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Conservative Endodontic Access – Cone Beam Computed Tomography (CBCT)-Guided Preparation and its Impact on Endodontic Referrals

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Conservative Endodontic Access –
Cone Beam Computed Tomography (CBCT)-Guided Preparation and its
Impact on Endodontic Referrals

Jeremiah M. Granados

D.M.D, Boston University, 2014

A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of
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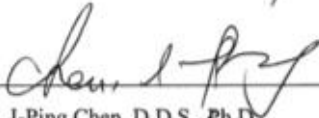
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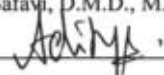
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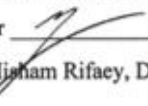
Conservative Endodontic Access – Cone Beam Computed Tomography (CBCT)-Guided Preparation
and its Impact on Endodontic Referrals

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Jeremiah M. Granados, D.M.D

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Abstract

Cone Beam Computed Tomography (CBCT) Images Enhance the Efficacy and Accuracy of Conservative Endodontic Access Preparation (change the title from this to the one of your thesis)

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Conservative endodontic access (CEA) results in minimal access in comparison to traditional endodontic access (TEA) which is defined as straight-line access. Our survey suggested that while 81% of general dentists would prefer to restore a tooth that received a CEA preparation, only 33% considered it a determining factor for their endodontic referrals (100 out of 129 responded: Response rate 77.52%). To test our hypothesis that CBCT images aid endodontists in CEA preparation, 45 extracted molars were accessed by one endodontic resident using techniques of TEA (Group A), CEA (Group B) or CEA with preoperative CBCT images provided (Group C)(n=15 per group). To determine the amounts of coronal dentin removal and the efficiency of each technique, the ratios of surface areas of coronal access to pulp floor were quantified from axial planes of CBCT images by CB Works software and the time spent for access preparation was recorded. Group A showed statistically significantly more coronal dentin removed when compared to Groups B and C by one-way ANOVA (surface areas of coronal access/pulpal floor: Group A: Group B: Group C= $1.37 \pm 0.38^*$: 0.88 ± 0.42 : 0.65 ± 0.14 ; data represent mean \pm SD, * $p < 0.05$). A tendency for reduced and more consistent surface area ratio when CBCT was used in CEA preparation (comparison between Group B and C, $p = 0.0504$). Moreover, the operation time was not significantly different among three groups. Interestingly, our data suggested that the use of CBCT reduced the CEA operation time initially however, this effect was diminished when operator became more. CBCT also better prevents the procedural errors including missing canal and pulpal floor perforation. Taken together, our data suggests that CBCT have a great potential to guide CEA preparation for beginners and CEA is a preferred access form to general dentists but is not a determining factor affecting their referral patterns.

I. Introduction

Endodontic treatment can consists of three equally important phases including canal preparation, microbiological control, and three-dimensional obturation (AAE Colleagues for Excellence 2010). Access cavity preparation is the first clinical step in endodontic therapy and is a key step toward the healing of pulpal and periapical infection. It should allow endodontists to remove obstructions in the pulp chamber, to locate all canal orifices and to clean the entire root canal system with minimum coronal tooth structure removed. Improper access preparation can lead to a multitude of subsequent treatment errors and ultimately case failure. In the Introduction, I will describe the pre-access analysis, concepts and techniques of traditional endodontic access preparation (TEA) and conservative endodontic access preparation (CEA), the comparisons between TEA and CEA, the use of CBCT imaging to potentially guide CEA, and how modern endodontics technology can overcome the concerns of CEA.

Pre-Access Analysis

Before access preparation is initiated, conceptual identification of the pulp chamber and root canal system needs to be carried out. This involves an intimate understanding of the dental structures including enamel, dentin, and pulp tissue. The “Law of Centrality” states that the pulp chamber of every tooth is in the center of the tooth at the level of cemento-enamel junction and can be used as a guideline for access preparation (Krasner & Rankow 2004). Clinically, common landmarks including cusp and groove location as well as operator experience are used in order to initiate endodontic access preparation. Tooth rotation, cuspal wear, and especially the presence of crowns/bridges, can confuse

the operator and decrease the accuracy of access preparation. Therefore, prior to the access preparation, the operators need to evaluate the orientation and location of root canal orifices thoroughly based on both clinical and radiographic findings.

Concepts and Techniques of Access Preparation

The first step clinical step in access preparation involves the removal of existing caries and faulty restorations. Next, bur penetration of the enamel, dentin, or overlying prosthetic material is done in order to enter the pulp chamber. Eventually, entrance into the pulp chamber is achieved and access refinement as well as root canal identification is initiated. Two most commonly used techniques in access preparations are traditional endodontic access (TEA) and conservative endodontic access (CEA).

- *Traditional Endodontic Access (TEA)*

The endodontic access cavity form must provide for the removal of all organic debris, give good access to the foramina, and offer a shape conducive to the placement of a dense permanent root canal filling (Schilder 1967). In order to achieve this goal, the concept of “straight line access” was adopted in endodontics and is the foundation for the traditional endodontic access (TEA). Straight line access involves removal of enough hard tissue in order to achieve direct-line access to the apical foramen or to initial curvature of the canal and has been thought to provide the best chance of debridement and reduce the risk of file breakage (Pathways of the Pulp 10th ed).

