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Cone-Beam Computed Tomography and Orthodontics: Awareness Assessment

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in conjunction with the
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Cone-Beam Computed Tomography and Orthodontics: Awareness Assessment

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree
Masters of Science in Orthodontics and Dentofacial Orthopedics

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September 2011

Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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Joseph M. Caruso, Professor of Orthodontics and Dentofacial Orthopedics.

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ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
CBCT	Cone-Beam Computed Tomography
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
E	Effective Dose
ICRP	International Commission on Radiological Protection
LNT	Linear No-Threshold
LLUSD	Loma Linda University School of Dentistry
MDCT	Multi-Detector Computed Tomography
MRI	Magnetic Resonance Imaging

ABSTRACT OF THE THESIS

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Warren D. Libby

Master of Science, Graduate Program in Orthodontics and Dentofacial Orthopedics
Loma Linda University, July 2011
Dr. V. Leroy Leggitt, Chairperson

Introduction: The purpose of this study was to evaluate a specific orthodontic community's knowledge and understanding of Cone-Beam Computed Tomography (CBCT) technology as well as awareness of the implications of CBCT use, including risk assessment, radiation dose estimation, diagnostic utility, and issues of informed consent. It is incumbent on the profession to understand how practitioners view this technology as it gains popularity and ease of use.

Materials and Methods: A 21-question survey with 13 additional demographic questions was distributed to several different populations affiliated with Loma Linda University School of Dentistry: 1) undergraduate dental students, 2) students in specialty programs (orthodontics, implant, oral surgery), and 3) orthodontic alumni. The survey tried to gain understanding of practitioners' knowledge of radiation dosage related to CBCT, diagnostic usage, and explore ethical issues such as informed consent, clinical and diagnostic utility, and the influence of business and market forces on CBCT usage.

Results were compiled and examined using non-parametric statistical tests (Independent Samples Kruskal-Wallis and Independent Samples Median) and post-hoc comparisons (Bonferroni, pairwise comparisons) to compare effects of education, time in

practice since residency completion, frequency of CBCT use, age, gender, and dental specialty.

Results and Conclusions: Level of education in dentistry, specialty training, years since completion of residency, age, and frequency of use of CBCT were all related to performance on Part 2 of the CBCT survey. Responses to Part 1 questions were similar among orthodontic alumni, however, significant differences were noted among inter-group comparisons when evaluating the questions in Part 1 of the CBCT Survey. Technical, objective knowledge of CBCT is related to subjective, value judgments about CBCT implementation with patients.

CHAPTER ONE

INTRODUCTION

Use of medical computed tomography (CT) radiographic imaging is increasing rapidly. A growing body of medical literature is linking increased low-dose exposure to ionizing radiation (such as diagnostic imaging) to a very small, but measurable, increased risk of mortality. Although the advantages of this technology are varied and numerous, its risks to patients are poorly appreciated in the medical community as shown by several surveys of medical health professionals. Some authors are calling for implementation of informed consent protocols for medical radiologic tests, especially the tests with higher doses and higher risk. In dentistry, cone-beam computed tomography (CBCT) is becoming widely used in a variety of disciplines. The advantages it offers are also numerous. My review of the literature revealed no published papers that seek to evaluate dental practitioners' understanding of this new technology. Use of CBCT is likely to continue to increase as the technology becomes more user-friendly, less expensive, and better marketed. It is timely and appropriate to seek to understand the orthodontic profession's perception of the effect of CBCT on its patient population.

Medical CT and Radiation Risks

Since the introduction of CT in the 1970's, its use in the medical field as a diagnostic tool has steadily increased.[2] Current estimates indicate that more than 62 million scans are performed annually in the United States. Some four million of these scans are for children.[2] Improvements in CT technology have made it easier to use in a wider variety of situations. For example, helical CT brings a faster scan and reduces the need to sedate children, which has contributed to an increase in the number of scans in younger patients.[1] With image acquisition based on ionizing radiation, CT does not come without risks, however.

Recent epidemiological studies have focused on the effects of low-dose radiation exposure over a lifetime. Based on data from populations affected by the atomic bomb, these studies are able to show a definite degree of risk of fatal cancer based on radiation exposure.[2] The risks of radiation are not isolated to cancer, however. Impaired intellectual development and increased risk of cardiovascular disease are among the various other effects of radiation exposure.[4]

Dosage values are reported a number of different ways. Effective dose (E), measured in Sieverts, is currently used. Effective dose is a term that "takes into account all of the irradiated organs and tissues, as well as their radiosensitivities."[20] It is the best means of measuring how much radiation a patient receives during any radiologic examination. Effective dose is the "product of an organ's equivalent dose and radiosensitivity, and is obtained by summing over all exposed organs and tissues."[20] The conversion of effective dose to a risk of mortality is taken to be about 5% per Sievert averaged over an entire population. That is, an effective dose of 10mSv (which is an

approximate dose for a single CT examination) can contribute to the radiation-induced deaths of 50 out of 100,000 people exposed, a mortality risk of 0.05%.[20]

Regression models of mortality risk generally show a linear increase in risk with increased dose. This model is well supported at doses over 100mSv. The epidemiological data to support extending the linear relationship below this dose is not clear. But there is some. Mathematical models are usually used to predict risks for doses less than 100mSv. These models assume a "linear no-threshold" (LNT) relationship between dose and risk. In other words, at low doses the linear relationship between risk and dose holds true, and there is no threshold dose beneath which there is no risk. The direct epidemiological data for this assumption are not conclusive.[13]

Because of the assumptions in the LNT model and the lack of direct epidemiological evidence for risk at low doses, risks associated with medical CT and other radiologic procedures at lower doses are unclear. McCollough states that, "The radiation dose associated with a CT examination (~ 1–14 mSv) is comparable to the annual dose received from naturally occurring sources of radiation, such as radon and cosmic radiation (1–10 mSv)."[13] It is important to keep in mind that the risks associated with radiation in the dose range of diagnostic radiology are estimated; direct correlation with epidemiological data is not consistent. However, it would seem prudent to assume there are risks at these lower doses, especially when children are involved.

Children have a greater lifetime risk of developing fatal cancer due to low-dose radiation compared to adults due, in part, to a greater number of years over which those effects can be manifested. Effective radiation dose to children is about 50% more due to their smaller size.[4] The lifetime risk does decrease with age.[1] Brenner states that in

children less than 15 years of age, an estimated 600,000 undergo CT each year in the United States. Of those 600,000, approximately 140,000 will ultimately die of cancer. The projected number of deaths attributed to CT is about 500, a roughly 0.35% increase over the background risk.[1]

We can draw at least two conclusions from the epidemiological studies of A-bomb survivors. One, the data (assuming the validity of the LNT model at low doses) indicate "the risk of all solid cancers is consistent with a linear increase in radiation dose." Two, that "children are much more radiosensitive than adults."[7]

CBCT and Dentistry

Cone-beam computed tomography (CBCT) is a variant of CT that is becoming popular in dental radiographic imaging, diagnosis, and treatment planning. CBCT is different from conventional CT in that the x-ray beam is conical rather than fan-shaped. The sensor and x-ray source make one revolution around the subject, rather than several as in conventional CT, resulting in less radiation exposure to the patient. The image quality is generally adequate for high-contrast areas (such as between bone and soft tissue), but inadequate for differentiating soft tissue types (such as would be required in an abdominal CT).[16]

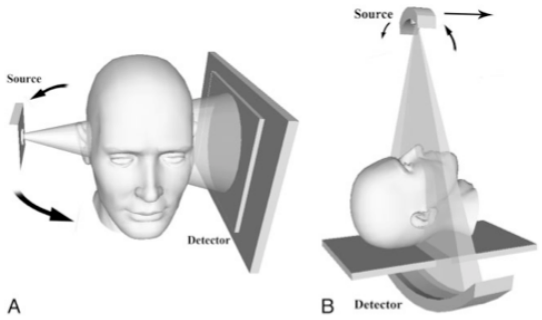

Figure 1. A: CBCT. B: MDCT. Image taken from Miracle.[15]

CBCT imaging in dentistry offers many advantages compared to conventional dental radiography, including: 3D data set, real-size data, potential for generating 2D images (e.g., lateral and panoramic views), lower radiation dose than conventional CT, in-office imaging, DICOM compatibility, and others. It also has its limitations: low contrast range, limited soft tissue information, movement artifacts affect the entire dataset, increased radiation dose compared to conventional films, increased noise from scattered radiation.[5]

CBCT images are acquired at a significantly lower dose than conventional CT. Based on the effective dose (E) calculations in the 2005 International Commission on Radiological Protection (ICRP), dosage for a typical multi-detector CT (MDCT) scan of the head is about 1-2mSv, whereas CBCT units range in dose from 13-498μSv with most units in the 30-80μSv range (depending on scanning protocol, field of view, and manufacturer).[15] For comparison, dosages for conventional films are as follows: 22.8μSv for a digital panoramic image and 6.8μSv for two cephalometric images.[11]

The effective dose for CBCT units is far lower than conventional CT in most cases, but significantly more than conventional dental films. Using the mathematical model (LNT) provided by ICRP, "The risk of fatal malignancy from a CBCT of the jaws

is between 1 in 100,000 and 1 in 350,000. This risk is based on an adult patient. In orthodontics, many of the patients are children and the risk is higher."[19, 25] Thus, despite the favorable difference between CBCT and conventional CT, we can conclude that, "Until we have clear evidence for a threshold dose below which our patients are not at risk, we must assume that radiography involves a small, but real, risk to our patients."[12]

Rationale for Radiation Dose Reduction

In light of the potential risks associated with radiation, the clinician must be able to justify the radiographic test and seek to optimize the results of the tests ordered. When a test is ordered dose-reduction protocols are warranted. The principle of As Low As Reasonably Achievable (ALARA) should be familiar to medical and dental professionals. It would be a mischaracterization to conceive of ALARA as meaning the less radiation, the better. Rather, ALARA seeks to maximize diagnostic yield from every image ordered while minimizing the potential for mistakes.[18] The potential risks and benefits for each patient are weighed by the clinician and the appropriate images acquired.[6] Some consider the concept of ALARA to include a cocktail of antioxidant dietary and medical supplements to reduce the deleterious effects of radiation on cellular DNA.[17] The principle of ALARA can be applied in a variety of different ways.

In the medical community some are of the opinion that many CT exams are simply unnecessary. Alternative means of diagnosis such as sonography and magnetic resonance imaging (MRI) are available and occasionally remain underused. Up to one-third of pediatric CT exams could be replaced by alternative tests or not done at all.[7, 29] Some CT scans are ordered in the practice of "defensive medicine." Clearly,

"eliminating nonbeneficial and inappropriate CT examinations likely represents the most important step toward reducing CT risk."[13] These conclusions from medicine have direct application to the dental community as well.

A critical difference between CBCT and conventional dental radiography is that excessive radiation does not adversely affect image quality. Thus, there is no visual reminder to the technician or dentist that the radiation dose is too high for that particular patient. This can lead to complacency in that the CBCT settings are set for the usual adult dose and remain unchanged for smaller patients, leading to unnecessary radiation absorbed by the patient. Tailoring the dose to patient size is another important means of reducing unnecessary radiation.

Reducing risks to patients through radiation reduction protocols can be accomplished in myriad ways. The clinician should consider the diagnostic needs of each particular patient, weigh the risks and benefits of certain imaging techniques, consider the ethical principles that compel healthcare providers to "first do no harm," seek to do good for the patient, and give patients (and their parents) enough information to make an informed decision about their treatment. Fulfilling these expectations requires an awareness of the significance of the radiologic tests one orders. As we shall see, that awareness is often lacking in the medical profession.

Conclusions and Study Direction

An exploration of the literature reveals at least six studies of medical professionals that indicate an appreciation of the ramifications of radiologic tests to be lacking. [8, 10, 25-28] Simple questionnaires given to physicians in pediatrics, emergency care,

radiology, and internal medicine as well as patients show that most physicians are unable to estimate the comparative exposure of a chest CT with a conventional chest film.[25] Rate of informed consent as perceived by patients for radiologic procedures was below 10%.[10] Some physicians indicated that they considered MRI to cause radiation.[8] While it is inappropriate to generalize extensively from the results of these studies, in light of the rapid increase in the number of medical CT exams, it is certainly of concern to think that the results of these studies might reflect the understanding of the majority of physicians.

The dental literature in general and orthodontic literature in particular are replete with studies of clinical applications of CBCT, yet include no formal inquiry into the awareness of orthodontists on the subject of increased patient exposure associated with these examinations compared to conventional imaging. Such a study that gauges the profession's grasp of the ramifications of the increasing use of CBCT is certainly timely and relevant.

CHAPTER TWO

MATERIAL AND METHODS

An online survey of 21 multiple-choice questions and 13 additional demographic questions was distributed to Loma Linda University School of Dentistry (LLUSD) dental students (D1, D2, D3, D4 classes), specialty residents (implant, orthodontics, and oral surgery), and LLUSD orthodontic alumni via email. The survey was developed after evaluating the referenced medical surveys for subject matter, formatting, number of questions, etc. A search for a similar survey in the dental literature yielded no such precedent. Hence, this is a novel survey with questions created by the researchers to ascertain a basic knowledge level of CBCT as well as explore ethical and value judgment questions related to its use.

