine

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>11.11</td>
</tr>
<tr>
<td>Yes</td>
<td>88.89</td>
</tr>
</tbody>
</table>

Figure 3: Frequency of CBCT Machine Brand

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planmeca</td>
<td>27.78</td>
</tr>
<tr>
<td>iCAT</td>
<td>30.56</td>
</tr>
<tr>
<td>Dentsply Sirona</td>
<td>2.78</td>
</tr>
<tr>
<td>Caresteam</td>
<td>27.78</td>
</tr>
<tr>
<td>Other</td>
<td>11.11</td>
</tr>
</tbody>
</table>

Figure 4: Radiographs for Initial Records

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D Pan and Lateral Ceph Only</td>
<td>14</td>
<td>38.89</td>
</tr>
<tr>
<td>CBCT Only</td>
<td>7</td>
<td>19.44</td>
</tr>
<tr>
<td>Full Mouth Series and 2D Lateral Ceph</td>
<td>1</td>
<td>2.78</td>
</tr>
</tbody>
</table>
2D Pan, Lateral Ceph, and CBCT as needed | 14 | 38.89

**Figure 5: Frequency of Extracting from CBCT**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>No</td>
<td>18</td>
</tr>
<tr>
<td>Yes</td>
<td>18</td>
</tr>
</tbody>
</table>

**Figure 6: Charges for CBCT Extraction**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBCT Scan Fee</td>
<td>18</td>
</tr>
<tr>
<td>2D Pan and Lateral Ceph Fees</td>
<td>9</td>
</tr>
</tbody>
</table>

**Figure 7: Frequency of CBCT Scans for Progress and Final Records**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>23</td>
</tr>
<tr>
<td>Yes</td>
<td>13</td>
</tr>
</tbody>
</table>

**Figure 8: Frequency of Progress and Final CBCT Charges**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
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<tr>
<td>No</td>
<td>28</td>
</tr>
<tr>
<td>Yes</td>
<td>6</td>
</tr>
</tbody>
</table>

**Figure 9: Charge CBCT Fee for Medicaid Patients**
<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>22</td>
<td>61.11</td>
</tr>
<tr>
<td>Yes</td>
<td>10</td>
<td>27.78</td>
</tr>
<tr>
<td>Does not see Medicaid patients</td>
<td>4</td>
<td>11.11</td>
</tr>
</tbody>
</table>

*Figure 10: CBCT Read for Pathology*

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthodontist Reads</td>
<td>14</td>
<td>38.89</td>
</tr>
<tr>
<td>Refer Out</td>
<td>22</td>
<td>61.11</td>
</tr>
</tbody>
</table>

*Figure 11: CBCT Reading Charge*

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorporated into CBCT Scan Fee</td>
<td>33</td>
<td>94.29</td>
</tr>
<tr>
<td>Charged Separately for Read</td>
<td>2</td>
<td>5.71</td>
</tr>
</tbody>
</table>

*Figure 12: Field of View for Initial CBCT Scans*

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10cm x 10cm</td>
<td>4</td>
<td>12.90</td>
</tr>
<tr>
<td>10cm x 17 cm</td>
<td>9</td>
<td>29.03</td>
</tr>
<tr>
<td>17cm x 17 cm</td>
<td>18</td>
<td>58.06</td>
</tr>
</tbody>
</table>

*Figure 13: Voxel Size for Initial CBCT Scans*
<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracted Pan and Lateral Ceph are Better</td>
<td>3</td>
<td>8.57</td>
</tr>
<tr>
<td>2D Pan and Lateral Ceph are Better</td>
<td>16</td>
<td>45.71</td>
</tr>
<tr>
<td>Both are Comparable</td>
<td>16</td>
<td>45.71</td>
</tr>
</tbody>
</table>

**Figure 14: Quality/Clarity of CBCT Extracted Images**

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>30</td>
<td>85.71</td>
</tr>
<tr>
<td>Yes</td>
<td>5</td>
<td>14.29</td>
</tr>
</tbody>
</table>