TEA is achieved clinically through the use of cylindrical diamonds, fissured burs, and round burs in order to completely remove the roof of the pulp chamber and preparation of axial walls that are parallel or slightly divergent. When adequately

prepared, the traditional endodontic access (through the concept of straight line access) allows for visualization of all root canal orifi from a given occlusal view.

- *Conservative Endodontic Access (CEA)*

Performance of root canal treatment through a more conservative access (CEA) has been recently advocated (Clark & Khademi 2010). The concept of CEA is in consistency with the application of “minimally invasive dentistry”. G.V. Black introduced the concept of “extension for prevention” and his cavity preparation designs were considered dogma for generations of dentists throughout the world (G.V. Black 1936). With the advancements of adhesive dentistry however, these concepts have been challenged, and many dentists today prepare far smaller cavity preparations than were advocated previously. Different from the concept of “straight line” access and complete unroofing the entire pulp chamber of TEA, CEA emphasizes the importance of preservation of the coronal tooth structure. CEA is a type of access preparation which allows endodontists to locate all canal orifices, debride pulp tissues from root canals, and avoid iatrogenic errors while the removal of as little tooth structure as necessary.

CEA is performed with the use of smaller round burs, and minimal use of cylindrical diamonds or fissured burs in an effort to perform the endodontic therapy while preserving as much coronal and cervical dentin as possible. Given that a smaller working area is utilized, high magnification and significant illumination is required and most often carried out through the utilization of a dental operating microscope. Additionally in CEA, the axial walls prepared are often times convergent from the pulpal floor to the occlusal surface.

Comparisons between TEA and CEA

TEA and CEA have their own advantages and disadvantages. In addition to helping the operator by allowing for a larger working area during endodontic treatment, advantages of TEA (defined as straight line access) include that its use has been shown to exert less strain on instruments during endodontic treatment (Patel & Rhodes 2007). Also, preparation of TEA and incorporation of straight line access allows for more consistent working length measurements throughout the procedure (Schroeder *et al.*, 2002).

Disadvantages of TEA include that there is a greater loss of dentin and it has been shown that teeth with a traditional endodontic cavity display a lower resistance to fracture (Krishan 2013). Also, regarding the restorative success of a tooth in which the access preparation was performed thru an existing crown, it has been proven that with TEA preparation, significant weakening of prosthetic restorations occurs (Bompolaki *et al.*, 2015).

CEA is becoming popular because it conserves more tooth structure. Another advantage of CEA preparation is that it has been shown to provide a greater resistance to fracture when compared to TEA preparation (Krishan 2013).

A major disadvantage of CEA preparation is that operator visibility is greatly reduced, which potentially leads to untreated anatomy (Krishan 2013). Additionally, without the significant preparation of cervical dentin via straight line access, there is a potential for increased strain on the instruments used to perform endodontic treatment. Finally, the constricted working area and decreased visibility may lead to a longer

operation time.

The Use of CBCT to Guide CEA

A thorough radiographic assessment assists the operator in determining the location and angulation of the root canal system. Historically, this was carried out in two-dimensions through periapical as well as bitewing radiographs. Today, an additional and very powerful imaging tool at our disposal is Cone-Beam Computed Tomography (CBCT).

The American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) released their most joint position statement in May of 2016 regarding the use of CBCT in endodontics. These series of position statements were released due to the increasing and popular use of this powerful technology and includes fourteen recommended applications for CBCT use in endodontics.

A major etiology of post treatment disease is persistent intra-radicular infection (Siqueira *et al.*, 2014) and the most common reason for its occurrence is failure to adequately locate, debride, disinfect, and obturate all the root canals present in a given tooth. One of the most powerful applications of CBCT is its ability to provide insight as to the number of root canals and their location within a given tooth, before the treatment is even started. This is significant because a recent retrospective cohort study on the incidence of missed canals in endodontically treated teeth found an overall incidence of missed canals to be 23.04% which values as high as 41.3%-46.5% for upper right and left molars respectively (Karabucak *et al.* 2016). The same study also found that teeth with a

missed canal were 4.38 times more likely to be associated with a lesion. One of the most difficult root canals to locate and subsequently treat is the second mesiobuccal canal of upper molars. Countless endodontic failures have been attributed to infection of this root canal space. CBCT technology can aid in the detection of these systems and has been shown to provide a higher specificity and sensitivity when compared to intraoral radiographic assessments in the detection of the MB2 canal (Vizzotto *et al.*, 2013). A recent survey of 1083 endodontists found that 50.69% of the respondents had access to CBCT imaging on-site (Setzer *et al.*, 2017). The same study found that there was a significantly greater usage of CBCT technology in residency programs compared with practicing endodontists. Knowing this, it is reasonable to forecast that the use of CBCT in endodontics will continue to grow.

CBCT technology can help guide CEA preparation through the valuable information it provides for pre-access analyses. Knowledge of the number root canals present in addition to their orientation within the tooth as well their orientation relative to each other, could allow for a more precise access cavity and thus, the preservation of dentin with CEA preparation. Additional information such as the presence of complex anatomy (i.e isthmus presence, broad canals buccolingually, developmental anomalies, etc.) can be planned for and taken into consideration all with the goal of increasing the efficacy and accuracy of CEA preparation.