Population sizes sampled are shown in Table 1. Respondents were given four weeks to reply to the survey. Reminder emails were sent weekly to those who hadn't responded. A personal verbal appeal was made to all dental students. The survey was closed 03/30/2011. Response rates are shown in Table 1. A copy of the survey is included (See Figure 2 and Appendix B).

Table 1. Survey populations, sample sizes, and response rates.

Survey Populations	Population Size	Respondents (Sample Size)	Response Rate
Orthodontic Alumni	190	68	35.8%
D1 students	108	34	31.5%
D2 students	101	33	32.7%
D3 students	98	38	38.8%
D4 students	91	41	45.1%
Orthodontic Residents	11	11	100.0%
OMFS Residents	14	3	21.4%
Implant Residents	12	1	8.3%

CONE BEAM COMPUTED TOMOGRAPHY (CBCT) SURVEY

For each question below, circle the number to the right that best fits your opinion on the importance of the issue. Use the scale above to match your opinion.

Part I Questions	Scale of Importance				
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. An informed consent discussion with patients regarding CBCT is necessary.	1	2	3	4	5
2. It is necessary for a dentist to discuss CBCT radiation exposure with patients.	1	2	3	4	5
3. The dental applications of CBCT are consistent with the radiologic principle As Low As Reasonably Achievable (ALARA).	1	2	3	4	5
4. A clinical exam by the dentist should always precede dental radiographs.	1	2	3	4	5
5. It is important for dentists to avoid redundant radiographs.	1	2	3	4	5
6. Information from CBCT scans improves clinical diagnosis.	1	2	3	4	5
7.Three-dimensional imaging (e.g., CBCT) is an essential part of dental diagnosis.	1	2	3	4	5
8. Information from CBCT scans improves treatment outcomes.	1	2	3	4	5
9. CBCT use makes dentistry more profitable.	1	2	3	4	5
10. A dentist is more likely to prescribe CBCT scans for patients if the CBCT machine is located in-office or on-site.	1	2	3	4	5
11. Rank imaging modalities in order of importance to dentistry	CBCT	MRI	Ultrasound		CT
1=Most important, 4=Least important.					

For each question below, circle the most appropriate answer to the right.

Part II Questions	True	False	Don't Know
1. A 10 year old child and a 50 year old adult exposed to the same dose of ionizing radiation incur the same risk of developing cancer.	T	F	DK
2. The biologic effects of low-dose radiation exposure are cumulative.	T	F	DK
3. There is a link between radiation in medical tests and risk of developing cancer.	T	F	DK
4. A typical CBCT scan exposes a patient to more radiation than a typical hospital CT scan.	T	F	DK
5. A typical CBCT scan exposes a patient to less radiation than a typical Magnetic Resonance Imaging (MRI) scan.	T	F	DK
6. Radiation exposure from a typical digital dental panoramic radiograph is higher than from a typical CBCT scan.	T	F	DK
7. The combined radiation exposure from a typical digital dental panoramic radiograph and a digital 20-film full mouth series is roughly equivalent to a typical CBCT scan.	T	F	DK
8. Excessive radiation dosage during a CBCT scan worsens final image quality.	T	F	DK
9. CBCT data can be used to replace conventional lateral cephalograms.	T	F	DK
10. CBCT data can be used to replace conventional panoramic radiographs.	T	F	DK

General Information					Dental Professionals Only		
Gender	M		F		Years since completion of residency or dental school		
Ethnicity					Number of CBCT scans ordered per month.		
Age					Percentage of patients who receive CBCT scans.		
Years of Education after High School					CBCT located:	On-site	Off-site
Occupation					Specialty		
Rate your general health	Excellent	Good	Fair	Poor	Who interprets CBCT data (self, Oral Maxillofacial Radiologist, other)?		
Rate your dental health	Excellent	Good	Fair	Poor			

Figure 2. Survey.

Answers considered correct for Part 2 of the CBCT survey are shown in Table 2.

Table 2. Answers considered correct to Part 2 CBCT Survey Questions.

Survey Part 2 Answers			
1	F	6	F
2	T	7	T
3	T	8	F
4	F	9	T
5	F	10	T

The number of responses submitted by the oral and maxillofacial surgery residents and the implant residents (3 and 1, respectively) was not sufficient to warrant statistical discussion. Responses by the orthodontic residents are referenced briefly as many subjects were aware of the nature of the study. Statistical tests used included Independent Samples Kruskal-Wallis Test and Independent Samples Median Test to identify differences between groups along with post-hoc pairwise comparisons and Bonferroni tests to isolate those differences.

CHAPTER THREE

RESULTS

General response rates are shown in Table 3. Not all respondents completed the entire survey and not all respondents completely filled out the demographic questions.

Table 3. Population sizes, sample sizes, and response rates.

Survey Populations	**Population Size**	**Respondents (Sample Size)**	**Response Rate**
Orthodontic Alumni	190	68	35.8%
D1 students	108	34	31.5%
D2 students	101	33	32.7%
D3 students	98	38	38.8%
D4 students	91	41	45.1%
Orthodontic Residents	11	11	100.0%
OMFS Residents	14	3	21.4%
Implant Residents	12	1	8.3%

Demographics

The figures below show largely male-dominated samples with Asian and Caucasian ethnicities comprising the majority and educational levels steadily rising through dental school to average about 10 years education post-high school for orthodontic alumni. Three subjects in the orthodontic alumni sample did not respond to the gender question. Tables for gender, ethnicity, and educational levels are found in Appendices C, D, and E, respectively.

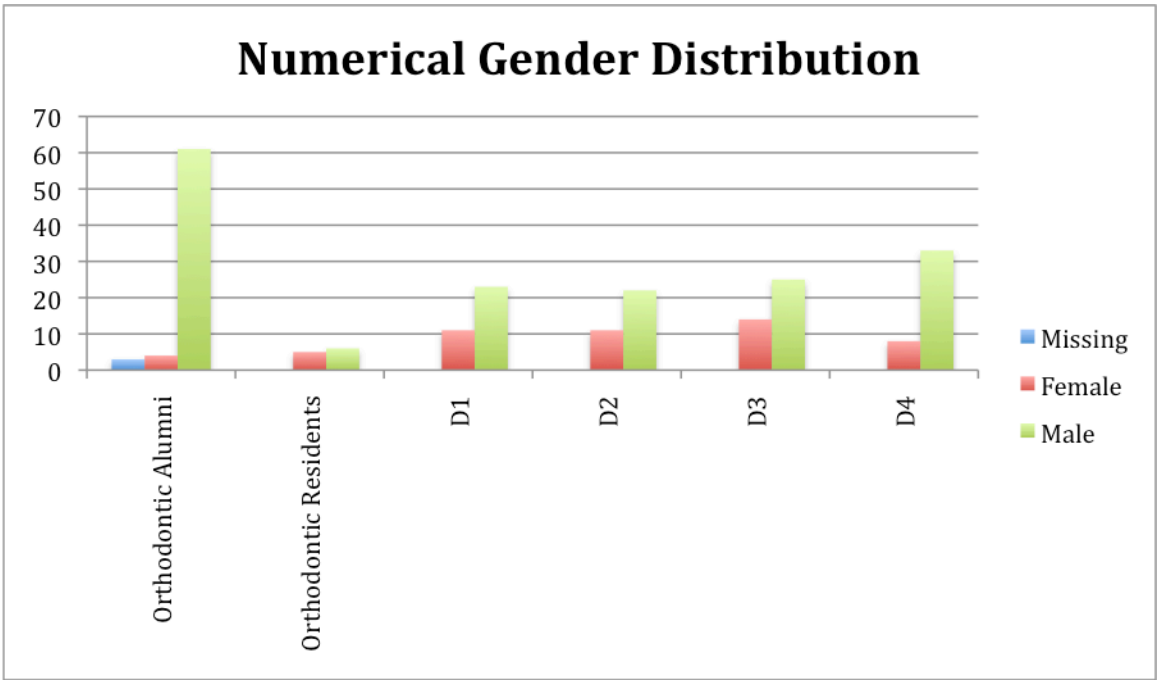

Figure 3. Numerical gender distribution of samples.

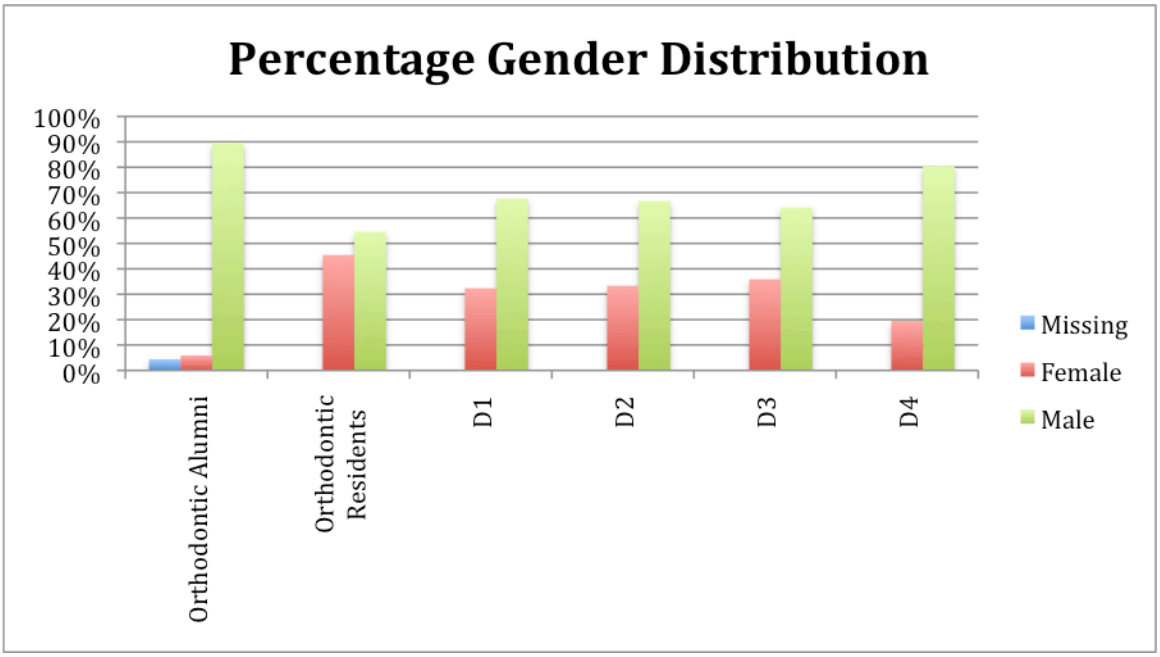

Figure 4. Percentage gender distribution of samples.

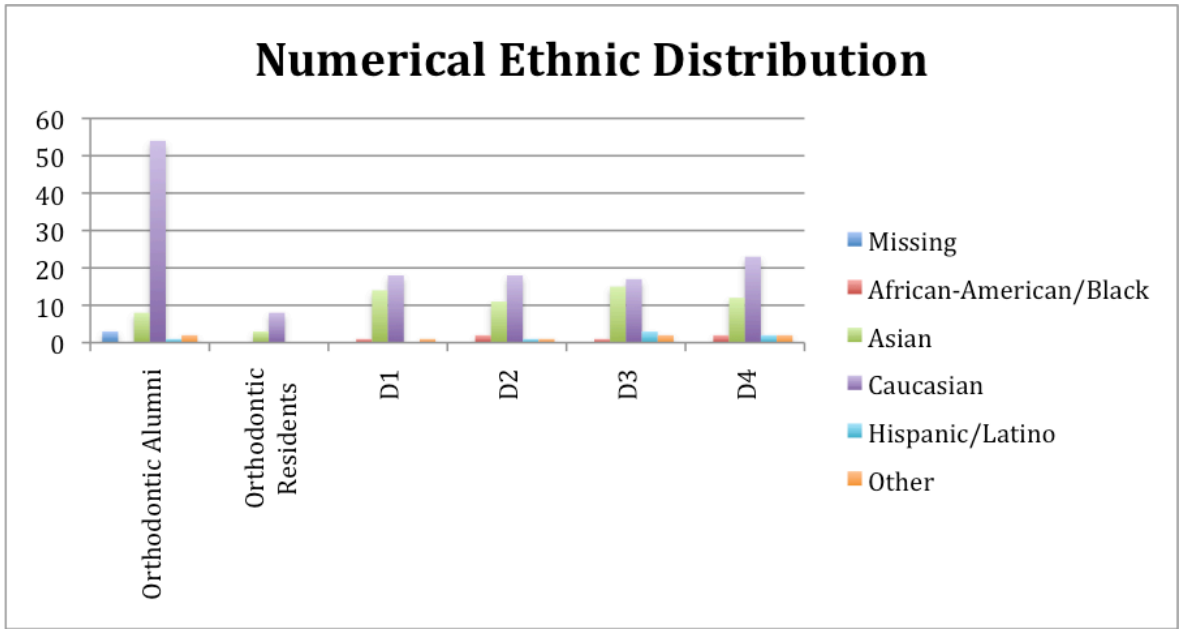

Figure 5. Numerical ethnic distribution of samples.

