Endodontics Program Directors', Residents', and Endodontists' Considerations About CBCT-Related Graduate Education

Hooman Rabiee, Neville J. McDonald, Reinhilde Jacobs, Alireza Aminlari, Marita R. Inglehart

Abstract: Over the past decade, cone beam computed tomography (CBCT) has been increasingly used by endodontists. The aims of this study were to assess endodontic program directors', residents', and endodontists' considerations concerning CBCT-related graduate education, attitudes, and professional behavior. Survey data were collected from 31 of the 56 directors of U.S. endodontic graduate programs, 73 of 270 contacted residents, and 689 of 2,221 contacted endodontists (response rates 55%, 27%, and 31%, respectively). Ten of the 31 responding programs did not offer a CBCT-related class. Of the 21 programs that offered a CBCT class, 91% of the program directors and 85% of the residents agreed strongly that future endodontists need training to be able to use CBCT. Residents were less satisfied than directors with the way CBCT was taught (on a five-point scale with 1=most negative: 3.26 vs. 4.37; $p<0.001$) and the quality of their clinical CBCT-related education (3.75 vs. 4.62; $p<0.001$). Both groups strongly agreed that there is a need for CBCT training in endodontics (4.81 vs. 4.90). Endodontists reported being less well educated than residents about CBCT in classroom-based (2.02 vs. 2.70; $p<0.001$) and clinical graduate education settings (2.09 vs. 2.97; $p<0.001$) and wanted more CBCT-related education in endodontic programs (4.37 vs. 3.18; $p<0.001$). Yet, they reported being more confident than residents in interpreting CBCT scans (3.57 vs. 2.75; $p<0.001$) and rated themselves more positively as having sufficient clinical experience (3.76 vs. 2.92; $p<0.001$) to be competent in utilizing CBCT. These findings about residents' and practicing endodontists' CBCT-related considerations suggest that endodontic program directors should add more CBCT-related education.

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A revolution in dental-maxillofacial imaging occurred when cone beam computed tomography (CBCT) was introduced into dentistry in 1998 by Mozzo et al.[1] CBCT is a three-dimensional (3D) imaging modality. It essentially involves imaging a volume that allows either the entire maxillofacial skeleton (large field of view) or a restricted dento-alveolar region involving a few teeth (small field of view) to be imaged. The U.S. Food and Drug Administration approved the first CBCT unit for dental use in the U.S. in 2001.[2] Since then, there has been a rapidly growing interest in CBCT and its maxillofacial imaging applications, and its use has spread widely in different oral health specialties. For example, in oral surgery and periodontics, CBCT is a valuable tool for diagnosing and treating oral cancer, accurately planning implants, and evaluating bone levels; in orthodontics, CBCT has been used to augment or replace traditional two-dimensional (2D) radiographs.[3-5]

In endodontics, CBCT use is exceptionally helpful in at least eight ways. First, it allows locating/identifying the anatomy of calcified canals.[6,7] Second, CBCT is able to locate 62% more apical lesions than

periapical radiographs[8] and can show both the position and the extent of the periapical lesion.[9] Third, while it is almost impossible to identify whether there is resorption and, if so, the type of resorption with periapical radiographs, CBCT allows recognizing the type of the resorption and thus allows planning the correct endodontic and restorative treatment.[10,11] Fourth, while CBCT does not always show a root fracture and can hardly visualize a crack, it provides information about five indirect radiologic findings on the CBCT that are consistent with confirmed vertical root fractures.[12] The fifth beneficial application of CBCT in endodontic practice is related to endodontic treatment planning for apical root resection since CBCT is an excellent aid for treatment planning and evaluating the anatomy of the root apex and the neighboring pathosis prior to endodontic surgery.[13] Sixth, while a broken instrument can be visualized on a periapical radiograph in the mesio-distal direction, CBCT allows localizing it to be identified in the bucco-lingual direction.[14] Seventh, CBCT can help to localize perforations, which enables endodontists to manage perforations with more successful outcomes.[15] Finally, the use of CBCT contributes to successful auto-transplantations of teeth.[16-18] In addition, lesions in cancellous bone cannot be consistently detected with periapical radiographs but can be identified with CBCT.[19] In summary, research has shown quite convincingly that CBCT use can be beneficial for endodontic diagnosis, treatment planning, and treatments.