The Use of Modern Endodontics Technology to Overcome the Concerns of CEA

One of the major concerns of CEA is whether the biological success in controlling the microbial infection can be achieved in a constraint access form. Few advancements

have been as monumental as the incorporation of the dental operating microscope (Carr 2010). The dental operating microscope enables the operator to see at far greater magnification with greater illumination than any other technology available.

Additionally, advancements in file technology, most notably thermal heat-treatment, have given us clinicians the option to instrument root canal systems with rotary files that possess far greater flexibility and resistance to breakage. Other technologies such as ultrasonics and advanced irrigation systems now enable the operator to make finer preparations for canal identification and access cavity refinements as well as allow for activation of endodontic irrigants. Similar to advancements in adhesives and material sciences in restorative dentistry, these technologies may enable operators to adopt the conservative endodontic access (CEA) when appropriate, and consider it a part component of minimally invasive endodontics.

Knowledge Gaps

Although the concept of conservative endodontic access (CEA) is increasing in popularity, the knowledge gaps we are presented with are that 1) guidelines for how to perform CEA are mostly missing in endodontic residency programs; 2) with the use of CBCT in endodontics on the rise, the effects of CBCT on CEA preparation remain unknown, 3) whether CEA preparation serves as a determining factor to endodontic referral patterns of general dentists has not been studied.

II. Research Aims

Aim 1: To study if CEA affects endodontic referral patterns

Aim 2: To assess if CBCT can better guide CEA preparation

Hypothesis

CEA preparation is the preferred access by general dentists and can be better guided with CBCT.

III. Materials and methods

Survey

To determine the influence of Conservative Endodontic Access (CEA) on the referral patterns of general dentists, a survey consisting of eight (8) questions was designed. The definition of CEA was described as “Different from traditional straight-line preparation, CEA is a technique of endodontic access with minimal size of access opening.” Images of CEA and traditional endodontic access (TEA) preparations were provided to the respondents (Figure 1).

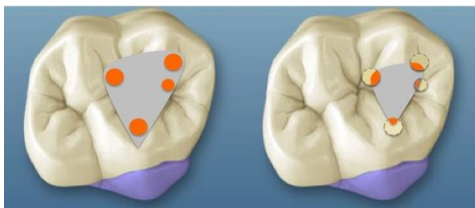


Fig.1: Images demonstrating TEA (left panel) and CEA (right panel) preparations in maxillary molars. Orange dots indicated canal orifi. Gray shadow showed the margin of access cavity. Canal orifi are directly visible in TEA but not CEA preparation.

Inclusion criteria were that the respondents had to be general dentists with an active license to practice dentistry (prosthodontists were not included) and that the respondents practiced in the state of Connecticut. The survey was disseminated in two ways; online or

paper copy. The online component of responses was generated using the platform “Survey Monkey” (www.surveymonkey.com). The paper component of responses consisted of the same survey printed in color and filled out by the respondents. Results and figures of each question were automatically generated by Survey Monkey software. Total of 129 survey questionnaires were sent out and 100 responses were received which leads to a response rate of 77.52% (100/129). The eight survey questions were listed in the appendix.

Tooth Collection

To compare the *amounts of tooth structure preserved by CEA and TEA preparations* and to determine the *effects of cone-beam computed tomography (CBCT) on efficacy and efficiency of CEA preparation*, human extracted upper and lower molars were collected by the Division of Oral and Maxillofacial Surgery and the Division of General Dentistry at the School of Dental Medicine, University of Connecticut Health. No IRB protocol was required since samples were anonymous and were considered medical waste. Exclusion criteria were teeth with caries beyond Class I, teeth with extensive fillings/crowns, atypical crown morphology, previously root canal treated teeth and 3rd molars. Extracted teeth were stored in normal saline until ready to be used.

Sample Randomization and Group Design

A total of 45 extracted upper and lower first or second molars were stored individually in small plastic vials labeled with an assigned sample identification number. The sample identification number consisted of two components. The first component was the upper versus lower identification number. Upper molars were assigned a prefix of one

(ie: 1.xx) and lower molars were assigned a prefix of two (ie: 2.xx). The second portion of the unique number was generated in sequence of tooth sample allocation.

Group allocation was done randomly into three groups (n=15 per group) using a random group allocation online software (www.randomlists.org). The three treatment groups were allocated based on the type of access preparation that would later be performed. They consisted of group A (TEA: traditional endodontic access), group B (CEA: conservative endodontic access without CBCT images), and group C (CEA+CBCT: conservative endodontic access with CBCT guidance).

Pre-operative CBCT Scans

Custom jigs for radiographic imaging were made for each of the samples using poly-vinyl siloxane (PVS) bite registration material (Correct-bite, Pentron) (Figure 2). Briefly, the PVS material was injected, using an impression gun (Dentsply) and syringe, into preformed plastic wells. While unset, a given tooth sample was introduced to the level of the cement-enamel junction (CEJ) and left for two minutes allowing the material to set. The jig was then removed from the well and labeled according to the sample number. The teeth were then removed from their corresponding jigs and re-stored in their labeled plastic vials.

