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**A Survey of Endodontists' Preference for the Treatment of External Cervical Resorption based on Periapical and Cone Beam Computed Tomography Images**

External cervical resorption (ECR) can be difficult to diagnose and manage because patients with this condition are typically asymptomatic, If detected, these lesions are often incidental findings on routine radiographs. ECR occurs immediately apical to the epithelial attachment of the tooth, usually at the cervical region.[1] Although, exact etiology is unknown, ECR has been associated with orthodontic treatment, trauma, and intracoronal bleaching, either alone or in combination.[1, 2]

Heithersay introduced a classification system for ECR, based on the extent of invasion towards the pulp and the furthest apical extent of the lesion. The 4-part classification system is defined as: class 1—small, invasive resorptive lesion near the cervical area with shallow penetration into dentin; class 2—well-defined, invasive resorptive lesion that has penetrated close to the coronal pulp chamber but with little or no extension into the root dentin; class 3—deeper invasion of the root dentin by resorbing tissues that extend into the coronal third of the root; class 4—large, invasive resorptive process that has extended beyond the coronal third of the root.[3] Heithersay recommended only treating defects categorized as class 1 through 3, due to the higher risk of failure associated with class 4 defects.[4]

Provided that the tooth is asymptomatic it may be left untreated, otherwise, interventional treatment or possibly extraction may be appropriate. Heithersay's recommended treatment included topical application of 90% aqueous solution of trichloroacetic acid, curettage, restoration with glass ionomer, and endodontic treatment, when necessary.[5] If extraction is indicated, single-tooth dental implants provide a sound treatment option with reported outcomes similar to endodontically treated teeth.[6] However, it should be noted that the majority of dental implant studies only provide information on fixture survival and not success rates.[7]

Heithersay's classification, based on periapical (PA) images, is useful for assessing and guiding treatment, but certain defects are better assessed with cone beam computed tomography (CBCT). Patel and Dawood presented a case study report in which CBCT imaging revealed the ECR lesion was more extensive than originally determined, leading to an altered treatment plan. They concluded that the true extent of external cervical resorption lesions cannot always be estimated from conventional radiographs.[8] In a review of CBCT in endodontics, Patel et al concluded that CBCT can be used as a diagnostic tool to assess the true nature of teeth (provisionally) diagnosed with root resorption to improve diagnosis and aid management.[9] Estrella et al determined CBCT was superior to conventional radiography in identifying and determining the extension of nonspecific inflammatory root resorption on root surfaces.[10] Patel et al reported CBCT to be 100% accurate in its ability to diagnose the presence and type of root resorption, performing significantly better as a treatment planning methodology.[11] Of course, CBCT should only be used when the need for imaging cannot be met by lower dose two-dimensional radiography.[12]

Goodell et al proposed a new ECR classification system based on the analysis of CBCT axial slices. This classification system, termed the Rohde classification system (figure 1), takes into account two important aspects of ECR: the amount of dentin loss in the cervical area and the amount of dentin loss at the external surface of the tooth.[13] Goodell et al concluded that treatment plans developed with intraoral PA radiographs differed from those developed with CBCT images in the majority of cases, owning to the observation that ECR lesion sizes were consistently underestimated with PA radiography compared to CBCT, also demonstrated by Estrela et al.[10] The study by Goodell et al was limited, however, by the number of examiners. The aim of this study was to investigate the treatment planning decisions of endodontists when they were presented only a PA image of a tooth compared to when they were presented with the PA image and an additional CBCT image of the same tooth.

## Materials and Methods

Members of the American Association of Endodontists (AAE) were emailed with an invitation to participate in a web-based survey (figure 2). The survey was designed to assess the impact of CBCT imagery versus conventional intraoral PA radiographs on treatment plan decisions. The email clearly stated that the survey was for an endodontic postgraduate resident research project and that no personally identifiable information would be requested. Data collection lasted four weeks during July and August 2018.

During the survey, respondents were tasked with making treatment decisions based on four PA radiograph images followed by four CBCT images. Case selection for images followed exclusion criteria from Goodell et al:[13]

1) teeth with apical radiolucent lesions identified in CBCT images
2) more than 30 days between CBCT and PA image acquisition
3) teeth not in the same condition in CBCT and PA images (restorative or endodontic treatment performed between images)
4) evidence of any other types of resorption such as replacement external root resorption or inflammatory external root resorption.