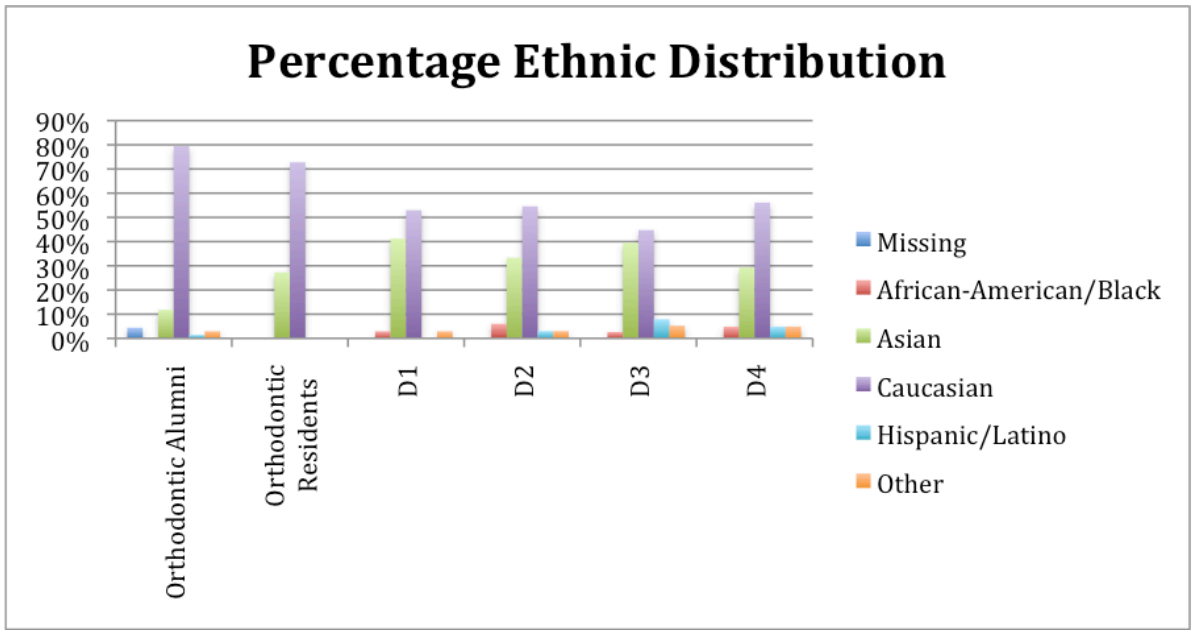

Figure 6. Percentage ethnic distribution of samples.

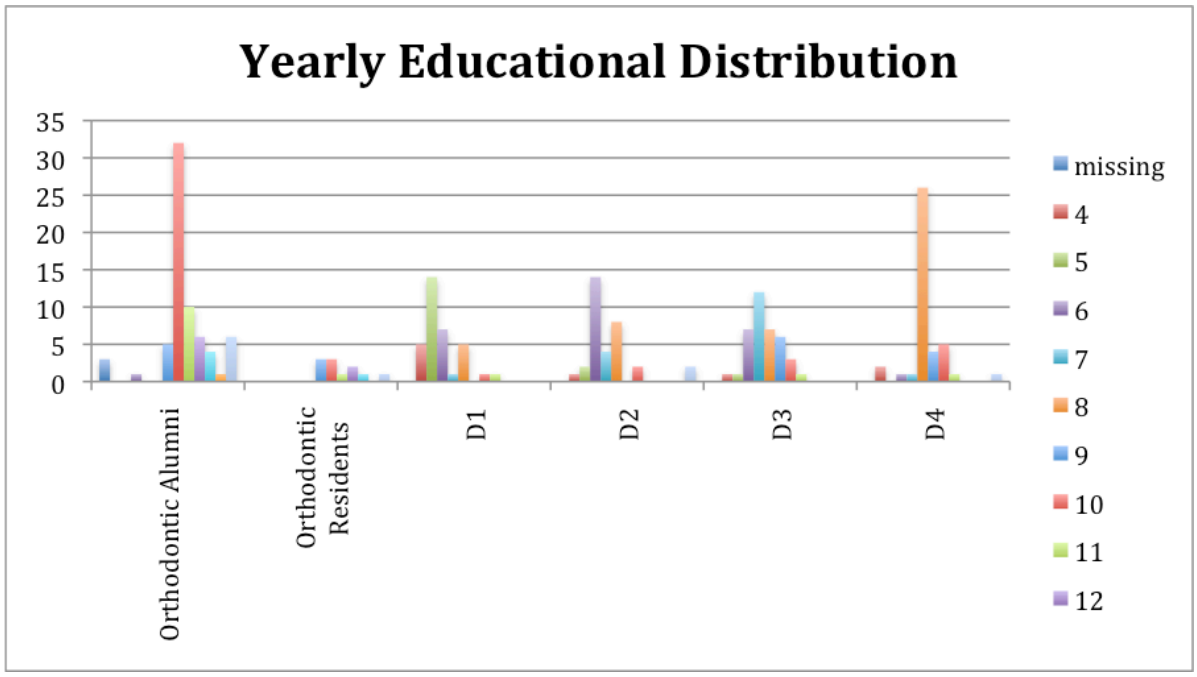

Figure 7. Yearly educational distribution of samples.

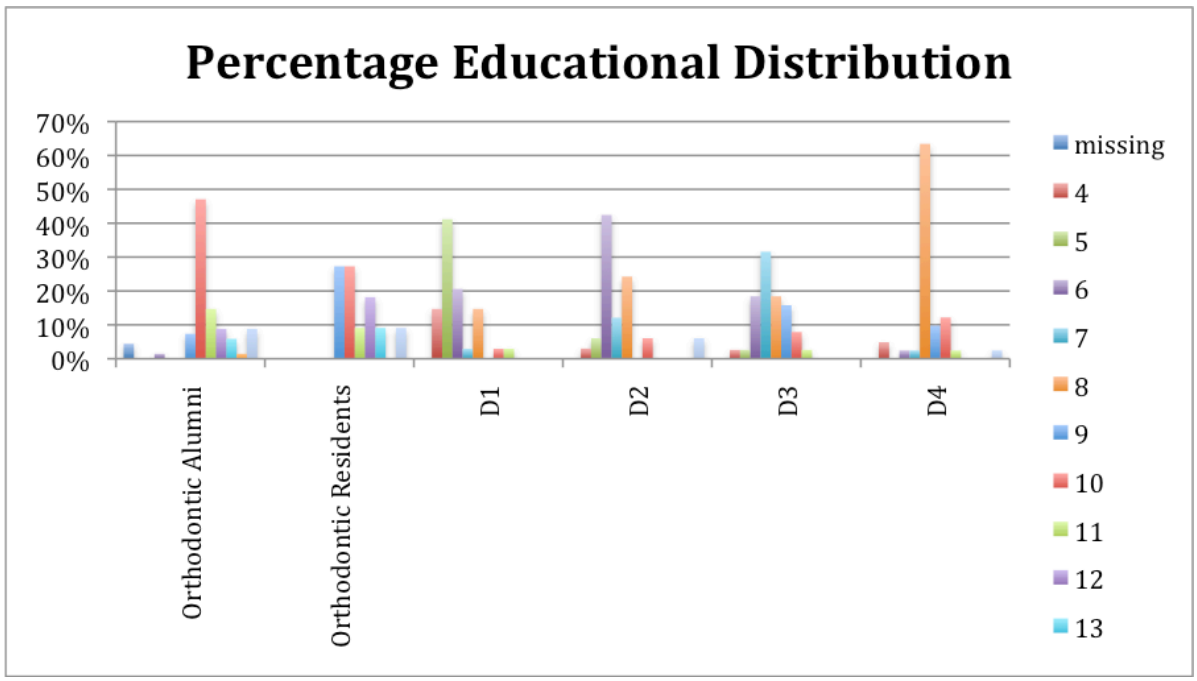

Figure 8. Percentage educational distribution of samples.

Survey Part 2 Responses

Sample groups' correct responses to Part 2 of the CBCT Survey are shown in Figure 9. "Don't Know" and incorrect answers were grouped together as both were considered to indicate ignorance of the subject matter of the question. Orthodontic residents scored the highest as a group with orthodontic alumni following. A progression throughout the dental students' samples shows a steadily increasing knowledge of CBCT throughout dental school. Orthodontic specialty training further enhances knowledge of CBCT as indicated by the difference between the D4 scores and orthodontic alumni and resident scores. The ten questions testing basic knowledge of CBCT comprising Part 2 of the CBCT survey were validated by the score distribution.

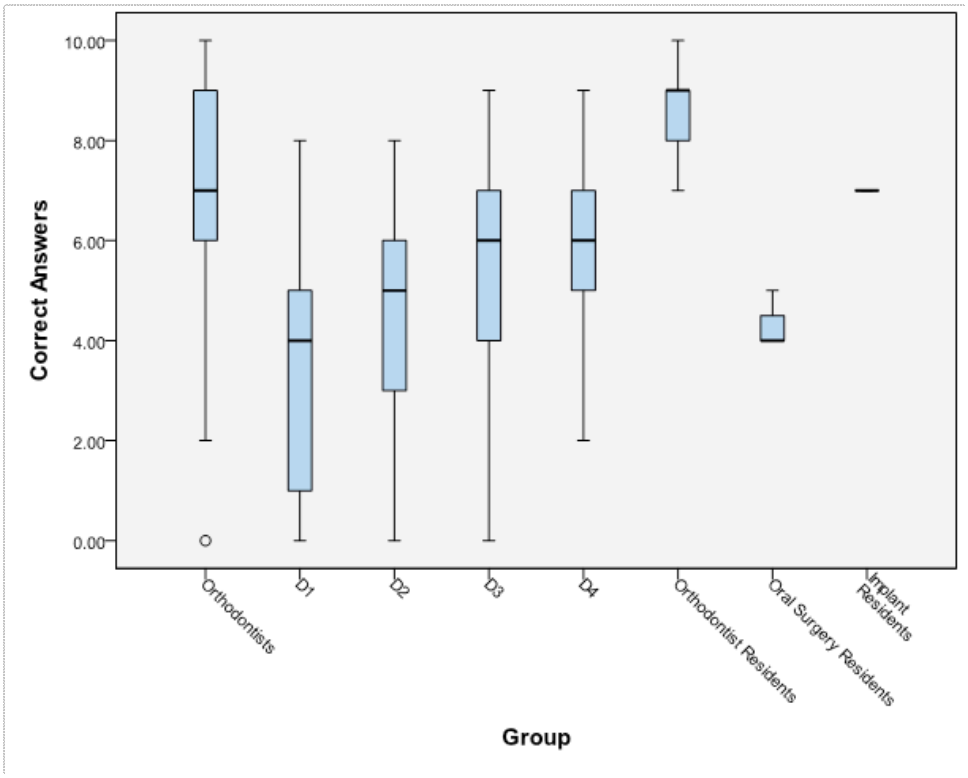

Figure 9. Distribution of correct answers on Part 2 of CBCT Survey for each population.

Good, Average, Poor Categories

Based on the distribution of correct answers in Part 2 of the CBCT Survey shown in Figure 9, the orthodontic alumni sample was arbitrarily categorized into groups of good awareness (8-10 correct answers), average awareness (6-7 correct answers), and poor awareness (0-5 correct answers). Using the dental students scoring as a calibration guide, most 1st and 2nd year dental students scored poorly. 3rd and 4th year dental students were borderline adequate in their awareness level. Current orthodontic residents were nearly all grouped in the good awareness. And the orthodontic alumni distribution fell primarily between the good and average awareness thresholds.

Based on the distribution of scores in Part 2 of the CBCT Survey, we can conclude that the sample group of alumni from Loma Linda University School of Dentistry Orthodontic Department is adequate or well-aware in their level of CBCT knowledge, confirming our alternative hypothesis.

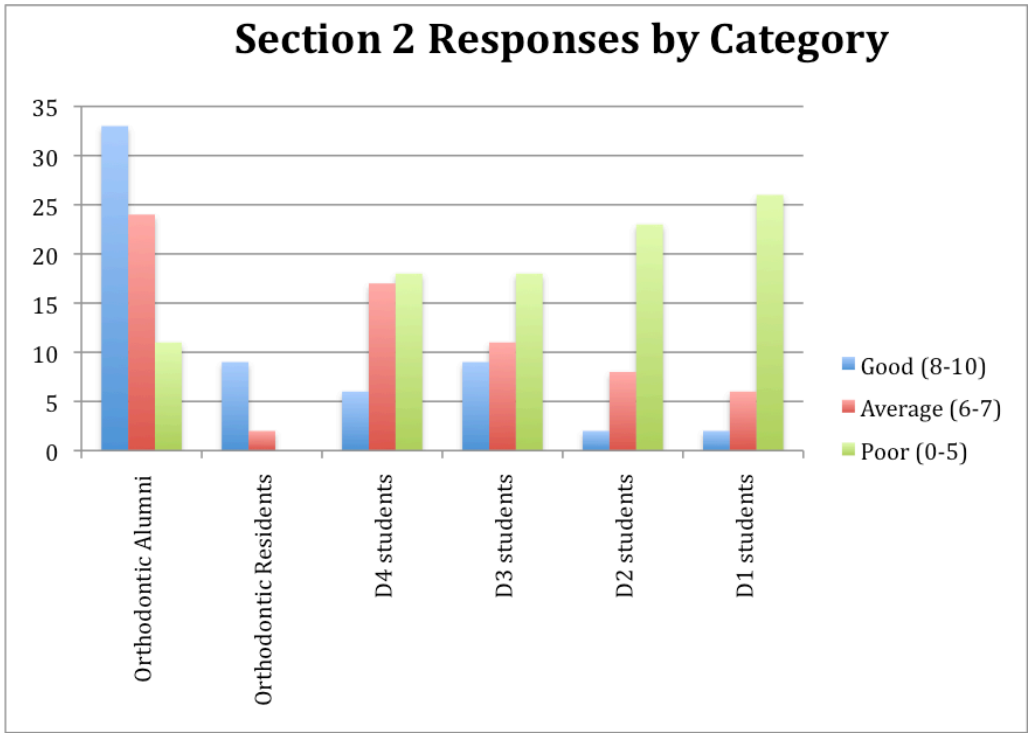

Figure 10. Number of respondents in categories of good, average, and poor awareness.