Given this exceptionally helpful use of CBCT in dentistry, it is not surprising that some dental schools in the U.S. and in European countries such as the United Kingdom, Belgium, Sweden, Germany, and Spain, as well as in other parts of the world such as in Turkey and India, already educate their students about CBCT and that other dental schools in these countries consider doing so.[20-26] In addition, studies have found that CBCT use was taught in dental graduate programs such as orthodontic residency programs,[5,27-31] oral and maxillofacial surgery programs[32,33] and oral radiology programs.[34-36] However, despite the extensive evidence concerning the benefits of CBCT use in endodontics, no prior studies have explored whether CBCT-related education is provided in endodontic residency programs in the U.S. The aims of this study were therefore to assess endodontic program directors', residents', and endodontists' considerations concerning CBCT-related graduate education, attitudes, and professional behavior.

Methods

The Health Sciences and Behavioral Sciences Institutional Review Board (IRB) at the University of Michigan determined on September 26, 2016, that this study was exempt from IRB oversight (#HUM00120664). Data were collected from 31 of the 56 directors of endodontic graduate programs in the U.S. (response rate 55%). The American Association of Endodontists (AAE) provided email addresses of 270 of the 544 residents in endodontic graduate programs in academic year 2016-17. After recruitment emails were sent to these 270 residents, 73 responses were received (response rate 27%). The AAE also made available postal addresses for its 4,100 members. A postal mailing to 2,221 members resulted in 689 returned surveys (response rate 31%).

The program director of the endodontic graduate program at the University of Michigan (NJM, second author) sent a recruitment email in October 2016 and a follow-up email in March 2017 to program directors of the 56 endodontic residency programs in the U.S. This email informed them about the study and provided a link to an anonymous web-based survey. In March 2017, the first author (HR), who was at the time a resident in an endodontic program, sent a first recruitment email to the 270 residents in the U.S. endodontic programs for whom email addresses were provided by the AAE. A follow-up email was sent in May 2017. Both emails informed the residents about the study and asked them to respond to an anonymous web-based survey that they could access with a link provided in the email. Seventy-three residents responded. In addition, 2,261 surveys were mailed to practicing endodontists whose addresses were provided by the AAE. Forty of these envelopes were returned due to delivery issues. Of the successfully mailed 2,221 surveys, 689 were returned.

Three questionnaires were developed for the three respondent groups. The draft of the program director survey was piloted with five endodontic faculty members; the draft of the resident survey was discussed with a resident; and the draft of the survey for the practicing endodontists was piloted with five practicing endodontists. The feedback was carefully considered, and final versions of the three surveys were then prepared.

The program director survey consisted of four parts. Part 1 asked for information about the program characteristics and whether the program offered a formal course in CBCT. The respondents from

those programs that did not offer a CBCT course then responded to questions in Part 2 that inquired about the reasons for not doing so and their attitudes concerning CBCT-related education for endodontic residents. The respondents whose programs offered a CBCT course answered the questions in Part 3. Those questions inquired about the way residents were educated about CBCT use and their attitudes related to CBCT-related graduate education. The final part for all respondents consisted of eight questions that inquired about CBCT-related educational experiences and 14 attitudinal questions. The resident survey consisted of three parts. Part 1 asked about the characteristics of their endodontic residency program; Part 2 inquired about their CBCT-related education; and the final part asked about their CBCT-related attitudes.

The survey for the practicing endodontists also consisted of four parts. Part 1 inquired about respondents' educational background and their practice characteristics; Part 2 asked questions about their CBCT-related education in dental school, residency programs, and continuing education efforts; Part 3 consisted of questions about attitudes toward CBCT use; and the final part inquired about CBCT use in their private clinical practice. Most of the attitudinal items were the same in all three surveys to allow for group comparisons.

The data were analyzed with SPSS (Version 22.0, IBM Corp., Armonk, NY, USA). Descriptive statistics such as frequency distributions, percentages, and means were computed to provide an overview of the responses. Inferential statistics, specifically independent sample t-tests, were used to test whether the mean answers of the directors vs. residents and of the residents vs. practicing endodontists differed significantly. A significance level of $p<0.05$ was accepted.

Results

Table 1 provides an overview of the response rates of the three groups of respondents and the characteristics of the endodontic residency programs that directors, residents, and clinicians had been part of. Most of the programs were in dental school settings (directors 77%, residents 86%). The length of the programs ranged from 24 to 36 months for the director-described programs and the residents' programs. The practicing endodontists' program length ranged from 15 to 48 months. Most programs were located in a suburb/large city (directors 62%, endodontists 58%) or in a moderately sized city (32%, 35%).