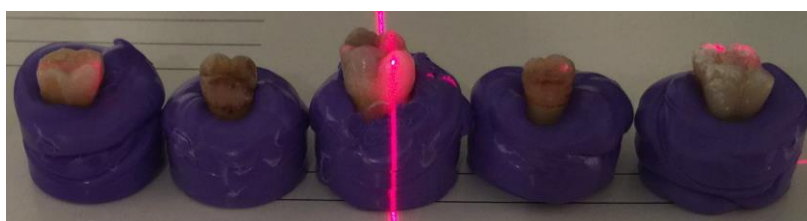


Fig. 2: Molars were embedded in custom made PVS jigs and only coronal structure above CEJ were exposed. Laser centering prior to CBCT scan. Five teeth were scanned at one time.

The samples were initially scanned using a 3-D Accuitomo (J. Morita USA, Inc.) CBCT scanner. Scan parameters were set to 90 kVP and 2.0m As, at a field of view of 150x100mms at the machine's "Hi-Fi" setting. Molars mounted in PVS custom jigs were scanned in groups of five samples per scan (Figure 3). The operator was only allowed to access CBCT images from teeth in group C.

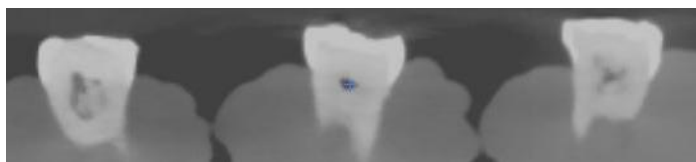


Fig. 3: The representative axial plane of pre-operative CBCT image. Five teeth were included per scan.

Access Preparations

All teeth were prepared by a single operator, a third-year resident (J. Granados). All access preparations were performed using a surgical operating microscope (Leica M-320, Leica Microsystems). Access preparations for group A (TEA) were performed with the goal of achieving straight line access resulting in either parallel or slightly divergent axial walls. All root canal orifices could be seen at a given occlusal view. The complete TEA preparation was also confirmed by inserting stainless steel handfiles into the canals apical one-third with enough preparation as to enable the instrument handles to be oriented in a vertical fashion with minimal bending or flexing.

CEA access preparations were performed with the aim of preserving as much coronal dentin as possible and practical. The strict adherence to "straight-line access" was not followed. Access to and identification of the largest canal (palatal canals of upper molars and distal canals of lower molars) was strategically performed first using #2 and #4 surgical length carbide round burs (Brasseler). From that given canal orifice, the

remaining canal orifi were searched for.

Access preparations for group B (CEA without CBCT) were performed as described above. Access preparations for group C (CEA + CBCT) were performed with the aid of CBCT images. For these samples, the pre-operative CBCT images were thoroughly reviewed. Sections of the pulpal floor (one from each axial, coronal, and sagittal view) were saved. These screenshot images were available to the operator during the access cavity preparations of the CEA+CBCT experimental group.

CBCT was used to guide CEA by utilizing the spatial relationship of the pulpal floor relative to the cementoenamel junction of the given tooth. For upper molars, the largest canal, palatal canal, was accessed and identified first. From there, the mesiobuccal canal was accessed and located using the CBCT images as a guide for approximate distance and orientation from the previously found palatal canal. Next the distobuccal canal was found and identified and finally any remaining canals (i.e mesiobuccal-two) was identified (again using the CBCT image, most noticeably in the axial views). For lower molars, the largest canal that was found first was the distal canal(s). From there the same technique for spatial orientation and distance was utilized to access the mesiobuccal and mesiolingual canals in the mesial root.

Access preparations were completed when all root canal orifi could be visualized and accessed by a size-10 k-file (Dentsply). Time to complete each access preparation was recorded for all samples in each of the three groups.

Post-operative CBCT Scans and Surface Area Measurements

Post-operative CBCT scans were performed using the same custom jigs, scan

groups, and parameters as the pre-operative scans described above. Pre-operative and post-operative CBCT images were analyzed using CB Works software. The CBCT image for each sample was analyzed independently by the operator without knowing the grouping information.

All measurements were taken in the axial view. The person performing all measurements for analysis was not aware of the sample grouping. Surface area measurements were taken from pre-operative images at the level of the pulpal floor and from post-operative images at the occlusal surface (Figure 4). The level of the slice for post-operative measurement was the most occlusal slice that included the entire access preparation. The image for a given sample was zoomed to 979.2% in the axial view and 200.7% for the coronal and sagittal views. The surface area was traced using the software tool and measured in mm². Each surface area was measured three times consecutively in the same manner. CBCT slices for measurements were saved using the screenshot function of CB Works software. The mean of the three surface area measurements was then calculated and recorded as the mean pre-operative surface area (pulpal floor) or the mean post-operative surface area (occlusal surface).