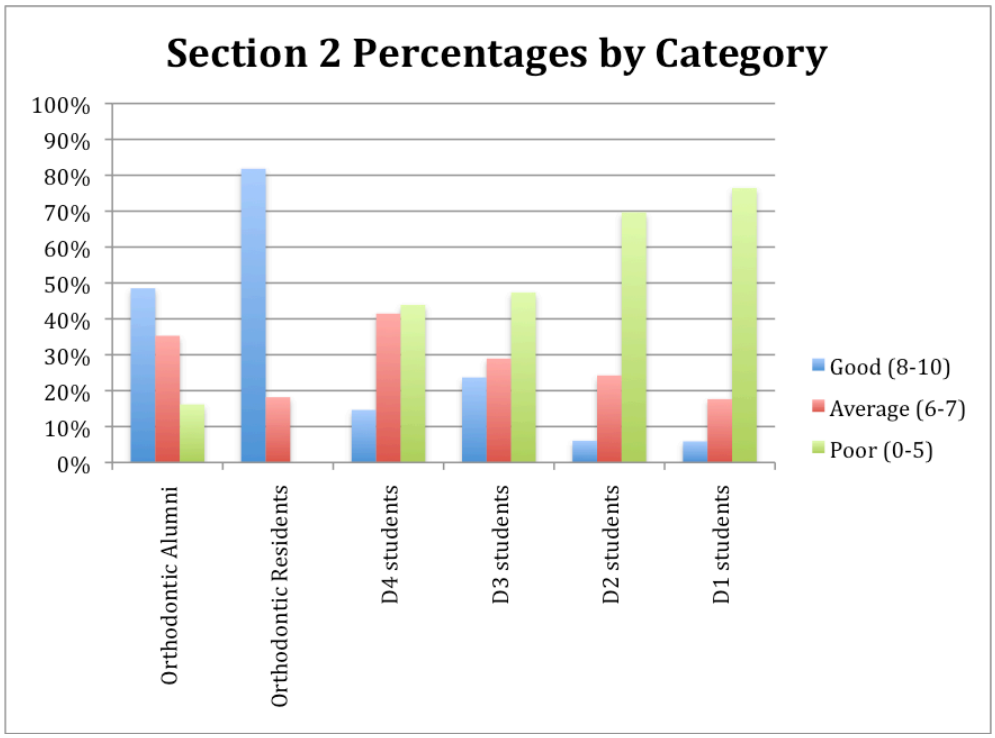

Figure 11. Percent of sample size categorized as good, average, or poor awareness.

Good, Average, Poor Categories Related to Part 1 of Survey

The ethical ramifications of CBCT use and value judgments addressed in Part 1 of the CBCT Survey were evaluated using the sample of primary interest, the orthodontic alumni. We examined the responses of the groups of good, average, and poor awareness to the ethical and value-driven questions posed in Part 1 of the CBCT Survey.

Using non-parametric Independent Samples Median Test and the Independent Samples Kruskal-Wallis Test with a significance level of 0.05 there were no significant differences among the responses of the good, average, and poor categories of orthodontic alumni to Part 1 of the CBCT Survey. Regardless of their score on Part 2, all groups essentially agreed on the responses to questions in Part 1. Questions regarding informed consent, radiation exposure reduction, diagnostic information, and treatment outcomes related to CBCT use were answered similarly by the good, average, and poor awareness groups of orthodontic alumni. There are several possible reasons for this: 1) the distribution of awareness levels among the orthodontic alumni was not varied enough to show a difference in ethical value judgments, 2) lack of power due to decreased sample size after categorization, 3) or the knowledge of CBCT tested in Part 2 was not relevant to the ethical questions posed in Part 1. As we shall see, however, when the Part 1 responses are compared among groups with a larger disparity in Part 2 scores, there are differences in value judgments based on level of awareness. Although not shown among the orthodontic alumni categories, comparison of other samples seems to indicate that knowledge level is related to ethical convictions and value judgments.

Good, Average, Poor Demographics

Comparison of the orthodontic alumni sample demographic information between the good, average, and poor awareness groups yields several noteworthy trends. The trends must be considered carefully, however, as not all respondents answered all the demographic questions. The sample size is decreased in some demographic categories.

Age

Younger orthodontists scored better than older orthodontists. See Table 4 and Figure 12. Post-hoc pairwise comparison (tested at significance level 0.05) shows a significant difference between the age of the good and poor awareness categories (significance level 0.040).

Table 4. Size of orthodontic alumni sample for age demographic by awareness category.

Orthodontic Alumni Sample (68)	**Category Sample Size**	**Age Demographic Responses**	**Missing**
Good Awareness	33	32	1
Average Awareness	24	24	0
Poor Awareness	11	9	2

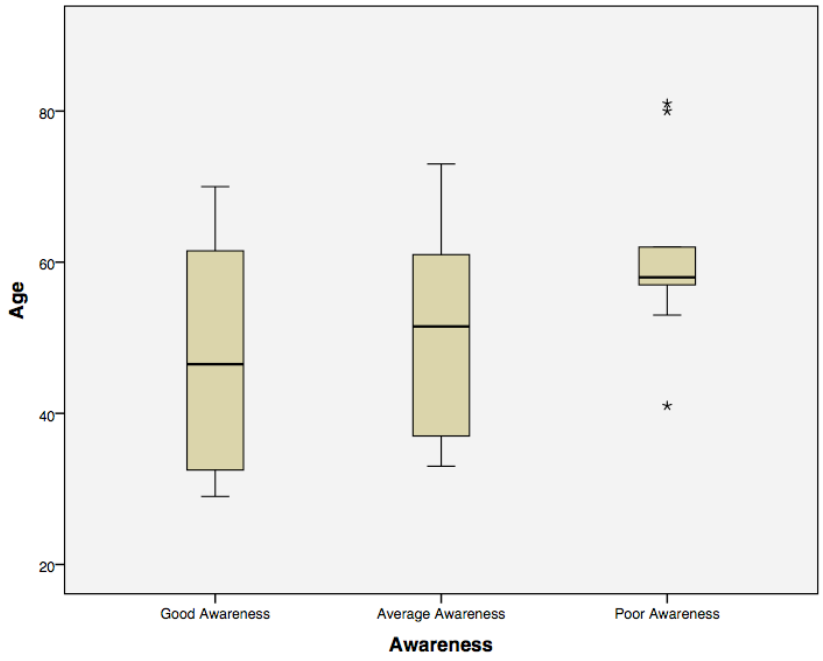

Figure 12. Awareness level versus age of orthodontic alumni sample.

Years Since Completion of Residency

Years since residency completion relates to categories of awareness. More recent graduates fared better than those who graduated earlier as indicated by Figure 13. Post-hoc pairwise comparison (tested at significance level 0.05) shows a significant difference between the years since residency completion of the good and poor awareness categories (significance level 0.038).

Table 5. Size of orthodontic alumni sample for years since residency completion demographic by awareness category

Orthodontic Alumni Sample (68)	Category Sample Size	Residency Completion Demographic Responses	Missing
Good Awareness	33	32	1
Average Awareness	24	23	1
Poor Awareness	11	9	2

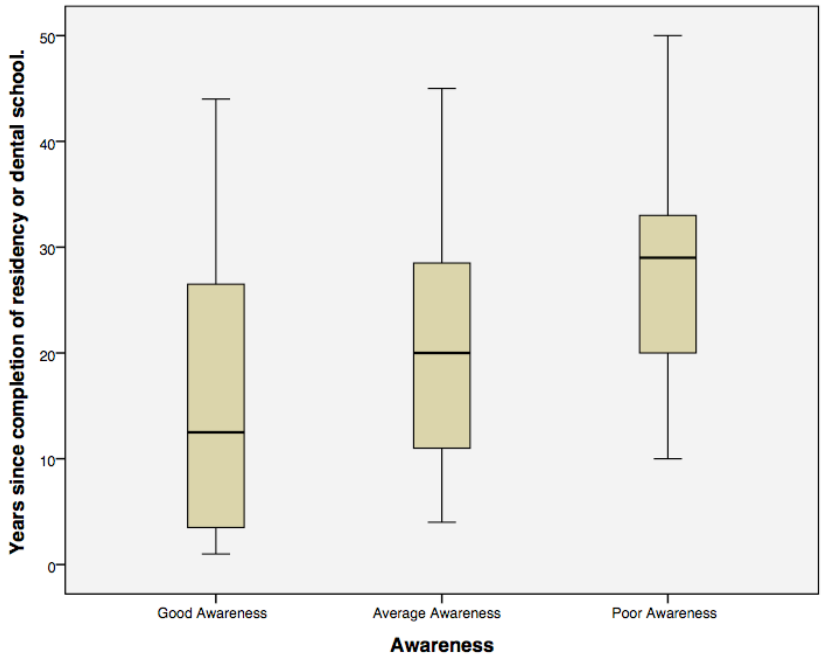

Figure 13. Awareness level versus years since completion of residency of orthodontic alumni sample.

Percentage of Patients Scanned

The number of orthodontists who answered this question was reduced from the total number sampled. (See Table 6). Power was reduced and no significant differences were noted based on Independent Samples Median testing. However, based on those

who did respond, the good awareness category had a larger range of percentage of patients scanned. (See Figure 14). Perhaps those who use the technology and have incorporated it into their practice scored better on Part 2 of the CBCT Survey.

Table 6. Size of orthodontic alumni sample for percentage of patients scanned demographic by awareness category

Orthodontic Alumni Sample (68)	Category Sample Size	Percentage Scanned Demographic Responses	Missing
Good Awareness	33	15	18
Average Awareness	24	14	10
Poor Awareness	11	1	10

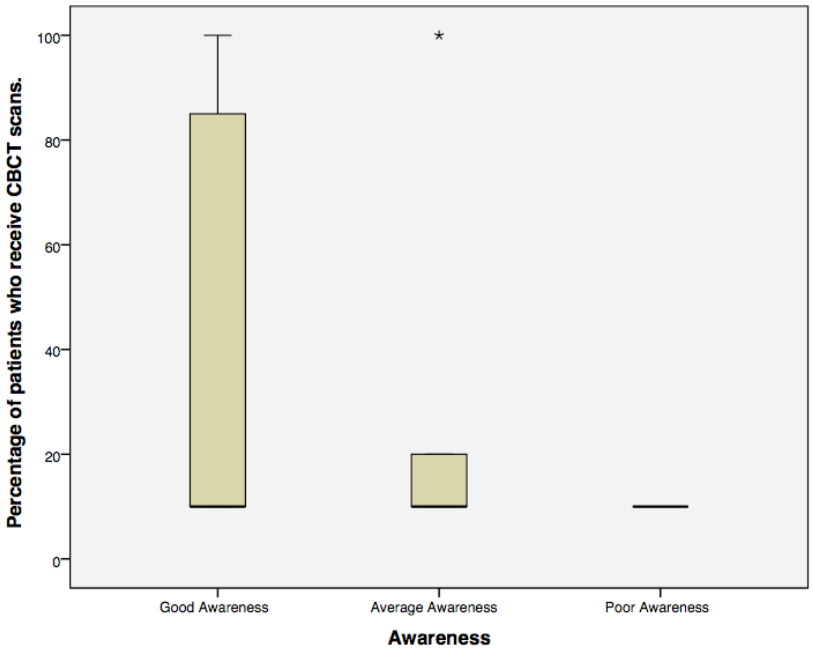

Figure 14. Awareness level versus percentage of patients scanned of orthodontic alumni sample.

Number of Scans Ordered per Month

The number of orthodontists who answered this question again was reduced from the total number sampled, shown in Table 7. Although no significant difference was noted, based on those who did respond, the good awareness category had a larger range of number of patients scanned per month. Perhaps those who use the technology and have incorporated it into their practice scored better on Part 2 of the CBCT Survey.