Ten of the 31 program directors reported that they did not offer a course about CBCT. Nine of these directors answered follow-up questions aimed at exploring why their program did not offer this education (Table 2). All responding directors disagreed strongly with the statement "Patients do not benefit from the use of CBCT for their endodontic treatment"; eight strongly agreed and one agreed with the statement "Future endodontists need to be able to use CBCT." Five program directors agreed/agreed strongly that other programs in their institution provided this service, while three disagreed strongly with this statement. Five directors disagreed/disagreed strongly that none of their endodontic faculty members were qualified to teach about CBCT; seven disagreed/disagreed strongly that there was not enough time in their program to teach about CBCT; and eight disagreed/disagreed strongly that they did not have the facilities to safely provide CBCT. When asked if they planned to add a CBCT course in the future, four of the eight responding directors answered "yes," and four answered "maybe."

Table 3 provides an overview of the responses of the 21 program directors who did offer a separate course about CBCT. When asked about when the course had been added to their curriculum, the answers ranged from two to eight years (mean 4.37 years, SD 2.006). Tuition had not increased in any of the programs due to CBCT use. The frequency with which the residents in these programs used CBCT in clinical settings ranged widely from only a few times a month to more than once a day.

Several Likert scale questions inquired about the program directors' thoughts concerning CBCT education. All program directors agreed/agreed strongly that residents were motivated to learn about CBCT, that future endodontists should be educated about CBCT, and that they have excellent faculty to instruct their students about CBCT use (Table 3). About 90% agreed/agreed strongly that they were very satisfied with the way CBCT was taught in their residency program and also with their clinical education; that their residents had sufficient clinical experiences to be competent in using CBCT; that upon graduation most of their residents would use CBCT in their practice; and that their graduates were confident about interpreting CBCT images.

Table 4 provides an overview of the residents' responses concerning their CBCT-related education.

Table 1. Overview of respondents' program characteristics

Characteristic	Directors N=31	Residents N=73	Endodontists N=688
Number	Programs	Residents	Endodontists
In U.S.	56	544	4,100
Contacted	56	270	2,221
Responded	31	73	688
Response rate	55%	27%	31%
Location in U.S.: number of states	n/a	n/a	43 & military
Year of program			
First	n/a	30 (42%)	n/a
Second		36 (51%)	
Third		5 (7%)	
Program setting			
Dental school	23 (77%)	63 (86%)	n/a
Hospital-based	4 (13%)	2 (3%)	
Armed services	3 (10%)	5 (7%)	
Degree granted			
Certificate	24 (77%)	61 (84%)	n/a
Master's degree	22 (71%)	38 (52%)	
Ph.D.	2 (7%)	0	
Average number of students per year	4.0	n/a	n/a
SD	1.912		
Range	2-10		
Length of program in months: mean	26.81	26.47	25.39
SD/range	4.549/24-36	4.337/24-36	3.924/15-48
Number of clinical instructors			
Full-time: mean	3.35	n/a	n/a
SD/range	1.684/1-7		
Part-time: mean	6.97		
SD/range	5.089/0-18		
Average % of patients covered by			
Medicaid	30%	n/a	7%
Insurance	25%	n/a	57%
Private pay	32%	n/a	25%
Location of program			
Rural (<5,000)	0	n/a	3 (0.4%)
Small town/city (5,000-24,999)	1 (3%)		45 (7%)
Moderate-sized city (25-250k)	10 (32%)		240 (35%)
Suburb near large city	2 (7%)		195 (29%)
Large city	17 (55%)		195 (29%)

Only 49% (N=36) reported that a CBCT course was part of their graduate program. The number of hours of classroom teaching ranged from zero to 90 (mean 12.91). The frequency of CBCT use by residents in clinical settings ranged from a few times a month to more than once a day. When asked to express their disagreement/agreement with statements about their CBCT-related education, the majority agreed/strongly agreed that future endodontists should be educated about CBCT (96%); that more education about CBCT use was needed in their own endodontic program (78%); and that they will use CBCT in their own practices after graduation (96%). Among the respondents, 69% agreed/strongly agreed that their program had excellent instructors to teach CBCT use, and 57% reported that they were very satisfied with their clinical education about CBCT use. However, only 39% were satisfied with their classroom-based education about CBCT use.