To compare the amount of coronal tooth structure preserved among three groups, surface area (SA) ratios were calculated using the following formula (Figure 4):

$$SA\ ratio = \frac{\text{mean post-op. SA ratio (occlusal surface)}}{\text{mean pre-op. SA ratio (pulpal floor)}}$$

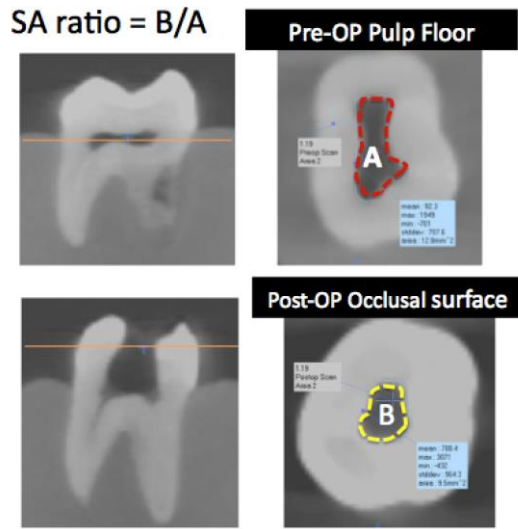


Fig. 4: The representative pre-operative (top panel) and post-operative (bottom panel) CBCT images showing axial planes of molars, pre-OP pulp floor and post-OP occlusal surfaces. The surface area (SA) ratio was calculated using formula: surface B (yellow dotted circle) divided by surface A (red dotted circle).

Statistical Analysis

Both SA ratio and the operation time required to complete access preparations were subjected for statistical analysis using Prism 5 software (GraphPad Software) with a one-way analysis of variance (one-way ANOVA) or Student's *t*-test as indicated in the figure legends. Statistically significant difference was reached when *p*-value smaller than 0.05. Data was presented as mean \pm standard deviation (SD).

IV. Results

Survey Questionnaire Collection

A total of 129 survey invitations were initiated. 112 of which were initiated through SurveyMonkey and 17 were completed by the paper version. The respondents included post-doctoral residents in the Advanced Education in General Dentistry program, faculty members in the Division of General Dentistry at University of Connecticut Health, and various general dentists throughout the state of Connecticut from

various clinical settings (private practice and community health centers). An email database of general dentists in Connecticut that function as mentors to pre-doctoral students was utilized for this survey.

In total 100 survey responses of the 129 invitations were obtained. 25 of the invitations were to residents and 104 invitations were to practicing general dentists in the state of Connecticut (of which 12 were faculty at the University of Connecticut School of Dental Medicine). The response rate obtained was 77.52% (100 out of 129). The questionnaire was attached in Appendix 1. The responses of this survey were discussed below.

a) Awareness of CEA

Question 1: *Are you aware of the concept of CEA?*

Previous knowledge of CEA was common among the respondents. Ninety-nine of the participants (99%) answered the question, and one of the participants (1%) skipped the question. Following a brief explanation of the concept of CEA, seventy-six (76.77%) of the general dentists answered that they were aware of the concept of CEA. Twenty-three (23.23%) of the general dentists answered that they were not aware of the concept of CEA (Figure 5).

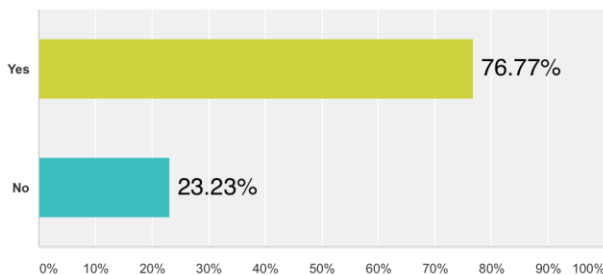


Fig. 5: Awareness of CEA. 76.77% of respondents were aware of the concept of CEA.

b) Preference for Restorative Phase Following Endodontic Treatment

Question 2: *Which of the access preparations below would you prefer to restore after endodontic therapy was completed (cartoon images provided as examples)?*

The respondents overwhelmingly preferred to restore a tooth which had undergone CEA during endodontic treatment. Figures of upper molars showing examples of TEA and CEA were provided and the general dentists were asked regarding their preference as to which of the examples they would prefer to restore. One-hundred (100%) of the respondents answered the question. 81 of the general dentists (81%) answered that they would prefer to restore the tooth depicting a cartoon with a CEA access preparation. 19 (19%) responded that they would prefer to restore the tooth depicting a cartoon of a tooth which underwent a TEA preparation (Figure 6).

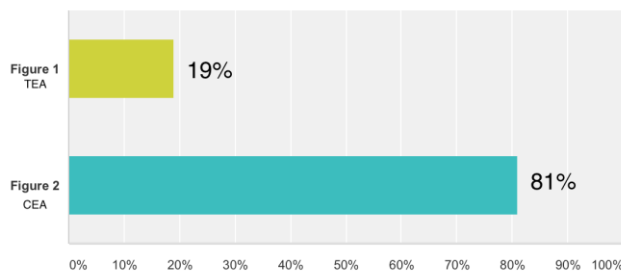


Fig. 6: Preference to restore a tooth with a CEA preparation. 81% of respondents prefer to restore a tooth that has undergone a CEA preparation (as opposed to a TEA preparation).

c) Agreement with the Concept of CEA

Question 3: *How much do you agree with the concept of CEA?*

Agreement regarding the overall concept of CEA was found to be mixed amongst the general dentists. One-hundred (100%) of the respondents answered the question. 35 (35%) answered that they strongly agree with the concept of CEA, 60 (60%) answered that they somewhat agree, and 5 (5%) answered that they disagree (Figure 7).