Table 7. Size of orthodontic alumni sample for scans per month demographic by awareness category

Orthodontic Alumni Sample (68)	**Category Sample Size**	**Scans per Month Demographic Responses**	**Missing**
Good Awareness	33	17	16
Average Awareness	24	17	7
Poor Awareness	11	3	8

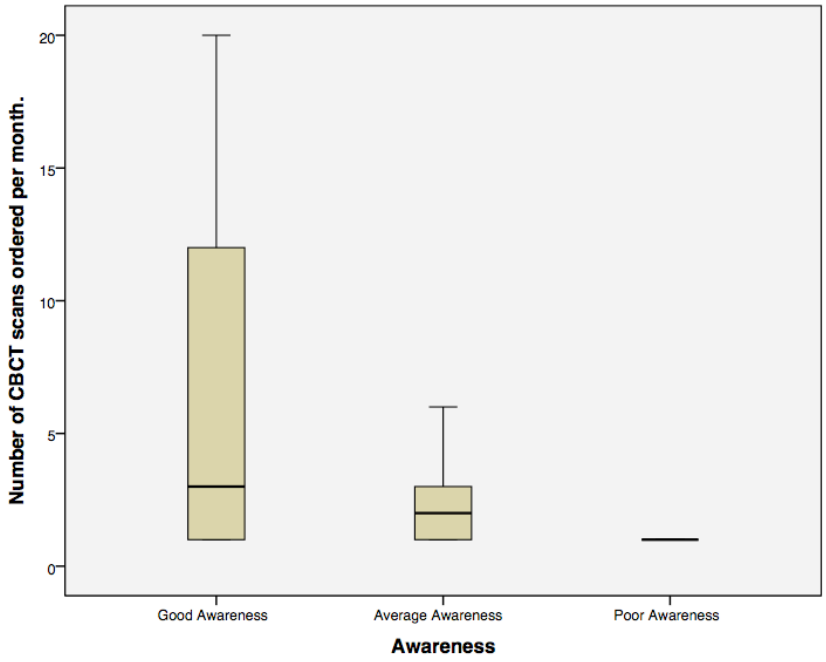

Figure 15. Awareness level versus number of CBCT scans ordered per month of orthodontic alumni sample.

Orthodontic Alumni, D1 Student, D4 Student, and Orthodontic Resident Samples in Part 1 of Survey

Although there weren't significant differences between categories of good, average, and poor awareness in the orthodontic alumni sample when answering the questions of Part 1 of the CBCT Survey, when the orthodontic alumni, D1 student, D4 student, and orthodontic residents samples in their entirety were compared, there were some significant differences in value judgments as shown by answers to Part 1. Scores on Part 1 were recorded on a five-point scale of strongly agree (1) to strongly disagree (5). D1 students were considered a highly educated lay population, as they were essentially college graduates with about six months dental education and training at the

time of the survey. Orthodontic alumni, on the other hand, were considered highly experienced and highly trained in the dental profession regardless of their scoring on Part 2 of the CBCT Survey. Orthodontic residents and D4 students were well-educated but still in training. Significant differences in responses to seven Part 1 questions were found between these sample groups using the non-parametric Independent Samples Kruskal-Wallis Test with a significance level of 0.05. Post-hoc Bonferroni tests showed which groups differed from each other. Sample sizes compared are shown in Table 8, and were consistent throughout the questions hereafter reviewed.

Table 8. Orthodontic alumni, D1 students, D4 students, and orthodontic resident sample sizes.

	Sample Size
Orthodontic Alumni	68
D1 Students	34
D4 Students	41
Orthodontic Residents	11

The difference in opinion between orthodontic alumni and D4 students was shown to be significant (0.027) when asked about informed consent and CBCT. Although the difference between D1 and D4 samples (0.068) was not statistically significant at the 0.05 level, it was close enough to warrant mentioning. (See Figure 16.) The sample size of the orthodontic residents wasn't large enough to provide enough power for a statistical difference. D4 and orthodontic residents thought informed consent was more important than the orthodontists or D1 students.

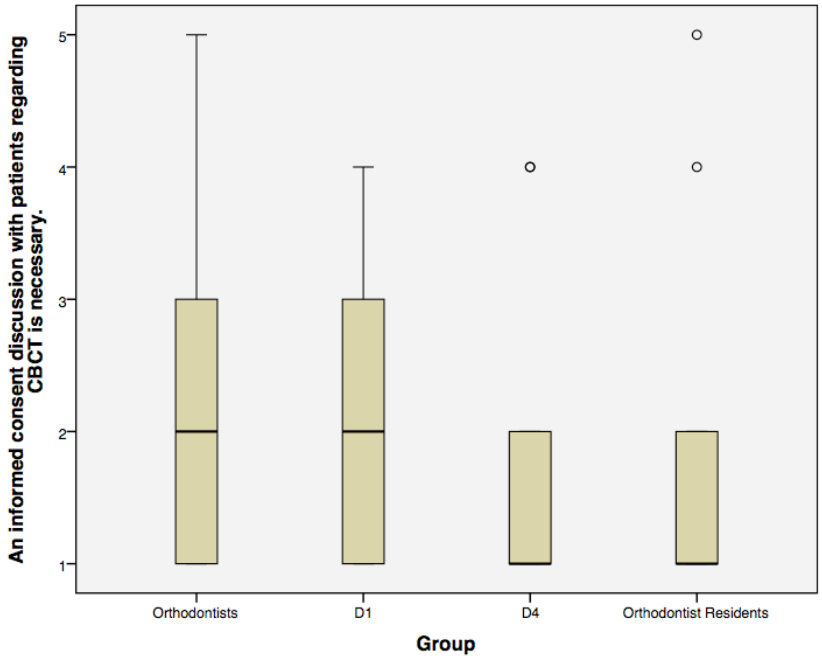

Figure 16. Part 1 Question 1. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

Figure 17 shows a distribution of responses to a question about discussion of radiation exposure with patients who are receiving a CBCT scan. All groups were clustered in the "agree" or "strongly agree" area and there were no statistically significant differences between responses.

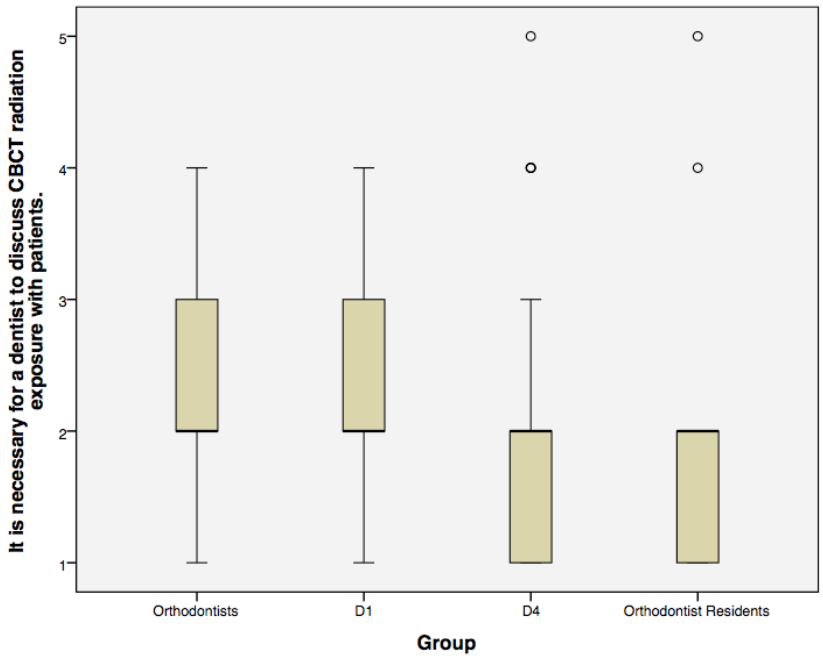

Figure 17. Part 1 Question 2. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

In Figure 18, the orthodontic alumni and D4 samples were significantly different (0.046) in their opinion of whether CBCT was consistent with the principle of ALARA with the D4 sample tending to affirm more strongly than the orthodontic alumni. There were no statistically significant differences between other samples, although the orthodontic residents showed the greatest range of responses.

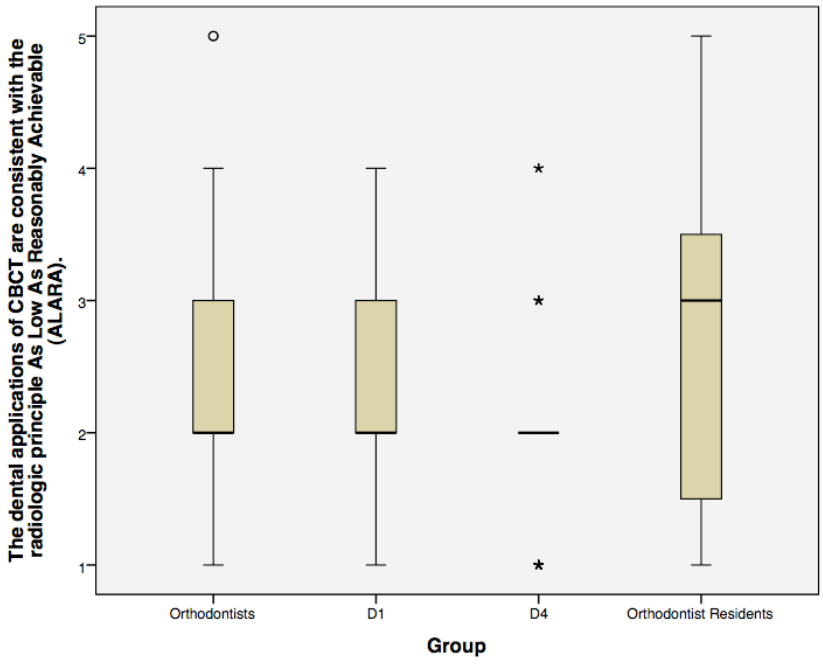

Figure 18. Part 1 Question 3. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

Shown in Figure 19, a question relating to a clinical exam prior to radiographic tests showed significantly different responses between the D1 and D4 samples (0.027). Although not statistically significant at 0.090 due to small resident sample size, the difference in answers between the D1 and orthodontic resident sample was interesting. Both the D4 and orthodontic residents felt more strongly that a clinical exam should precede radiographic tests compared to the other samples.

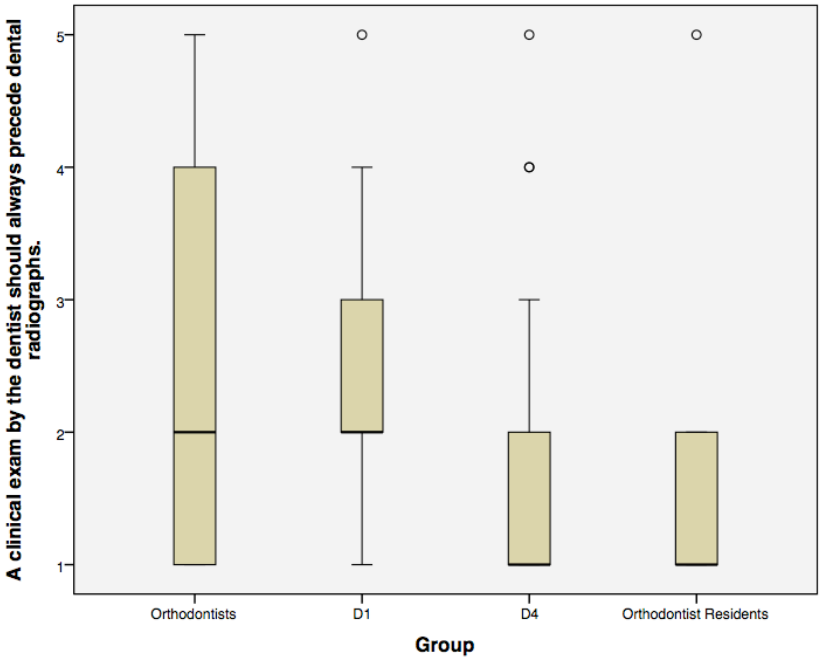

Figure 19. Part 1 Question 4. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

In a question asking about the importance of avoiding redundant radiographs, the D1 and orthodontic resident samples' opinion differed significantly (0.031) with the residents agreeing more strongly that redundant radiographs should be avoided. (See Figure 20.)

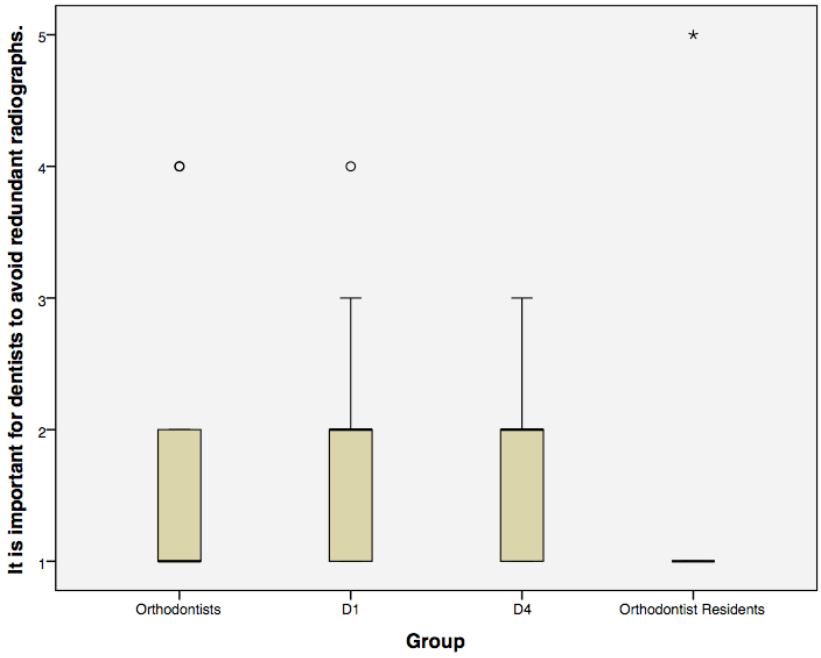

Figure 20. Part 1 Question 5. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

Figure 21 shows the distribution of responses for a question about whether the information from CBCT scans improves clinical diagnosis. The D1-D4 and D1-orthodontic resident samples did not differ significantly, but their significance levels at 0.099 and 0.057, respectively, were close to being statistically significant. The D1 sample was more likely to strongly agree that CBCT information improved clinical diagnosis than the D4 or orthodontic resident samples.