Table 5 compares the mean responses of the program directors and the residents concerning their CBCT-related education and patient-related consider-

Table 2. Responses of program directors who did not offer a separate course about cone beam computed tomography (CBCT), by number of respondents (N=9)

Statement	1	2	3	4	5	Mean SD
Future endodontists need to be able to use CBCT.	0	0	0	1	8	4.89 0.333
Other programs in our institution provide this service.	3	0	0	4	1	3.00 1.690
None of our endodontic faculty is qualified to teach about CBCT.	3	2	3	0	0	2.00 0.926
There is not enough time in our program to teach about CBCT.	4	3	1	0	0	1.63 0.744
We do not have the facilities to safely provide CBCT.	7	1	0	0	0	1.13 0.354
Patients do not benefit from the use of CBCT for their endodontic treatment.	9	0	0	0	0	1.00 0.000

Note: Response options were 1=disagree strongly, 2=disagree, 3=neutral, 4=agree, and 5=agree strongly. One respondent skipped four of the six items.

Table 3. Responses of program directors who offered a separate course about cone beam computed tomography (CBCT), by percentage of respondents (N=21)

Item	1	2	3	4	5	Mean SD
Frequency of CBCT use by residents in clinical setting[a]	0	13%	27%	13%	47%	3.93 1.143
Statement[b]						
Residents are motivated to learn about CBCT.	0	0	0	5%	95%	4.95 0.218
Future endodontists should be educated about CBCT.	0	0	0	10%	91%	4.90 0.301
We have excellent faculty to instruct our students about CBCT use.	0	0	0	29%	71%	4.71 4.63
Our residents have sufficient clinical experiences to be competent in using CBCT.	0	0	10%	14%	76%	4.67 0.658
Upon graduation, most residents will use CBCT in their practice.	0	0	10%	29%	62%	4.52 0.680
I am very satisfied with the way CBCT is being taught in our residency program.	0	0	9%	38%	57%	4.52 0.602
Our graduates are confident about interpreting CBCT images.	0	0	10%	33%	57%	4.48 0.680
I am very satisfied with the clinical education we provide for our residents about CBCT use.	0	0	5%	29%	67%	4.62 0.590

[a]Response options were 1=never, 2=a few times a month, 3=a few times a week, 4=once a day, and 5=more than once a day.
[b]Response options were 1=disagree strongly, 2=disagree, 3=neutral, 4=agree, and 5=agree strongly.

ations. On average, both groups agreed very strongly that there is a need for CBCT use in endodontics (on a five-point scale with 5=agree strongly: 4.90 vs. 4.81; p=0.088) and that, after graduation, residents will use CBCT in their own practice (4.60 vs. 4.63; p=0.823). However, residents were on average less satisfied with the way CBCT was taught in their residency program (3.26 vs. 4.37; p<0.001) and with their clinical education about CBCT (3.75 vs. 4.53; p<0.001) when their answers were compared to those of the program directors.

Both groups responded on average in a neutral way to the statement that CBCT is expensive for patients (residents 3.13 vs. directors 2.71; p=0.091) and to the statement that many patients are concerned about increased radiation associated with CBCT imaging (2.74 vs. 2.57; p=0.437). However, the directors disagreed less with the statement that many of their patients inquired about CBCT (2.26 vs. 1.79; p=0.018) than the residents. Compared to program directors, residents agreed on average more strongly that having competent staff to support CBCT

Table 4. Residents' responses concerning their cone beam computed tomography (CBCT)-related education, by percentage of respondents (N=73)

Variable	1	2	3	4	5	Mean SD
Frequency of CBCT use by residents in clinical setting[a]	0	10%	24%	14.5%	52.5%	4.10 1.091
Statements[b]						
Future endodontists should be educated about CBCT.	0	0	4%	11%	85%	4.81 0.490
Endodontic residents are motivated to learn about CBCT.	0	0	3%	18%	79%	4.76 0.492
Upon graduation, I will use CBCT in my practice.	0	1%	3%	27%	69%	4.63 0.613
More education about CBCT is needed in my residency program.	2%	7%	15%	22%	56%	4.25 1.016
We have excellent faculty to instruct us about CBCT use.	6%	12%	14%	36%	33%	3.78 1.193
I am very satisfied with the clinical education I have about CBCT use.	6%	19%	18%	30%	27%	3.55 1.236
I am very satisfied with the way CBCT is taught in my program.	10%	24%	19%	25%	22%	3.26 1.311
I am very satisfied with the classroom-based education about CBCT.	11%	18%	33%	21%	18%	3.16 1.236
I have sufficient clinical experience to be competent in using CBCT.	6%	47%	22%	0	25%	2.92 1.308