Basic assumptions for the patient were provided as well as the tooth number and Heithersay class number for the resorptive defect. Respondents were not informed that the PA image and CBCT image were of the same patients and teeth. Thus, respondents made treatment decisions on a total of four cases. Six mutually exclusive treatment options were available for each case: no treatment, active monitoring; non-surgical root canal therapy (NSRCT) with no attempt to repair the lesion; NSRCT with repair from an internal approach; NSRCT with external surgical repair; external surgical repair without NSRCT; or extraction.

Consistency scores were created for each respondent. Individuals who chose the same treatment plan for both the PA radiograph and CBCT image of each case were determined to be consistent. Thus, study respondents were categorized as either 100%, 75%, 50%, 25%, or 0% consistent after reviewing the CBCT image.

In addition to clinical judgements, respondents were asked to disclose their gender, length of experience, type of practice (e.g. solo practice, small group practice, etc.), and whether or not they were a board-certified endodontist. Respondents were also asked if they work solely with other endodontists or with other specialists, including general dentists. Finally, to assess respondents' exposure to CBCT they were asked questions including, "Are implants offered at your practice?" and "How accessible is CBCT for your use in patient treatment planning?"

Pairwise comparisons were accomplished using the chi-square test. In cases of multiple comparisons, the Kruskal-Wallis test was used. Post-hoc comparisons for significant results were accomplished using Dunn-Bonferroni tests. Significance was declared at $P < 0.05$ for all tests. All data were analyzed by using SPSS version 25.0 (SPSS, Chicago, IL).

## Results

A total of 807 respondents initiated the survey. However, only 627 surveys were completed; resulting in a completion rate of 77.7%. Among the competed surveys, 20 respondents (3.0%) indicated that they do not use CBCT. These individuals were retained in the analyses as they did not differ in their proposed treatment plans from those with access to CBCT on any of the PA images nor any of the CBCT images (all $P>0.05$). Similarly, the non-CBCT users were no different than CBCT users with respect to board certification ($P=0.11$); however, they did differ in experience and practice type. The non-CBCT users primarily worked as solo practitioners (n=15, 75%) and most reported at least 10 years' experience (n=15, 75%). Respondent characteristics are shown in table 1.

Overall, the majority of respondents (n=331, 52.8%) reported being more than 10 years post-endodontic residency. Sixty-eight respondents (10.8%) reported that they were still in an

endodontic residency; 142 (22.6%) reported being less than 5 years post-residency; and 86 (13.7%) reported being between five- and ten-years post-residency. Differences in treatment plans were observed based on experience for all CBCT images (all $P<0.01$) and half of the PA radiographs ($P<0.05$). However, it is worth noting that treatment consistency or the likelihood of choosing an alternative approach versus selecting the same treatment after viewing the CBCT image was not affected by the respondent's experience, $P=0.24$.

In contrast, a gender difference was observed for experience ($P<0.01$). More men reported having 15+ years' experience while a greater proportion of women reported having less than 5 years' experience. A small yet significant gender difference was also noted in a respondents' likelihood to alter their treatment plan after reviewing a CBCT image ($P=0.04$) Ninety-six men (20.6%) remained constant with their treatment plans, opting for the same approach when presented with both the PA radiograph and CBCT images. In contrast, only 18 women (11.3%) remained consistent with their initial treatment plans. Conversely, women were more likely to alter their approach based on new information. No differences in treatment consistency were observed based on board certification ($P=0.78$), performing implants ($P=0.42$), type of practice ($P=0.14$), or the types of colleagues in one's group practice ($P=0.75$).

A total of four cases were presented to the survey respondents (figure 3). For case 1, with the PA radiograph alone, the most recommended treatment plan was NSRCT with external repair. With the addition of the CBCT axial slice, the most recommended treatment plan was NSRCT with internal repair. For case 2, with the PA radiograph alone, the most recommended treatment plan was no treatment. With the addition of the CBCT axial slice, the most recommended treatment changed to extraction. For case 3, with the PA radiograph alone, the most recommended treatment was NSRCT with external repair. With the addition of the CBCT axial slice, the most recommended treatment was extraction. For case 4, with the PA radiograph alone, the most recommended treatment was no treatment. With the addition of the CBCT axial slice, the most recommended treatment changed to extraction.