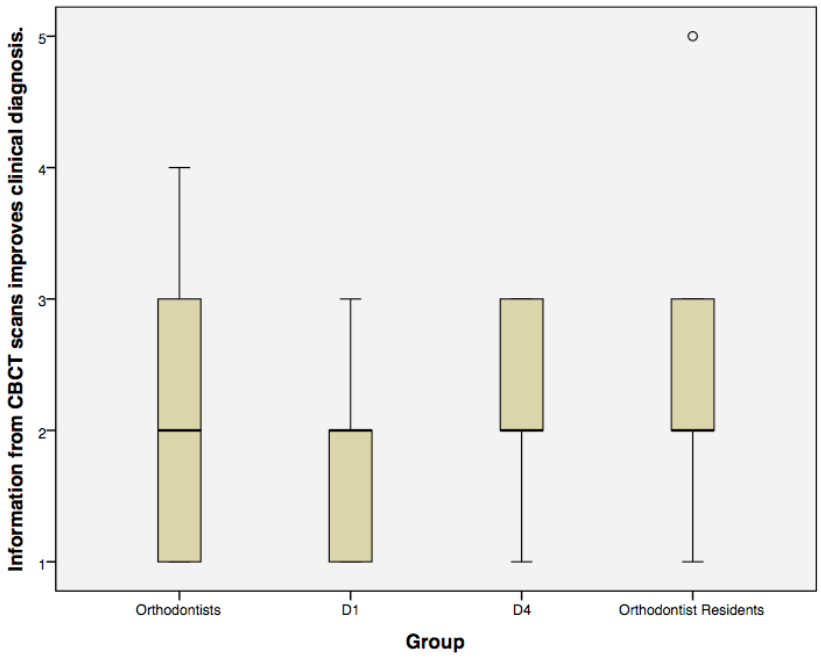

Figure 21. Part 1 Question 6. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

When asked if three-dimensional imaging was essential to dental diagnosis, responses from the D1-orthodontic alumni and D1-orthodontic resident samples differed significantly at 0.007 and 0.032 respectively. The D1 sample tended to affirm that CBCT was essential to dental diagnosis, whereas the orthodontic alumni and residents tended to disagree. (See Figure 22).

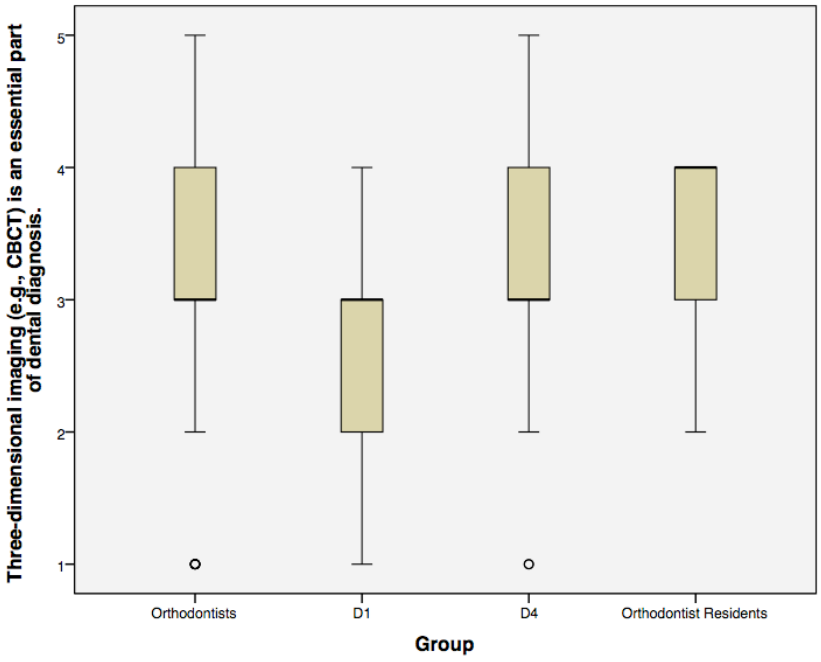

Figure 22. Part 1 Question 7. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

Figure 23 shows the distribution of responses to a question of whether CBCT improves treatment outcomes. Significant differences were found between the D1-orthodontic alumni (0.006) and D1-orthodontic resident (0.002) samples with the D1 sample tending to agree with the statement and the remaining groups more neutral in their responses.

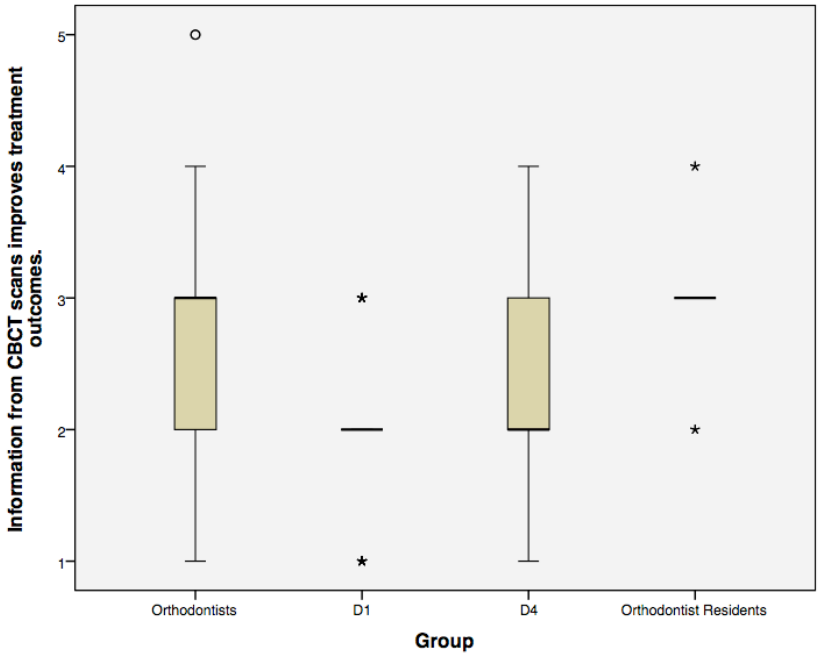

Figure 23. Part 1 Question 8. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

With more experience in the dental industry and a potential for greater understanding of dentistry as a business, orthodontic alumni were less likely to agree that CBCT use makes dentistry more profitable than were D1 or D4 students, with a significance of 0.000 for both orthodontic alumni-D1 and orthodontic alumni-D4 sample comparisons. (See Figure 24).

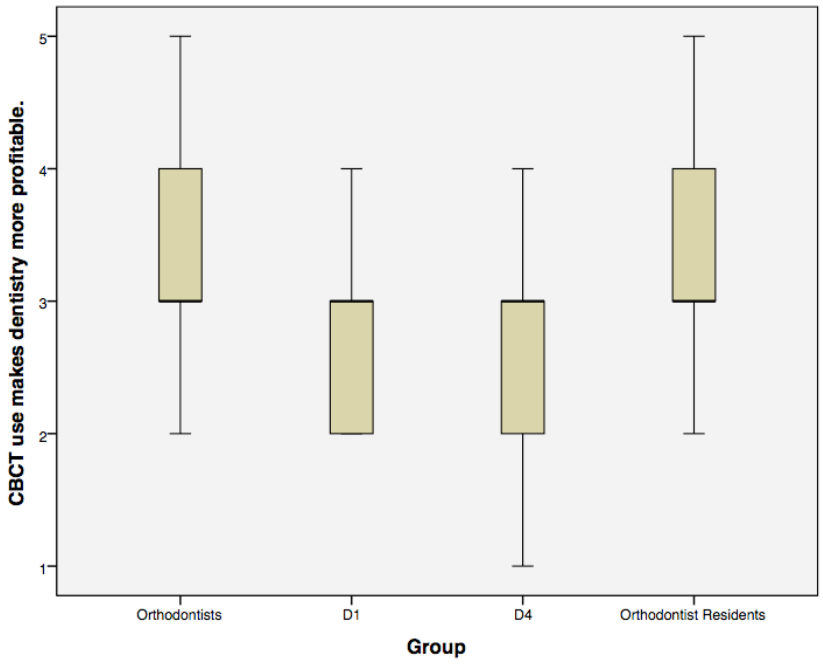

Figure 24. Part 1 Question 9. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

There were no significant differences in agreement among the four groups when asked if a doctor was more likely to prescribe a CBCT if it was located on-site rather than off-site. (See Figure 25).

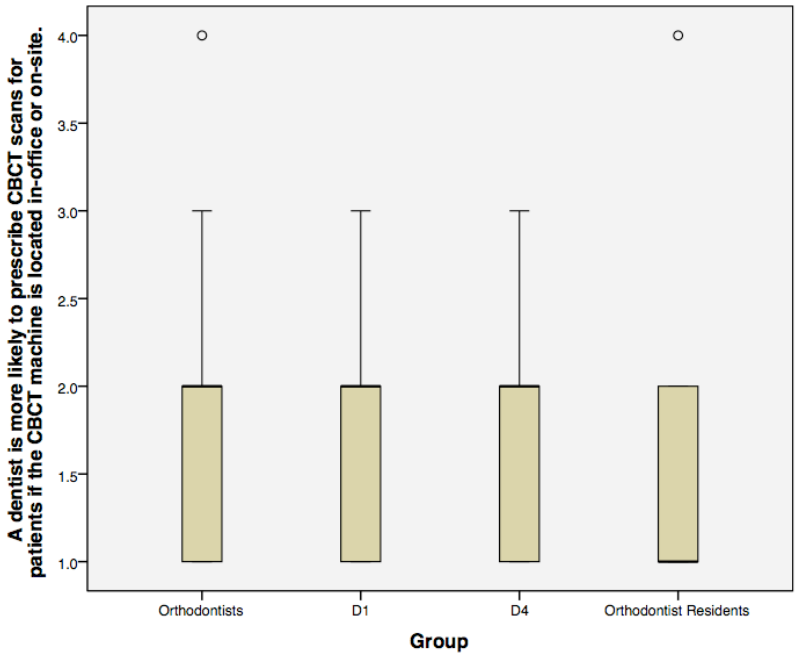

Figure 25. Part 1 Question 10. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

The final question for Part 1 of the CBCT Survey asked respondents to rank four imaging modalities in order of importance to dentistry: CBCT, MRI, Ultrasound, and CT. Significant differences in rankings were noted with CBCT, Ultrasound, and CT. As shown in Figure 26, orthodontic alumni and residents ranked CBCT significantly higher than D1 students (significance levels of 0.000 and 0.033, respectively).

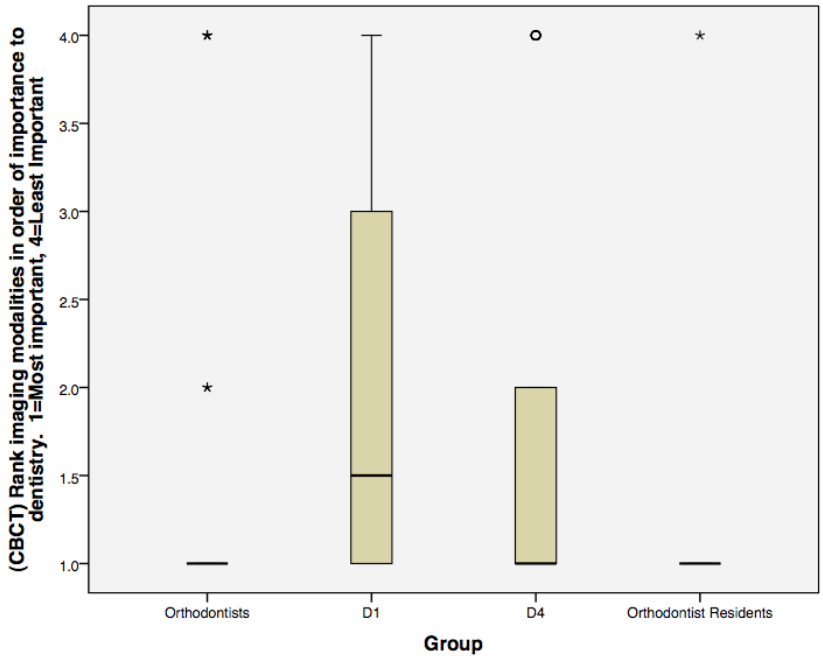

Figure 26. Rank of CBCT. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

There was no significant difference in rankings among all four groups for MRI. (See Figure 27.)