[a]Response options were 1=never, 2=a few times a month, 3=a few times a week, 4=once a day, and 5=more than once a day.
[b]Response options were 1=disagree strongly, 2=disagree, 3=neutral, 4=agree, and 5=agree strongly.

Table 5. Program directors' and residents' responses (mean and SD) regarding education about cone beam computed tomography (CBCT) and CBCT use

Statement	Directors	Residents	p-value
Education about CBCT			
There is a need for CBCT in endodontics.	4.90 0.305	4.81 0.601	0.088
Upon graduation, most residents/I will use CBCT in their/my practice.	4.60 0.621	4.63 0.613	0.823
I am very satisfied with the way CBCT is being taught in our residency program.	4.37 0.890	3.26 1.311	<0.001
Our graduates are/I am confident about interpreting CBCT images.	4.40 0.724	2.75 1.180	<0.001
I am very satisfied with the clinical education we provide for our residents/I have about CBCT use.	4.53 0.776	3.75 1.128	<0.001
Residents are motivated to learn about CBCT.	4.95 0.183	4.76 0.492	0.028
Patient-related considerations			
CBCT is expensive for patients.	2.71 1.189	3.13 0.948	0.091
Many of our patients inquire about CBCT for their endodontic treatment.	2.26 1.094	1.79 0.804	0.018
Many patients are concerned about increased radiation associated with CBCT imaging.	2.57 1.006	2.74 1.028	0.437
Having competent staff to support CBCT is a challenge.	2.68 1.107	3.45 1.014	0.001
Maintenance of CBCT equipment is a challenge.	2.80 1.031	3.28 0.826	0.015

Note: Response options ranged from 1=disagree strongly to 5=agree strongly.

Table 6. Residents' and practicing endodontists' responses (mean and SD) regarding their education about cone beam computed tomography (CBCT)

Statements	Residents	Clinicians	p-value
Radiology-related statements			
I am well educated about radiology in general.	2.77 1.238	4.30 0.762	<0.001
Radiology is an important diagnostic tool for dentists/dental hygienists/specialists.	4.70 0.938	4.83 0.544	0.227
I am well educated about CBCT:			
In my classroom-based dental school education.	2.56 1.124	1.50 1.018	<0.001
In my clinical dental school education.	2.45 1.131	1.45 0.955	<0.001
In my classroom-based graduate education.	2.70 1.266	2.02 1.422	<0.001
In my clinical graduate education.	2.97 1.404	2.09 1.464	<0.001
In continuing education courses.	2.82 1.072	3.75 1.145	<0.001
By reading professional materials about CBCT.	2.79 1.054	3.82 1.039	<0.001
CBCT-related statements			
I have sufficient clinical experiences to be competent in using CBCT.	2.92 1.308	3.76 1.247	<0.001
I am interested in learning more about CBCT.	3.81 1.440	4.27 0.948	0.009
I am interested in learning how to interpret CBCT scans.	3.64 1.475	4.21 1.003	0.002
I am confident in interpreting CBCT scans.	2.75 1.180	3.57 1.198	<0.001
More education about CBCT is needed in endodontics residency programs.	3.18 1.417	4.37 0.888	<0.001

Note: Response options ranged from 1=disagree strongly to 5=agree strongly.

was a challenge (2.68 vs. 3.45; p=0.001) and that the maintenance of CBCT equipment was a challenge (2.80 vs. 3.28; p=0.015).