Overall, 114 respondents (18.2%) selected the same treatment plan regardless of whether presented with the PA radiograph or the CBCT image. After viewing the CBCT image, 181 respondents (28.9%) changed treatment plans in one of the four cases; 201 respondents (32.1%) changed treatment plans in two of the four cases; 106 respondents (16.9%) changed three of the four treatment plans; and 25 respondents (4%) changed every treatment plan (see Table 2). When presented with a CBCT image of a Rohde class 2 ECR lesion, 288 respondents (45.9%) selected a more aggressive treatment plan. When presented with Rohde class 1 ECR lesions, cases 1 and 3, only 65 (10.3%) and 73 (11.6%) respondents, respectively, changed to a more aggressive treatment plan.

## Discussion

The results of this present study indicate no significant difference in consistency of treatment recommendations based on access to CBCT, respondent experience, board certification, placing implants in their practice, type of practice, or the types of colleagues in one's group practice. Interestingly, the individuals who indicated that do not use CBCT did not differ in their proposed treatment plans compared to those with access to CBCT. There was a statistically significant difference in consistency of treatment recommendations based on gender. Men were 60.5% consistent with their initial treatment plan, whereas women were only 54.8% consistent. Although, the clinical significance of this finding is questionable and when looking at a much larger group would likely not be seen.

Numerous studies, including those by Patel[11] and Estrella[10], have been published regarding the higher sensitivity of CBCT, compared to PA radiographs, in terms of detecting external resorptive lesions. It is unsurprising, therefore, that in the current study, 81.8% of respondents chose to alter at least one of the four treatment plans after viewing the corresponding CBCT. A similar trend was found in the study by Ee, in which preoperative CBCT imaging led to treatment plan modifications in approximately 62% of cases.[14] It is noteworthy that when treatment modifications were made after viewing the CBCT, there was a slight trend toward more aggressive treatment. Furthermore, Rohde class 2 ECR lesions appear to entail

much more aggressive treatment plans. In this survey, respondents were four times more likely to change to a more aggressive treatment plan when viewing Rohde class 2 ECR lesions compared to Rohde class 1 ECR lesions. Similar to what Patel and Dawood[8] reported, it is likely that the CBCT image allowed the 'true' extent of the external resorption to be realized, leading to the altered, in this case more aggressive, treatment plan.

A three-dimensional classification system for ECR was recently proposed by Patel.[15] This classification systems takes into consideration the height, circumferential spread, and proximity to the root canal, utilizing a combination of PA radiograph and CBCT imaging. Patel's classification system takes into consideration aspects that the Rohde classification does not, such as height and proximity to the root canal. However, one aspect of ECR that is not considered with Patel's classification system is the presumptive size of the perforation defect on the root surface. They both consider the circumferential spread of the lesion; however, the Rohde classification system also considers the width of the perforation defect, 2.5mm being the threshold for a Rohde class 2 lesion. The need for consideration of the width of the perforation defect is reiterated in the case series by Salzano and Tirone, in which they hypothesized that horizontal tooth structure loss in the critical cervical area would be more detrimental to prognosis than the apical extension.[16]

A limitation of this study is that only a single PA radiograph and a screen shot of the axial slice was available to the respondents. Normal clinical situations would allow clinicians to have access to multiple angles of PA radiographs and the ability to scroll through the entire axial view of the CBCT image. Survey respondents were provided a screen shot of the most severe extent of the axial slice. Another limitation is the limited number of respondents.

## Conclusion

Our results indicate a trend toward more aggressive treatment plans after viewing the CBCT axial slice. With the addition of a CBCT image, 81.8% of survey respondents opted to alter a treatment plan developed with a PA radiograph. More research is required to determine if utilizing novel ECR classification systems such as the Rohde classification system or Patel's three-dimensional classification systems to recommend specific treatment plans has any effect on tooth survival outcomes.