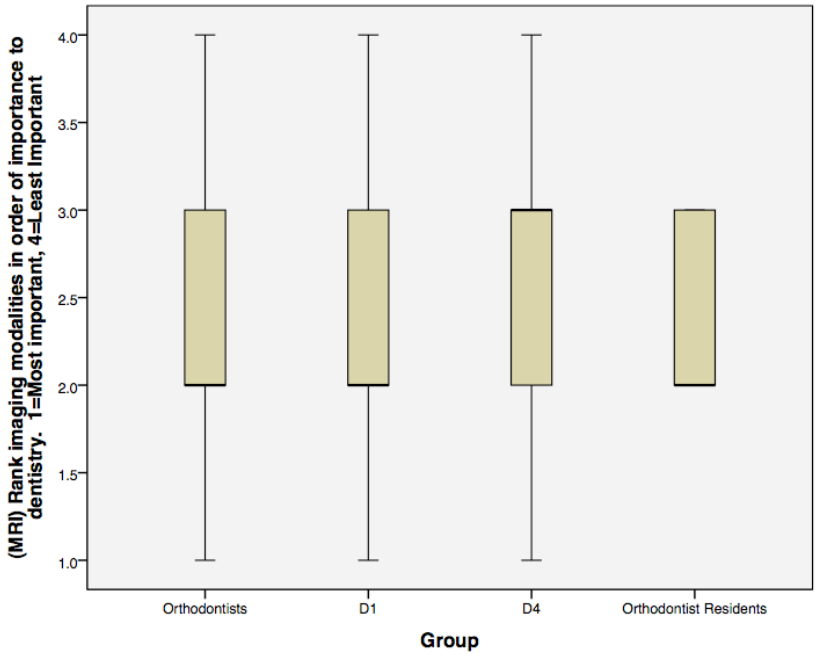

Figure 27. Rank of MRI. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

There were significant differences in rankings of Ultrasound when comparing the D1 sample to the other three samples. (See Figure 28.) The D1 sample tended to rank Ultrasound higher than the other groups. (D1-orthodontic alumni: 0.000, D1-D4: 0.003, D1-orthodontic residents: 0.014)

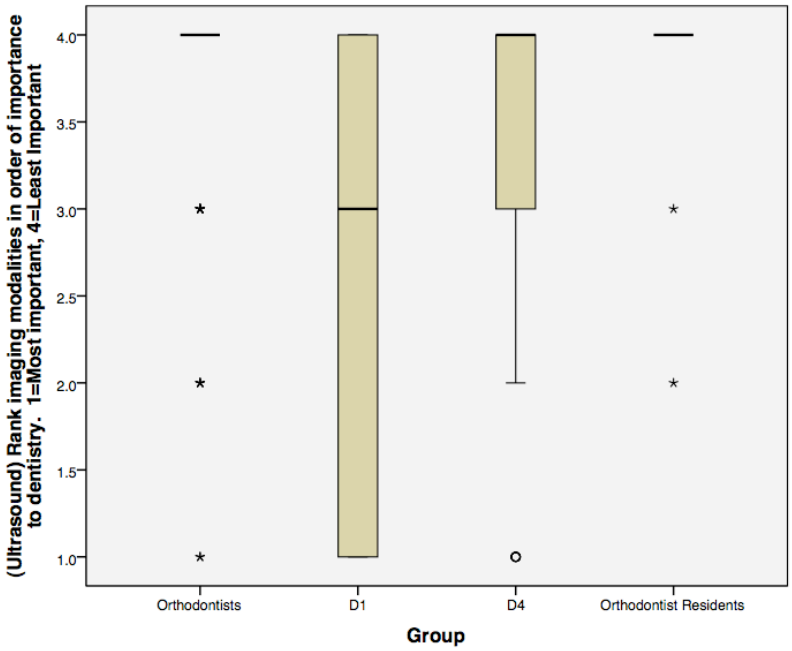

Figure 28. Rank of Ultrasound. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

D1 students differed from the orthodontic alumni and D4 samples when ranking importance of CT as well. Figure 29 shows that D4 and orthodontic alumni samples ranked CT higher than did D1 (significance of 0.038 and 0.002, respectively).

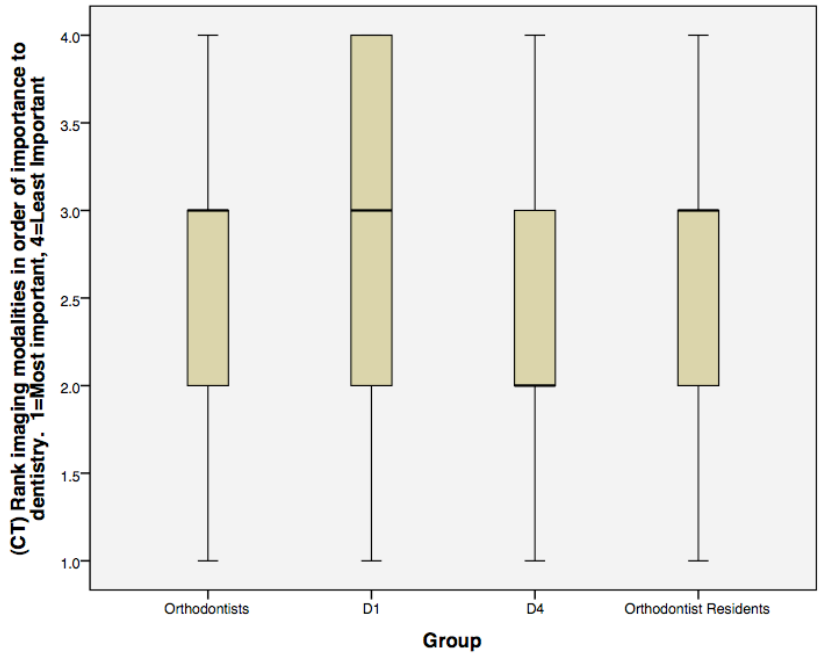

Figure 29. Rank of CT. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents.

Level of education in dentistry and familiarity with CBCT technology affected responses to questions in Part 1 of the CBCT Survey. In some ways, the differences were expected and predictable. In others, the results were enlightening as to how each sample group views the technology and its application in dentistry. Tables with significance levels for all comparisons are found in Appendix F.

CHAPTER FOUR

DISCUSSION

The primary aim of this study was to determine the CBCT awareness level of orthodontists who graduated from Loma Linda University School of Dentistry Orthodontics. Because of the novel nature of the survey, other groups were included in the study to act as reference and to provide context and contrast for the answers supplied by the orthodontists. This study has sought to understand primarily what orthodontists know about CBCT, and secondarily what their opinions are on the implications of increased CBCT use in their discipline and dentistry in general.

To summarize the findings of this study, the sample of orthodontic alumni were largely Caucasian males with about 10 years of reported education after high school. The dental student samples were still male-dominated and mostly Caucasian, but were more heterogeneous in the gender and ethnic categories with Asian being the next largest ethnic group reported. D1 students began with about five years of post-high school education.

The scoring distribution in Part 2 of the CBCT survey approximated our expectations based on clinical and didactic experience. Residents in the orthodontic program scored highest, followed by orthodontic alumni, then the dental students in decreasing order of progress in dental school. The results from Part 2 validated the

survey as an instrument capable of measuring our intended metric, namely awareness of CBCT use in dental patients.

Arbitrary categories based on the received distribution allowed us to categorize good, average, and poor awareness for comparison. The answers to Part 1 of the CBCT survey were all quite similar among the categories in the orthodontic alumni sample. Reasons for this uniformity might include a lack of power in the number in each group of good, average, or poor awareness; questions structured in such a way that they do not parse the differences between orthodontists (i.e., the measuring instrument is not sensitive enough); or general uniformity of opinion among the alumni from the same university. There is potential for more work to be done on this topic.

Although there were not significant differences among the good, average, and poor categories of orthodontic alumni in their responses to Part 1, there were some interesting trends when the demographics of these three categories were compared. Those in the good awareness category were younger, had graduated from residency more recently, and were more apt to be using CBCT on their patients more frequently. It should be mentioned that Loma Linda University School of Dentistry Orthodontics implemented CBCT in their clinic and curriculum in 2001. Thus, those who finished their residency 10 years ago or less were trained in CBCT analysis and use. The good awareness category includes those who graduated less than 10 years ago from the orthodontic program. The average and poor categories contain almost no graduates from less than 10 years ago. A possible confounding variable for this finding include a sampling error or bias based on who chose to answer the survey (i.e., those who had more experience and education with CBCT were more likely to complete the survey).

Aside from the uniformity of the orthodontic alumni sample, there were some differences in response to Part 1 questions between orthodontic alumni and residents and D1 and D4 students illustrated in this paper. The larger the disparity between scores on Part 2, the more likely it was to find different responses to the questions posed in Part 1. The D1 sample in general differed more from the other three groups when examining responses to Part 1 questions. Education and knowledge of CBCT seem to inform the opinions reported in Part 1. Although there were statistically significant differences among some groups, all groups had similar responses when asked about informed consent and discussing radiation dosage with patients. The utility of CBCT in diagnosis and improving treatment outcomes as well as profitability of CBCT was perceived differently by orthodontists and D1 students with dental students overestimating the worth and profitability of CBCT related to orthodontists. A disparity in understanding other imaging modalities and their relationship to dentistry and orthodontics was noted between these groups as well.

The data generated by the survey contain possibilities for additional analysis. The data supplied by this survey will allow further investigation into the validity of the questions, the ability to predict responses based on certain questions, and identification of trends based on demographic metrics such as age, education level, gender, ethnicity, overall and dental health, and others. A variety of other hypotheses and questions could be explored with these data.

One such line of further investigation could be related to informed consent. Orthodontic alumni, resident, and D1 and D4 samples tended to agree that informed consent was a necessary part of a CBCT survey (See Figure 30.) In light of the similarity

of convictions among all the samples, it would be telling to determine what the profession perceives the thresholds of risk to be for informed consent, if the risk from CBCT warrants a verbal and/or written informed consent, and to what extent the orthodontists who think informed consent is necessary are actually obtaining it prior to ordering CBCT surveys on their patients.

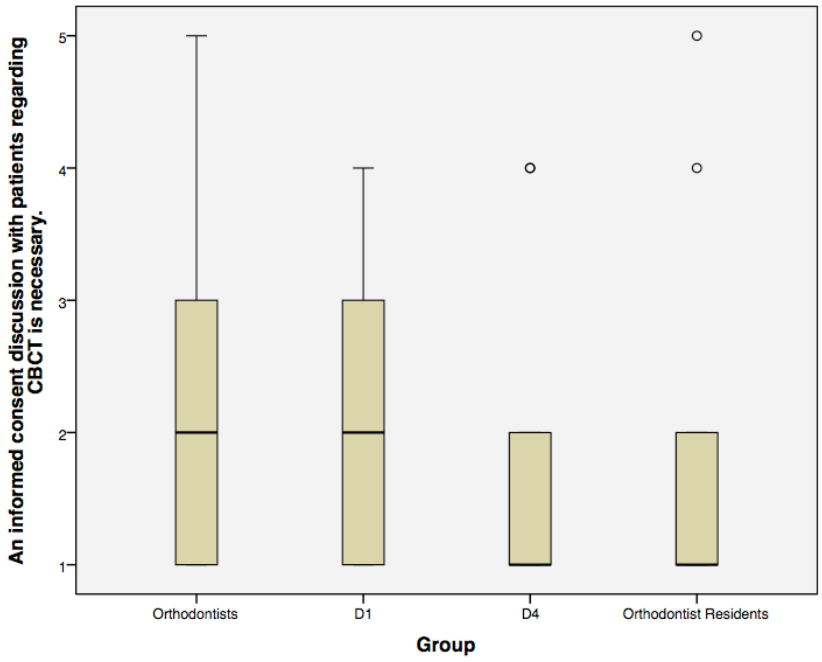

Figure 30. Comparison of responses of orthodontic alumni, D1 students, D4 students, and orthodontic residents regarding CBCT and informed consent.

Other work to be done could include further validation and calibration of questions, especially those in Part 2. Such calibration might be achieved by the circulation of these questions to a wider audience, such as dental radiologists (who would certainly be able to contribute to improving the clarity and intent of each question), oral and maxillofacial surgeons, implantologists, endodontists, medical colleagues in

radiology, patient populations, and others. The results from each of these groups will help refine the measuring instrument and help us better understand how each of these groups perceives CBCT technology.

Alternatively, specifically targeting a certain population will allow the refinement of questions based on that specific group. A challenge encountered in this study was creating a set of questions that were not too simple for the specialists and not too complex for the college graduate. It may be impossible to create a survey with sensible technical questions that is understood by both oral and maxillofacial radiologists as well as patients, for example, with the disparity between levels of specialized education being so great. However, the ability to compare responses between various populations may be lost in this case.

It would behoove the profession to facilitate the evolution of an instrument capable of measuring the basic knowledge needed to safely and effectively apply sound radiographic principles to the use of CBCT in dental patients, and to also determine what sort of non-technical convictions and values drive orthodontists to embrace or ignore new technologies. To have the evolution of imaging in the dental profession driven by market influences, sales tactics, insurance coverage plans, perceived or real legal and liability issues, and turf wars among medical and dental professionals would be unfortunate. Members of the profession should be clear on the implications of the technologies they decide to use on their patients, and how and why they choose to implement them. Such clarity can be estimated by a calibrated and widely circulated set of questions. One of the intentions of this paper is to begin that process.