Table 6 compares the average responses of residents with those of practicing endodontists concerning radiology-related statements in general, their CBCT-related education, and CBCT-related statements. The practicing endodontists agreed more strongly on average that they were well educated about radiology than the residents (4.30 vs. 2.77; p<0.001). However, both groups agreed on average strongly that radiology is an important diagnostic tool for dentists, dental hygienists, and specialists (4.83 vs. 4.70; p=0.227). Compared to the practicing endodontists, the residents disagreed less strongly on average with statements concerning their classroom-based and clinical CBCT-related education in dental school and in their residency program. The clinicians agreed more strongly that they were well educated about CBCT in continuing education courses (3.75 vs. 2.82; p<0.001) and by reading professional materials (3.82 vs. 2.79; p<0.001) and that they were interested in learning more about CBCT (4.27 vs. 3.81; p=0.009) and more about how to interpret CBCT scans (3.57 vs. 2.75; p<0.001) than the residents. The clinicians also agreed more strongly than the residents that education about CBCT is needed in endodontic residency programs (4.37 vs. 3.18; p<0.001).

Discussion

Research has provided ample evidence that CBCT is of great value for providing the best possible endodontic care for patients[37] for such reasons as allowing the practitioner to locate/identify the anatomy of calcified canals[6,7] and to locate more apical lesions than periapical radiographs[8] and being excellent in helping with treatment planning and evaluating the anatomy of the root apex and the neighboring pathosis before endodontic surgery.[13] In consideration of the many benefits of CBCT, the question is whether

U.S. endodontic residency programs prepare their graduates in the best possible way for optimally using CBCT in their future practice.

This study therefore collected information from directors of endodontic graduate programs, from residents of these programs, and from practicing endodontists to gain a more comprehensive understanding of the status quo of current CBCT-related graduate education and related attitudes. The fact that 31 directors of the 56 endodontic graduate programs in the U.S. responded to this survey might be an indication that these administrators had a certain awareness of the importance of this topic. Surprisingly, ten of these program directors reported that their program did not offer a separate course on CBCT use, and only four indicated that they definitely planned to add such a course in the future. This finding is inconsistent with the data showing a 90% (strong) agreement regarding the need for training of future endodontists in CBCT and with the fact that directors disagreed strongly with the statement that patients do not benefit from the use of CBCT for their endodontic treatment. No data were collected concerning the reasons for not offering such a course. However, the program directors who did not offer a course largely disagreed with the statement that they did not have the facilities to safely provide CBCT and that none of their faculty was qualified to teach CBCT (Table 2). If these programs have trained faculty plus the facilities, potential costs for adding such a course might not be the primary reason for not addressing this need. While clinical education in CBCT is of course crucial, preparing residents in classroom-based settings for their CBCT-related clinical activities is clearly necessary.

Not surprisingly, all 21 directors whose programs did offer a separate CBCT course agreed/strongly agreed that future endodontists should be educated about CBCT. They also strongly agreed on average that residents were motivated to learn about CBCT and that they were satisfied with the way CBCT was taught in their program and with the clinical education their residents received. Most importantly, they reported that no tuition increase had been necessary to cover the cost of the CBCT education they provided.

One interesting finding was that the program directors' responses concerning the status of CBCT-related education were consistent with the residents' experiences. The residents' responses showed that only 49% had a separate didactic course about CBCT as part of their program and that their frequency of CBCT use ranged widely from 10% who used it only a few times a month to 52.5% who used it more than once a day. Both program directors and residents agreed strongly on average that there is a need in endodontics for CBCT and that most residents will use CBCT after graduation. These responses are not surprising given the extensive benefits of CBCT use for diagnosis, treatment planning, and treatment purposes in endodontics.

Unfortunately, however, residents' mean responses concerning their satisfaction with their programs' educational offerings and their assessment of their confidence concerning interpreting CBCT scans were substantially less positive than the program directors' assessments. On average, residents agreed significantly less with the statements that they were satisfied with the way CBCT was taught in their residency program and with their CBCT-related clinical education than the program directors. The discrepancy between the program directors' and residents' responses to the statement "Our graduates are/I am confident about interpreting CBCT images" was even more striking: while residents responded on average in a slightly disagree/neutral way, program directors agreed/agreed strongly with this statement. This finding could serve as a wakeup call for program directors because it implies that residents may not perceive themselves as being optimally prepared for future use of CBCT in their own practices.