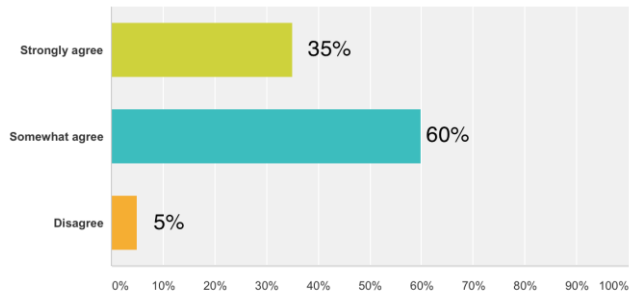


Fig. 7: Agreement with the concept of CEA. 35% of the respondents strongly agree with the concept of CEA, 60% somewhat agree, and 5% disagree.

d) History with Excessively Large Access Preparations

Question 4: *How often do you find that teeth that are restoring which have received endodontic treatment have had excessively large access preparations?*

The general dentists were asked regarding how often they found that teeth they were restoring after endodontic treatment had undergone what they considered to be excessively large access preparations. One-hundred (100%) of the respondents answered the question. 2 (2%) always, 31 (31%) often, 60 (60%) sometimes, and 7 (7%) never, found that they encounter having to restore teeth which have undergone excessively large access preparations (Figure 8).

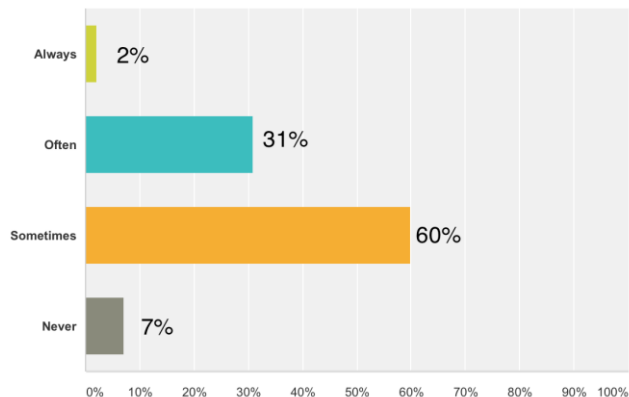


Fig. 8: History with excessively large access preparations. Respondents reported that 60% sometimes and 31% often times, they were left having to restore teeth which had received excessively large access preparations.

e) Current Referral Patterns

Question 5: *What percentage of your patients who need endodontic treatment do you refer out to a specialist?*

General dentists in the state of Connecticut tend to refer their endodontic cases to an endodontist. One-hundred (100%) of the respondents answered the question. 25 (25%) reported that they refer all of their endodontic treatment for their patients to an endodontist, 35 (35%) reported that they refer more than half of their endodontic cases, and 40 (40%) reported that they refer less than half of their endodontic cases (Figure 9).

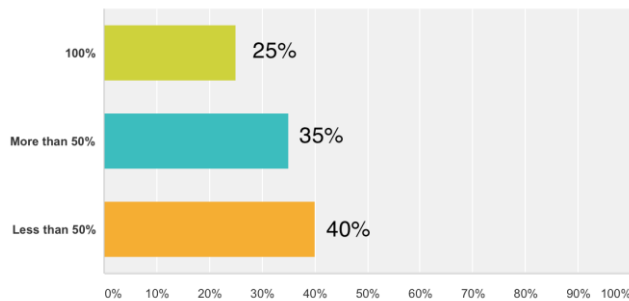


Fig. 9: Current referral patterns. 25% of the respondents refer all, and 35% refer more than half of their endodontic cases to an endodontist.

f) CEA as a Determining Factor for Endodontic Referrals

Question 6: *Would the size of access opening be a determining factor for your endodontic referrals?*

CEA was not found to be a determining factor for endodontic referrals. One-hundred (100%) of the respondents answered the question. When asked whether the size of access opening would be a determining factor for their endodontic referrals, 33 (33%) of general dentists answered yes, and 67 (67%) answered no (Figure 10).

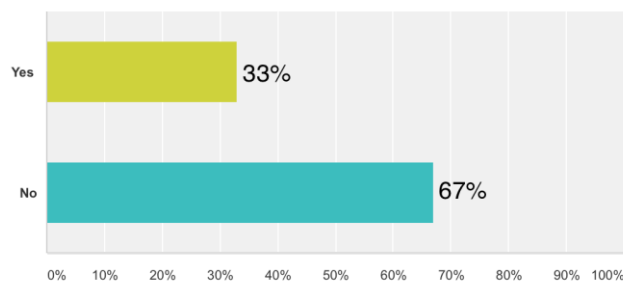


Fig. 10: CEA as a determining factor for endodontic referrals. 67% of the respondents answered that CEA would not be a determining factor for endodontic referrals.

g) Access Cavity they Prefer Endodontists Prepare

Question 7: *Which type of access opening do you prefer endodontists to prepare for patients?*

When asked which type of access preparation they prefer endodontists prepare on their patients during endodontic treatment, the respondents showed a tendency to prefer their patients undergo a CEA preparation. One-hundred (100%) of the respondents answered the question. 7 (7%) of the dentists preferred their patients receive a TEA preparation, 32 (32%) preferred their patients receive a CEA preparation, and 61 (61%) would accept either form (Figure 11).