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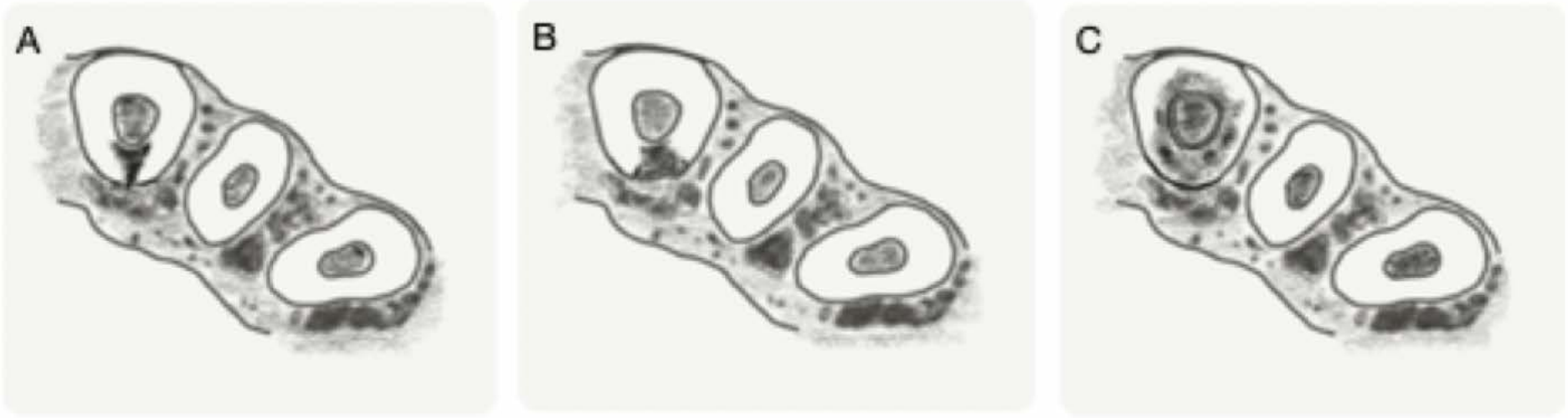



**Figure 1** - (*A*) Rohde class 1: significant dentin resorption (defined as resorption of more than one half the original axial wall thickness) in less than one-third of the tooth circumference; (*B*) Rohde class 2: significant dentin resorption in less than one-third of the tooth circumference with a presumptive perforation defect 2.5mm or larger in any dimension; (*C*) Rohde class 3: significant dentin resorption involving greater than one-third of the tooth circumference.

**Figure 2** - Survey Questions

1. **Gender**
   A. Male
   B. Female

2. **How many years has it been since graduating endodontic residency?**
   A. I'm a current resident
   B. Less than 5 years
   C. 5-10 years
   D. 10-15 years
   E. Greater than 15 years

3. **In what type of practice setting do you work?**
   A. Small private practice
   B. Large group/corporate
   C. Government
   D. Academia

   ***2(Group/corporate). What type of group/corporate practice do you work in?***
   A. Endodontists only
   B. Endodontist(s) and general dentist(s) only
   C. Endodontist(s) and other specialists (ie, periodontist, oral surgeon), with or without general dentist(s)

4. **Are implants offered at your practice?**
   A. Yes
   B. No

5. **How accessible is CBCT for your use in patient treatment planning?**
   A. We expose CBCT images at our practice
   B. We do not expose CBCT images at our practice, but refer when needed
   C. I don't generally use CBCT

   *The following assumptions apply to all remaining questions:*
   1. *The patient is asymptomatic and initially unaware of the condition*
   2. *The tooth responds to sensibility testing (EPT and cold)*
   3. *The patient has no pain to percussion or palpation*
   4. *The tooth has physiological mobility and periodontal probing <4mm*
   5. *No caries clinically visible and, if present, restorations margins are intact and sealed*
   6. *No patient financial considerations are to be considered in the treatment plan*
   7. *The patient wished to keep his or her natural tooth if possible and does not have any unique personal or temporal consideration that would affect treatment decisions*
   8. *No historic radiographs are available*

6. **This PA image (tooth #19) represents Heithersay class 2.**


**If you only had this image, considering the previous assumptions, how would you treatment plan?**
   A. No treatment/active monitoring
   B. NSRCT with no attempt to repair the lesion
   C. NSRCT with an attempt to repair the lesions from an internal approach
   D. NSRCT with an attempt to repair the lesion from an external surgical approach
   E. External surgical repair without RCT
   F. Extraction

**7. This PA image (tooth #14) represents Heithersay class 3.**


**If you only had this image, considering the previous assumptions, how would you treatment plan?**

A. No treatment/active monitoring
B. NSRCT with no attempt to repair the lesion
C. NSRCT with an attempt to repair the lesions from an internal approach
D. NSRCT with an attempt to repair the lesion from an external surgical approach
E. External surgical repair without RCT
F. Extraction

**8. This PA image (tooth #19) represents Heithersay class 2.**

**If you only had this image, considering the previous assumptions, how would you treatment plan?**

A. No treatment/active monitoring
B. NSRCT with no attempt to repair the lesion
C. NSRCT with an attempt to repair the lesions from an internal approach
D. NSRCT with an attempt to repair the lesion from an external surgical approach
E. External surgical repair without RCT
F. Extraction