**Figure 15: Patient Radiation Concerns with Initial CBCT Scans**

**RESPONSES ANALYZED BY REGION (EAST VS. WEST)**

<table>
<thead>
<tr>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA</td>
<td>WI</td>
</tr>
<tr>
<td>OR</td>
<td>MI</td>
</tr>
<tr>
<td>ID</td>
<td>IL</td>
</tr>
<tr>
<td>WY</td>
<td>IN</td>
</tr>
<tr>
<td>CA</td>
<td>OH</td>
</tr>
<tr>
<td>NV</td>
<td>MS</td>
</tr>
<tr>
<td>UT</td>
<td>AL</td>
</tr>
<tr>
<td>CO</td>
<td>FL</td>
</tr>
<tr>
<td></td>
<td>-West</td>
</tr>
<tr>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>No</td>
<td>1 (9.09%)</td>
</tr>
<tr>
<td>Yes</td>
<td>10 (90.91%)</td>
</tr>
</tbody>
</table>

*Figure 16: Frequency of In-House CBCT Machine Per Region*

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th></th>
<th>East</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Planmeca</td>
<td>2 (18.18%)</td>
<td></td>
<td>8 (32.00%)</td>
<td></td>
</tr>
<tr>
<td>iCAT</td>
<td>5 (45.45%)</td>
<td></td>
<td>6 (24.00%)</td>
<td></td>
</tr>
<tr>
<td>Dentsply Sirona</td>
<td>0</td>
<td></td>
<td>1 (4.00%)</td>
<td></td>
</tr>
<tr>
<td>Carestream</td>
<td>3 (27.27%)</td>
<td></td>
<td>7 (28.00%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>7 (9.09%)</td>
<td></td>
<td>3 (12.00%)</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 17: CBCT Machine Brand Per Region*
### Figure 18: Initial Radiographs Taken Per Region

<table>
<thead>
<tr>
<th>Procedure</th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D Pan and Lateral Ceph Only</td>
<td>4 (36.36%)</td>
<td>10 (40.00%)</td>
</tr>
<tr>
<td>CBCT Only</td>
<td>3 (27.27%)</td>
<td>4 (16.00%)</td>
</tr>
<tr>
<td>Full Mouth Series and 2D Lateral Ceph</td>
<td>0</td>
<td>1 (4.00%)</td>
</tr>
<tr>
<td>2D Pan, Lateral Ceph, and CBCT as needed</td>
<td>4 (36.36%)</td>
<td>10 (40.00%)</td>
</tr>
</tbody>
</table>

### Figure 19: Frequency of Extraction from CBCT Scans Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>6 (54.55%)</td>
<td>12 (48.00%)</td>
</tr>
<tr>
<td>Yes</td>
<td>5 (45.45%)</td>
<td>13 (52.00%)</td>
</tr>
</tbody>
</table>

### Figure 20: Fees to Extract from CBCT Scans Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBCT Scan Fee</td>
<td>6 (100%)</td>
<td>12 (57.14%)</td>
</tr>
<tr>
<td>2D Pan and Lateral Ceph Fees</td>
<td>0</td>
<td>9 (42.86%)</td>
</tr>
</tbody>
</table>

### Figure 21: Frequency of CBCT Scans for Progress and Final Records Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>6 (54.55%)</td>
<td>17 (68.00%)</td>
</tr>
<tr>
<td>Yes</td>
<td>5 (45.45%)</td>
<td>8 (32.00%)</td>
</tr>
</tbody>
</table>
Figure 22: Frequency of Charges for Progress and Final CBCT Scans Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>10 (100%)</td>
<td>18 (75.00%)</td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>6 (25.00%)</td>
</tr>
</tbody>
</table>

Figure 23: CBCT Charges for Medicaid Patients Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>6 (54.55%)</td>
<td>16 (64.00%)</td>
</tr>
<tr>
<td>Yes</td>
<td>3 (27.27%)</td>
<td>7 (28.00%)</td>
</tr>
<tr>
<td>Does not see Medicaid patients</td>
<td>2 (18.18%)</td>
<td>2 (8.00%)</td>
</tr>
</tbody>
</table>

Figure 24: CBCT Scan Reads for Pathology Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthodontist Reads</td>
<td>5 (45.45%)</td>
<td>9 (36.00%)</td>
</tr>
<tr>
<td>Refer Out</td>
<td>6 (54.55%)</td>
<td>16 (64.00%)</td>
</tr>
</tbody>
</table>