The comparisons of residents' and practicing endodontists' responses were also of interest. The educational background of these two groups of respondents needs to be considered when interpreting these findings. It is important to realize that a significant percentage of the practicing endodontists had graduated both from their dental school and their endodontic graduate program before CBCT was introduced into dentistry about two decades ago.[1] Their average year of graduation from their endodontics residency programs was 1998, and their graduation years ranged from 1964 to 2016. Furthermore, even after CBCT use began in dentistry, educational efforts did not immediately catch up with this innovation. Research published in 2012 showed that while the majority of dental schools in the U.S. (50 out of 56 responding schools) and the U.K. (ten out of 15 schools) had CBCT equipment in 2012, education of predoctoral dental students about the interpretation of CBCT scans was not as widely provided (U.S. 48%; U.K. 57%).[20]

Adibi et al. concluded in their analysis of CBCT educational efforts in the U.S. that while most dental schools were doing some form of teaching about CBCT for predoctoral as well as postdoctoral students, the schools and programs varied widely in

their efforts and in their expectations concerning what and how much students were expected to learn.[38] It is therefore not surprising that the mean response of practicing endodontists concerning their classroom-based and clinical CBCT education in dental schools and residency programs was significantly less positive than residents' mean responses to these questions. However, it is noteworthy that endodontists reported significantly more positive educational experiences in continuing education classes and by reading professional material, showing their interest in CBCT-related education. This conclusion is also supported by the fact that practicing endodontists agreed/agreed strongly that they were interested in learning more about CBCT and in learning how to interpret CBCT scans and that more education about CBCT is needed in endodontic residency programs. The finding that their responses were significantly more supportive of these statements than residents' responses could be interpreted as support for the high relevance of CBCT in their own clinical practice.

Parashar et al.'s research found that CBCT equipment was widely available in dental schools in the U.S. and the U.K. in 2012, but they also reported that only ten dental schools in the U.S. and two in Australia actually provided CBCT training.[20] While this situation may have changed for the better over the past six years, program directors of endodontic programs cannot necessarily assume that their endodontic residents received a solid foundation in the use of CBCT and especially in interpreting CBCT scans during their predoctoral education. Providing a solid foundation for all incoming endodontic residents might therefore be important to ensure that all graduates feel confident at least in interpreting CBCT scans. Role models for such efforts can be found in oral and maxillofacial surgery (OMS) and orthodontics graduate programs. In 2015, Whitesides et al. reported that 87% of the OMS programs in the U.S. had CBCT equipment and that OMS residents received considerable and important training in CBCT.[39] This finding is not surprising because CBCT allows a much improved visualization of the complex relationships and boundaries between teeth and their pathosis and anatomic features in the alveolus and jaws, such as the maxillary sinus and mandibular canal and foramen.[2] Orthodontics is, after OMS, the only other dental specialty in which CBCT use is quite high.[5,40] Smith et al. reported in 2011 that most orthodontic residents received both didactic and practical (hands-on) training.[27] An analysis of how to best ensure that graduates of U.S. endodontic residency programs are competent to use CBCT in their future practice, which educational practices would be helpful, and how to cope with challenges might be a worthwhile effort in the future.

Overall, this study confirmed that CBCT has a place in endodontics and that education about CBCT use in endodontic residency programs as well as in CE courses for practicing endodontists is needed. Since CBCT is improving treatment planning and treatment outcomes, it would be beneficial to have real-time CBCT availability in endodontic program clinics. In addition, given that CBCT overcomes many of the limitations of periapical radiography, dental insurance companies should be covering the cost of CBCT.

This study had several limitations. Having a 55% response rate for the program directors was acceptable but not optimal because subgroup analyses were not possible due to the small number of respondents in some subgroups. For example, it was not possible to compare the responses of directors whose programs offered vs. did not offer a didactic CBCT course. A second limitation was that an in-depth exploration of the types of clinical education residents and practicing endodontists had received was not possible as we wanted to avoid increasing the length of the survey. Future research should focus on this question to allow a better understanding of the best possible ways to structure endodontic residents' CBCT education.

Conclusion

This study found that endodontic residency programs in the U.S. differed widely in their CBCT-related educational efforts in both classroom and clinical settings. However, all program directors agreed that future endodontists need to be able to use CBCT. Program directors and residents agreed strongly that there is a need for CBCT in endodontics and that graduates will use CBCT in their practices. However, they did not agree to the same degree that they were satisfied with the way CBCT was taught in their residency programs. Program directors were more positive about their educational efforts than were the residents. Residents were less confident about interpreting CBCT scans than program directors perceived them to be. Practicing clinicians agreed more strongly than residents that more endodontic graduate education about CBCT use is needed, and they were interested in learning more about CBCT use and how to interpret CBCT scans. These results confirm that CBCT has a place in endodontics and especially in endodontic residency programs and that educational efforts should be expanded.

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