CHAPTER FIVE

CONCLUSIONS

- Scoring distribution on Part 2 of the CBCT survey related positively to level of dental education, confirming the ability of the Part 2 questions to measure CBCT knowledge.
- Good, average, and poor categories of orthodontic alumni based on scoring of Part 2 questions answered Part 1 questions similarly.
- Good, average, and poor groups of orthodontic alumni based on scoring of Part 2 questions differed significantly in several demographic categories, including age, years since residency completion, and frequency of CBCT use. Younger orthodontic alumni who had finished residency more recently and who used CBCT more frequently were more likely to score well on Part 2 questions.
- Significant differences between samples of orthodontic alumni, residents, D1, and D4 students were found on most Part 1 questions. The larger disparity in educational levels among these groups resulted in larger scoring differences in both Part 2 and Part 1 survey questions, leading us to conclude that technical, objective knowledge of CBCT relates to value judgments about the implications of CBCT technology to patient care.

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APPENDIX A

INFORMED CONSENT

To: [Email]
From: wlibby@llu.edu

Subject: LLU Orthodontic Research Survey
Body: Loma Linda University School of Dentistry
Department of Orthodontics
159 West Hospitality Lane, Suite 200
San Bernardino, CA 92408
909.558.4616

Dear Dr. [LastName],

As a dental professional, you are invited to participate in a survey about cone-beam computed tomography (CBCT) use in dentistry. The purpose of this student research project is to better understand how dental professionals, like you, perceive and use CBCT.

Participation in this study involves answering questions about CBCT applications in the dental and orthodontic professions and will take approximately 10 minutes. Whether or not you participate is entirely voluntary, and will not affect your relationship with Loma Linda University, Department of Orthodontics.

There is a risk of breach of confidentiality; however surveymonkey's software ensures this risk is minimal. If you wish to participate, please finish reading this letter and click on the link provided. A random identification number will be associated with your email address for the sole purpose of identifying the winner of a drawing for an Apple iPad. Completion of the survey confirms entrance in the drawing. Your email will not be linked to your responses. The winner of the iPad will be notified via email.

You will have four weeks from today to complete the survey.

Although you may not benefit directly from this study, the information provided will potentially benefit dental patients and practitioners who use or are considering using CBCT.

You may contact an impartial third party not associated with this study regarding any question or complaint by calling 909.558.4647 or e-mailing patientrelations@llu.edu for information and assistance.

Thank you in advance for giving consideration to this invitation. If you have any questions, please email at wlibby@llu.edu or call 909.844.7013.

By clicking on the link provided you will be giving your consent to participate. This link is uniquely tied to this survey and your email address. Please do not forward this message. Here is the link:
https://www.surveymonkey.com/s.aspx

Sincerely,

Warren Libby, DDS, MA
Student Investigator

V. Leroy Leggitt, DDS, MS, PhD
Principal Investigator

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APPENDIX B

SURVEY AS FORMATTED FOR WEB DISTRIBUTION

CBCT Awareness Assessment: D1

1. Part 1

For each question below, select the option that best fits your opinion on the importance of the issue.

*** 1. An informed consent discussion with patients regarding CBCT is necessary.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 2. It is necessary for a dentist to discuss CBCT radiation exposure with patients.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 3. The dental applications of CBCT are consistent with the radiologic principle As Low As Reasonably Achievable (ALARA).**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 4. A clinical exam by the dentist should always precede dental radiographs.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 5. It is important for dentists to avoid redundant radiographs.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 6. Information from CBCT scans improves clinical diagnosis.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 7. Three-dimensional imaging (e.g., CBCT) is an essential part of dental diagnosis.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 8. Information from CBCT scans improves treatment outcomes.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 9. CBCT use makes dentistry more profitable.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

*** 10. A dentist is more likely to prescribe CBCT scans for patients if the CBCT machine is located in-office or on-site.**

Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

Page 1

CBCT Awareness Assessment: D1

*** 11. Rank imaging modalities in order of importance to dentistry.**
1=Most important, 4=Least Important

	1	2	3	4
CBCT	○	○	○	○
MRI	○	○	○	○
Ultrasound	○	○	○	○
CT	○	○	○	○

2. Part 2

For each question below, select the most appropriate answer.

*** 1. A 10 year old child and a 50 year old adult exposed to the same dose of ionizing radiation incur the same risk of developing cancer.**

○ True ○ False ○ Don't Know

*** 2. The biologic effects of low-dose radiation exposure are cumulative.**

○ True ○ False ○ Don't Know

*** 3. There is a link between radiation in medical tests and risk of developing cancer.**

○ True ○ False ○ Don't Know

*** 4. A typical CBCT scan exposes a patient to more radiation than a typical hospital CT scan.**

○ True ○ False ○ Don't Know

*** 5. A typical CBCT scan exposes a patient to less radiation than a typical Magnetic Resonance Imaging (MRI) scan.**

○ True ○ False ○ Don't Know

*** 6. Radiation exposure from a typical digital dental panoramic radiograph is higher than from a typical CBCT scan.**

○ True ○ False ○ Don't Know

*** 7. The combined radiation exposure from a typical digital dental panoramic radiograph and a digital 20-film full mouth series is roughly equivalent to a typical CBCT scan.**

○ True ○ False ○ Don't Know

CBCT Awareness Assessment: D1

*** 8. Excessive radiation dosage during a CBCT scan worsens the final image quality.**

○ True ○ False ○ Don't Know

*** 9. CBCT data can be used to replace conventional lateral cephalograms.**

○ True ○ False ○ Don't Know

*** 10. CBCT data can be used to replace conventional panoramic radiographs.**

○ True ○ False ○ Don't Know

3. Demographic Information

Please answer all applicable questions.

*** 1. Gender**

○ Male

○ Female

*** 2. Ethnicity**

*** 3. Age**

*** 4. Years of Education After High School**

*** 5. Occupation**

*** 6. Rate your general health.**

*** 7. Rate your dental health.**

*** 8. Years since completion of residency or dental school.**

*** 9. Number of CBCT scans ordered per month.**

CBCT Awareness Assessment: D1

* **10. Percentage of patients who receive CBCT scans.**

* **11. CBCT located:**

* **12. Specialty**

* **13. Who interprets CBCT data?**

APPENDIX C

TABLE OF GENDER DISTRIBUTION OF SAMPLES

Group		Frequency	Percent
Orthodontic	Missing	3	4.4%
Alumni	Female	4	5.9%
	Male	61	89.7%
	Total	68	100.0%
D1	Female	11	32.4%
	Male	23	67.6%
	Total	34	100.0%
D2	Female	11	33.3%
	Male	22	66.7%
	Total	33	100.0%
D3	Female	14	36.8%
	Male	25	63.2%
	Total	38	100.0%
D4	Female	8	19.5%
	Male	33	80.5%
	Total	10	100.0%
Orthodontic	Female	5	45.5%
Residents	Male	6	54.5%
	Total	11	100.0%

APPENDIX D

TABLE OF ETHNIC DISTRIBUTION OF SAMPLES

Group		Frequency	Percent
Orthodontic Alumni	Missing	3	4.4%
	African-American/Black	0	0.0%
	Asian	8	11.8%
	Caucasian	54	79.4%
	Hispanic/Latino	1	1.5%
	Other	2	2.9%
	Total	68	100.0%
D1	Missing	0	0.0%
	African-American/Black	1	2.9%
	Asian	14	41.2%
	Caucasian	18	52.9%
	Hispanic/Latino	0	0.0%
	Other	1	2.9%
	Total	34	100.0%
D2	Missing	0	0.0%
	African-American/Black	2	6.1%
	Asian	11	33.3%
	Caucasian	18	54.5%
	Hispanic/Latino	1	3.0%
	Other	1	3.0%
	Total	33	100.0%
D3	Missing	0	0.0%
	African-American/Black	1	2.6%
	Asian	15	39.5%
	Caucasian	17	44.7%
	Hispanic/Latino	3	7.9%
	Other	2	5.3%
	Total	38	100.0%
D4	Missing	0	0.0%
	African-American/Black	2	4.9%
	Asian	12	29.3%
	Caucasian	23	56.1%
	Hispanic/Latino	2	4.9%
	Other	2	4.9%
	Total	41	100.0%
Orthodontic Residents	Missing	0	0.0%
	African-American/Black	0	0.0%

Asian	3	27.3%
Caucasian	8	72.7%
Hispanic/Latino	0	0.0%
Other	0	0.0%
Total	11	100.0%

APPENDIX E

TABLE OF EDUCATIONAL DISTRIBUTION OF SAMPLES

Group	Years Education Since High School	Frequency	Percent
Orthodontic	Missing	3	4.4%
Alumni	6	1	1.5%
	9	5	7.4%
	10	32	47.1%
	11	10	14.7%
	12	6	8.8%
	13	4	5.9%
	14	1	1.5%
	15	6	8.8%
	Total	68	100.0%
D1	4	5	14.7%
	5	14	41.2%
	6	7	20.6%
	7	1	2.9%
	8	5	14.7%
	10	1	2.9%
	11	1	2.9%
	Total	34	100.0%
D2	4	1	3.0%
	5	2	6.1%
	6	14	42.4%
	7	4	12.1%
	8	8	24.2%
	10	2	6.1%
	15	2	6.1%
	Total	33	100.0%

D3	4	1	2.6%
	5	1	2.6%
	6	7	18.4%
	7	12	31.6%
	8	7	18.4%
	9	6	15.8%
	10	3	7.9%
	11	1	2.6%
	Total	38	100.0%
D4	4	2	4.9%
	6	1	2.4%
	7	1	2.4%
	8	26	63.4%
	9	4	9.8%
	10	5	12.2%
	11	1	2.4%
	15	1	2.4%
	Total	41	100.0%
Orthodontic	9	3	27.27%
Residents	10	3	27.27%
	11	1	9.09%
	12	2	18.18%
	13	1	9.09%
	15	1	9.09%
	Total	11	100.00%

APPENDIX F

TABLE OF DIFFERENCES TO PART 1 QUESTIONS AMONG ORTHODONTIC ALUMNI, ORTHODONTIC RESIDENTS, D1, AND D4 STUDENTS

	Groups	Significance
Question 1	Orthodontic Alumni-D1	1.000
	Orthodontic Alumni-D4	0.027
	Orthodontic Alumni-Orthodontic Residents	0.664
	D1-D4	0.068
	D1-Orthodontic Residents	0.707
	D4-Orthodontic Residents	1.000
Question 2	Orthodontic Alumni-D1	1.000
	Orthodontic Alumni-D4	0.601
	Orthodontic Alumni-Orthodontic Residents	0.998
	D1-D4	0.412
	D1-Orthodontic Residents	0.689
	D4-Orthodontic Residents	1.000
Question 3	Orthodontic Alumni-D1	1.000
	Orthodontic Alumni-D4	0.046
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	0.641
	D1-Orthodontic Residents	1.000
	D4-Orthodontic Residents	0.646
Question 4	Orthodontic Alumni-D1	0.832
	Orthodontic Alumni-D4	0.441
	Orthodontic Alumni-Orthodontic Residents	0.590
	D1-D4	0.027
	D1-Orthodontic Residents	0.090
	D4-Orthodontic Residents	1.000
Question 5	Orthodontic Alumni-D1	0.738
	Orthodontic Alumni-D4	1.000
	Orthodontic Alumni-Orthodontic Residents	0.265
	D1-D4	1.000
	D1-Orthodontic Residents	0.031
	D4-Orthodontic Residents	0.177
Question 6	Orthodontic Alumni-D1	0.485
	Orthodontic Alumni-D4	1.000
	Orthodontic Alumni-Orthodontic Residents	0.586
	D1-D4	0.099
	D1-Orthodontic Residents	0.057
	D4-Orthodontic Residents	1.000
Question 7	Orthodontic Alumni-D1	0.007

	Orthodontic Alumni-D4	1.000
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	0.113
	D1-Orthodontic Residents	0.032
	D4-Orthodontic Residents	1.000
Question 8	Orthodontic Alumni-D1	0.006
	Orthodontic Alumni-D4	1.000
	Orthodontic Alumni-Orthodontic Residents	0.480
	D1-D4	0.168
	D1-Orthodontic Residents	0.002
	D4-Orthodontic Residents	0.157
Question 9	Orthodontic Alumni-D1	0.000
	Orthodontic Alumni-D4	0.000
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	1.000
	D1-Orthodontic Residents	0.186
	D4-Orthodontic Residents	0.126
Question 10	Orthodontic Alumni-D1	1.000
	Orthodontic Alumni-D4	1.000
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	1.000
	D1-Orthodontic Residents	1.000
	D4-Orthodontic Residents	1.000
Rank of CBCT	Orthodontic Alumni-D1	0.000
	Orthodontic Alumni-D4	0.131
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	0.121
	D1-Orthodontic Residents	0.033
	D4-Orthodontic Residents	1.000
Rank of MRI	Orthodontic Alumni-D1	1.000
	Orthodontic Alumni-D4	0.268
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	0.528
	D1-Orthodontic Residents	1.000
	D4-Orthodontic Residents	0.768
Rank of Ultrasound	Orthodontic Alumni-D1	0.000
	Orthodontic Alumni-D4	1.000
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	0.003
	D1-Orthodontic Residents	0.014
	D4-Orthodontic Residents	1.000
Rank of CT	Orthodontic Alumni-D1	0.955
	Orthodontic Alumni-D4	0.038
	Orthodontic Alumni-Orthodontic Residents	1.000
	D1-D4	0.002
	D1-Orthodontic Residents	1.000
	D4-Orthodontic Residents	0.713