Figure 25: Charges for Reading CBCT Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorporate into CBCT Fee</td>
<td>10 (100%)</td>
<td>23 (92.00%)</td>
</tr>
<tr>
<td>Charge Separately to Read</td>
<td>0</td>
<td>2 (8.00%)</td>
</tr>
</tbody>
</table>

Figure 26: Initial CBCT Scans Field of View Per Region

<table>
<thead>
<tr>
<th></th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voxel Size</td>
<td>West</td>
<td>East</td>
</tr>
<tr>
<td>---------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>0.2</td>
<td>3 (30.00%)</td>
<td>3 (12.50%)</td>
</tr>
<tr>
<td>0.3</td>
<td>4 (40.00%)</td>
<td>10 (41.67%)</td>
</tr>
<tr>
<td>0.4</td>
<td>1 (10.00%)</td>
<td>6 (25.00%)</td>
</tr>
<tr>
<td>Doesn’t Know</td>
<td>2 (20.00%)</td>
<td>5 (20.83%)</td>
</tr>
</tbody>
</table>

**Figure 27: Initial CBCT Voxel Sizes Per Region**

<table>
<thead>
<tr>
<th>Extracted Pan and Lateral Ceph is Better</th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 (9.09%)</td>
<td>2 (8.33%)</td>
</tr>
<tr>
<td>2D Lateral Pan and Ceph is Better</td>
<td>4 (36.36%)</td>
<td>12 (50.00%)</td>
</tr>
<tr>
<td>Both are Comparable</td>
<td>6 (54.55%)</td>
<td>10 (41.67%)</td>
</tr>
</tbody>
</table>

**Figure 28: Image Quality Evaluation Per Region**

<table>
<thead>
<tr>
<th>No</th>
<th>West</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 (80.00%)</td>
<td>22 (88.00%)</td>
</tr>
<tr>
<td>Yes</td>
<td>2 (20.00%)</td>
<td>3 (12.00%)</td>
</tr>
</tbody>
</table>

**Figure 29: Patient Radiation Concerns Per Region**
APPENDIX C – SURVEY SAMPLE

CBCT Use in Orthodontic Residency Programs in USA

1. Where is your program located?
   a. Drop down list of all 50 states in USA

2. Does your program have an in-house CBCT machine?
   a. Yes
   b. No

3. Which brand of CBCT machine did you acquire for taking initial orthodontic records?
   a. Planmeca
   b. iCAT
   c. Dentsply Sirona
   d. Carestream
   e. Vatech
   f. PreXion
   g. Air Techniques
   h. ACTEON
i. Other (short answer)

4. For initial records, which of the following radiographs do you take?
   a. 2D pan and lateral ceph
   b. CBCT only
   c. Full mouth series and 2D lateral ceph
   d. 2D pan, lateral ceph, and CBCT as needed

5. Do you extract 2D pan and lateral ceph from your CBCT scan?
   a. Yes
   b. No

6. If you extract 2D pan and lateral ceph from your CBCT scan, do you charge for CBCT scan fee or 2D pan and lateral ceph?
   a. CBCT scan fee
   b. 2D pan and lateral ceph fees

7. Do you take CBCT scans for progress and final records?
   a. Yes
   b. No

8. Do you charge for progress and final CBCT?
9. If you see Medicaid patients, do you have a code to charge for CBCT?
   a. Yes
   b. No
   c. I do not see Medicaid patients

10. Do you read your own CBCT scan for pathology?
    a. I read CBCT myself
    b. I refer out for my CBCT scan reading

11. How do you charge for reading CBCT?
    a. Incorporate into the CBCT scan fee
    b. Charge separately for reading the scan

12. What field of view do you use for the initial CBCT scans?
    a. 10cm x 10cm
    b. 10cm x 17cm
    c. 17cm x 17cm

13. What is the voxel size of the CBCT scans you take for initial exams?
a. 0.1 voxel
b. 0.2 voxel
c. 0.3 voxel
d. 0.4 voxel
e. 0.5 voxel
f. 0.6 voxel
g. I don’t know

14. Do you feel that the image quality/clarity from the extracting pan/lateral ceph from CBCT is as good as the 2D pan/lateral ceph?
   a. Extracted pan/lateral ceph is better
   b. 2D pan/lateral ceph is better
   c. Both are comparable

15. Have your patients expressed any radiation concerns with taking CBCT scans as a part of initial records?
   a. Yes
   b. No