**9. This PA image (tooth #14) represents Heithersay class 4.**


**If you only had this image, considering the previous assumptions, how would you treatment plan?**

A. No treatment/active monitoring
B. NSRCT with no attempt to repair the lesion
C. NSRCT with an attempt to repair the lesions from an internal approach
D. NSRCT with an attempt to repair the lesion from an external surgical approach
E. External surgical repair without RCT
F. Extraction

**10. This axial-slice CBCT image (tooth #19) represents Rohde class 1. The corresponding PA radiograph is provided for reference.**



**If you only had these images, considering the previous assumptions, how would you treatment plan?**

A. No treatment/active monitoring
B. NSRCT with no attempt to repair the lesion
C. NSRCT with an attempt to repair the lesions from an internal approach
D. NSRCT with an attempt to repair the lesion from an external surgical approach
E. External surgical repair without RCT
F. Extraction

**11. This axial-slice CBCT image (tooth #14) represents Rohde class 3. The corresponding PA radiograph is provided for reference.**


**If you only had these images, considering the previous assumptions, how would you treatment plan?**

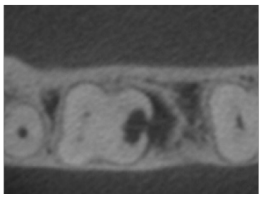
A. No treatment/active monitoring
B. NSRCT with no attempt to repair the lesion
C. NSRCT with an attempt to repair the lesions from an internal approach
D. NSRCT with an attempt to repair the lesion from an external surgical approach
E. External surgical repair without RCT
F. Extraction

**12. This axial-slice CBCT image (tooth #14) represents Rohde class 2. The corresponding PA radiograph is provided for reference.**


**If you only had these images, considering the previous assumptions, how would you treatment plan?**

A. No treatment/active monitoring
B. NSRCT with no attempt to repair the lesion
C. NSRCT with an attempt to repair the lesions from an internal approach
D. NSRCT with an attempt to repair the lesion from an external surgical approach
E. External surgical repair without RCT
F. Extraction

**13. This axial-slice CBCT image (tooth #19) represents Rohde class 1. The corresponding PA radiograph is provided for reference.**




A. No treatment/active monitoring
B. NSRCT with no attempt to repair the lesion
C. NSRCT with an attempt to repair the lesions from an internal approach
D. NSRCT with an attempt to repair the lesion from an external surgical approach
E. External surgical repair without RCT
F. Extraction