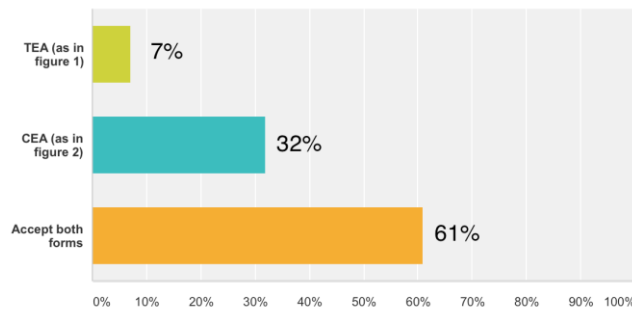


Fig. 11: Access cavity preferences for endodontists to prepare for their patients. 61% of respondents would accept either a CEA or TEA preparation for their patients.

h) Likelihood to Refer to Specialist who Performs CEA

Question 8: *Would you be more likely to refer to an endodontist who performs CEA?*

Nearly half of the general dentists surveyed reported that they would be more likely to refer to an endodontist who performs CEA. One-hundred (100%) of the respondents answered the question. 58 (58%) of the dentists would be more likely to refer to an endodontist who performs CEA whereas 42 (42%) reported that they would not be more likely (Figure 12).

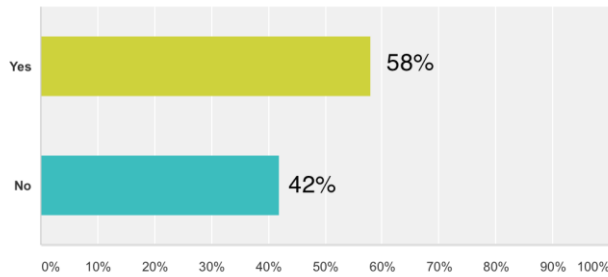


Fig. 12: Likeliness to refer to a specialist who performs CEA. 58% of the respondents report that they would be more likely to refer to an endodontist who performs CEA.

Surface Area (SA) Ratio Preparation for TEA vs. CEA

The raw data of SA ratio of three groups is attached in the Appendix 5-8.

To investigate the accuracy and extent of coronal structure preserved after CEA or TEA preparations, we measured the pulpal and occlusal surfaces followed by calculation of SA ratio in each group. As described earlier, the formula used for calculation the surface area ratio of each sample is shown below.

$$SA\ ratio = \text{mean post-op. SA ratio (occlusal surface)} / \text{mean pre-op. SA ratio (pulpal floor)}$$

Our results showed that the mean of SA ratio in Group A was larger than 1 indicating divergent cavities prepared by TEA whereas the SA ratios in Group B and C were less than 1 suggesting convergent cavities prepared by CEA technique. The SA ratios in Group B (CEA) and Group C (CEA + CBCT) were statistically significant smaller than the one in Group A (TEA) while no significant difference was found between Group B and Group C (Figure 13). This result was consistent with the concept of CEA preparation which leads to more tooth structure preserved.

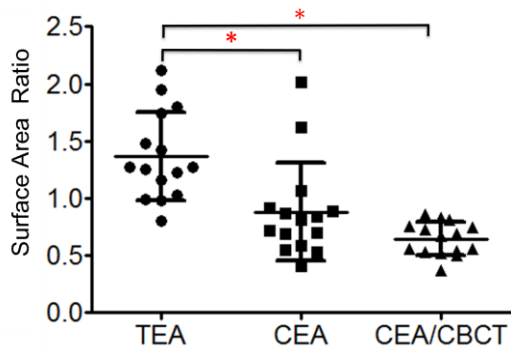


Fig. 13: Surface area ratio of Gr. A (TEA), Gr. B (CEA), and Gr. C (CEA + CBCT). Data presented are mean \pm SD for groups of 15 teeth. * $p < 0.05$ by one-way ANOVA.

Effect of CBCT on the Surface Area Ratio of CEA Prepared Groups

To investigate the effects of CBCT on the surface area ratio of CEA prepared groups, we subjected data from Gr. B (CEA) and Gr. C (CEA + CBCT) for statistical analysis by Student's *t*-test. There was no statistically significant difference in the surface area ratio between Gr. B (CEA), and Gr. C (CEA + CBCT). However, a *p*-value of 0.0504 was detected which indicates a tendency for reduced surface area ratio when CBCT is utilized for CEA preparation. In addition, the SD in Gr. C is smaller than the one in Gr. B suggesting that with the aid of CBCT, more consistent CEA preparation can be obtained.

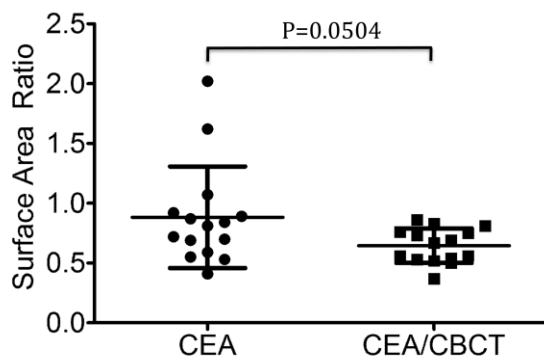


Fig. 14: Surface area ratio of Gr. B (CEA), and Gr. C (CEA + CBCT). Data presented are mean \pm SD. Statistics performed by Student's *t*-test.