**14. Are you a board certified Endodontist?**

A. Yes
B. No

Figure 3. Treatment Consistency after CBCT Image Review

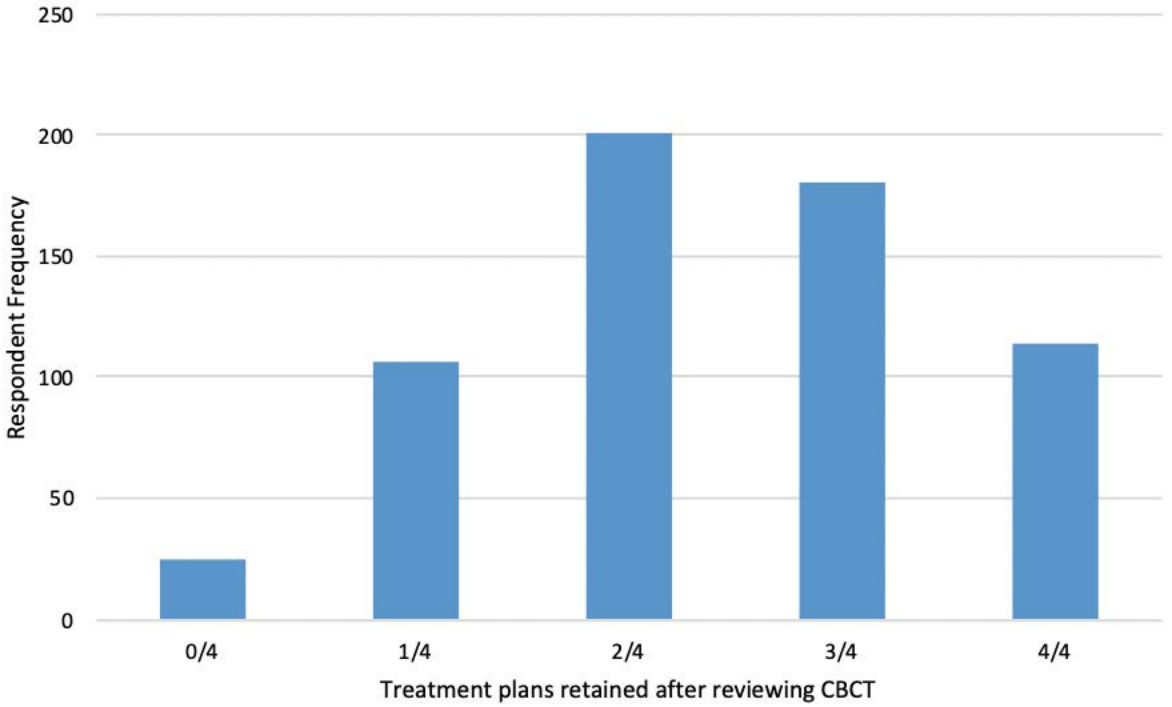


Table 1. Respondent Characteristics by CBCT Availability

| | We expose CBCT images at our practice n (%) | We do not expose CBCT images at our practice but refer when needed n (%) | I do not use CBCT n (%) |
|---|---|---|---|
| Gender | | | |
| Male | 350 (75.1) | 102 (72.3) | 15 (75.0) |
| Female | 116 (24.9) | 39 (27.7) | 5 (25.0) |
| Experience | | | |
| Current resident | 63 (13.5) | 5 (3.5) | 0 (0.0) |
| <5 years | 119 (25.5) | 21 (14.9) | 2 (10.0) |
| 5 to 10 years | 61 (13.1) | 22 (15.6) | 3 (15.0) |
| 10 to 15 years | 55 (11.8) | 16 (11.3) | 4 (20.0) |
| >15 years | 168 (36.1) | 77 (54.6) | 11 (55.0) |
| Practice Type | | | |
| Solo practitioner | 139 (29.8) | 80 (56.7) | 15 (75.0) |
| Small group practice | 227 (48.7) | 40 (28.4) | 4 (20.0) |
| Large group / corporate practice | 24 (5.2) | 14 (9.9) | 0 (0.0) |
| Government / Academia | 76 (16.3) | 7 (5.0) | 1 (5.0) |
| Work Environment [2] | | | |
| Endodontists only | 220 (87.6) | 31 (57.4) | 4 (100.0) |
| Endodontists and general dentists only | 2 (0.8) | 5 (9.3) | 0 (0.0) |
| Endodontists and other specialists | 29 (11.6) | 18 (33.3) | 0 (0.0) |
| Implants offered at your practice | | | |
| Yes | 92 (19.7) | 27 (19.1) | 0 (0.0) |
| Board certified endodontist | | | |
| Yes | 144 (31.0) | 31 (22.0) | 5 (5.0) |

1. Significance based on Kruskal Wallis test

2. Sample does not sum to 627 due to non-response

Table 2. Treatment Consistency after CBCT Image Review

| Case | Image set | Heithersay/ Rohde Class | Treatment Plan | Percent of Treatment Plans Retained | | | | | Total | P |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0% | 25% | 50% | 75% | 100% | | |
| 1 | 6 & 10 | 2/1 | No Change | 9 | 48 | 142 | 153 | 114 | 466 | <0.001 |
| | | | Less Aggressive | 8 | 35 | 35 | 18 | 0 | 96 | |
| | | | More Aggressive | 8 | 23 | 24 | 10 | 0 | 65 | |
| 2 | 7 & 12 | 3/2 | No Change | 4 | 29 | 71 | 112 | 114 | 330 | <0.001 |
| | | | Less Aggressive | 0 | 3 | 5 | 1 | 0 | 9 | |
| | | | More Aggressive | 21 | 74 | 125 | 68 | 0 | 288 | |
| 3 | 8 & 13 | 2/1 | No Change | 12 | 57 | 146 | 166 | 114 | 495 | <0.001 |
| | | | Less Aggressive | 3 | 20 | 31 | 5 | 0 | 59 | |
| | | | More Aggressive | 10 | 29 | 24 | 10 | 0 | 73 | |
| 4 | 9 & 11 | 4/3 | No Change | 5 | 65 | 157 | 165 | 114 | 506 | <0.001 |
| | | | Less Aggressive | 2 | 4 | 12 | 4 | 0 | 22 | |
| | | | More Aggressive | 18 | 37 | 32 | 12 | 0 | 99 | |
| | | | Total | 25 | 106 | 201 | 181 | 114 | 627 | |