Operation Time for TEA vs. CEA Preparation

To investigate the efficiency of the different access cavity preparation techniques, we examined group differences in operation time. The operation time was recorded until the canal orifices can be identified. There was no statistically significant difference in operation time among three groups.

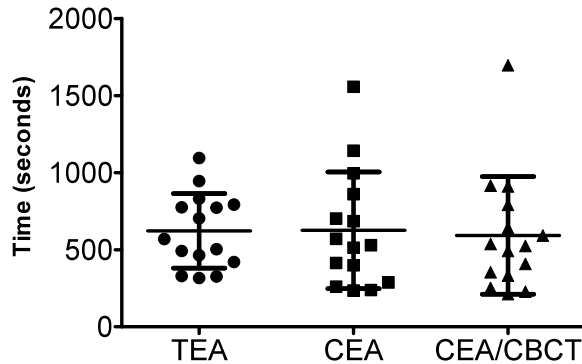


Fig. 15: Operation time of Gr. A (TEA), Gr. B (CEA), and Gr. C (CEA + CBCT) was not statistically significant different. Data presented are mean \pm SD for groups of 15 teeth. * $p < 0.05$ by one-way ANOVA.

Effect of CBCT on CEA Preparation Operation Time

To investigate the effects of CBCT on the operation time of CEA prepared groups, we subjected data from Gr. B (CEA) and Gr. C (CEA + CBCT) for statistical analysis. There was no statistically significant difference in operation time between Gr. B (CEA) and Gr. C (CEA + CBCT).

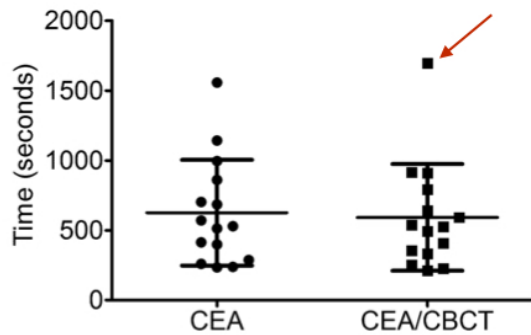


Fig. 16: Operation time of Gr. B (CEA), and Gr. C (CEA + CBCT). Data presented are mean \pm SD. Statistics performed by Student's t -test. Red arrow indicates severely calcified sample which resulted in prolonged operation time.

Calcified Root Canal Systems

The distribution of teeth with calcified root canal systems between groups was not uniform. Gr. A (TE) contained one sample, Gr. B (CEA) contained two samples, and Gr. C (CEA + CBCT) contained three samples, which were deemed to be severely calcified. The degree of calcification was associated with the length of operation time required (See Appendix). The outlier in Group C (CEA/CBCT) had a very calcified pulp chamber and required the most time to prepare (red arrow in Figure 16).

Procedural Errors

Two procedural errors were both identified in Group B (CEA). Perforation during access cavity preparation occurred in one sample in Gr. B (CEA) and none of the samples of Gr. A (TEA) or Gr. C (CEA + CBCT). Also, after completion of access cavity preparations, the pre-operative CBCT scans were cross-referenced for missed anatomy and a MB2 canal was missed in Gr. B (CEA). There were no missing canals in Gr. A (TEA) or Gr. C (CEA + CBCT).

V. Discussion

Endodontics involves the prevention and treatment of apical periodontitis. Endodontic treatment requires access to and complete debridement of the pulp and root canal system. One of the earliest and most critical steps in performing endodontic treatment is access preparation. Performance of root canal treatment through a more conservative access (CEA) has been advocated (Clark & Khademi 2010). This concept aims to achieve minimally invasive endodontics as well as that of minimally invasive dentistry. Although the concept of conservative endodontic access is increasing in

popularity, the knowledge gaps in this field included 1) guidelines for how to perform CEA are mostly missing in endodontic residency programs; 2) with the use of CBCT in endodontics on the rise, the effects of CBCT on CEA preparation remain unknown, 3) whether CEA preparation serves as a determining factor to endodontic referral patterns of general dentists has not been studied.

In this study, we tested the hypothesis that *CEA preparation is the preferred access by general dentists and can be better guided with CBCT* by conducting a survey to general dentists in Connecticut and by performing access preparations in extracted molars with or without the aid of CBCT images.

Survey Response Rate

The objective of the survey was to determine the effect of CEA preparation on endodontic referral patterns. To achieve the highest response rate possible that was most reflective of the dental community at large, we decided to confine our survey general to dentists practicing locally in the state of Connecticut. A benchmark of 35-40% has been published in research looking at appropriate sample sizes for survey studies (Baruch & Holtom 2008). Additionally, execution of a survey using multiple modes of distribution and setting up reminders for non-responders has been shown to also increase the response rates for survey studies (Yun & Trumbo 2000). We used two modes of distribution, an online platform (SurveyMonkey) as well as a paper version. The response rate obtained was 77.52% (100 out of 129).

Awareness of CEA among General Dentists

Minimally invasive dentistry has been defined as the “focus on maximum conservation of demineralized, non-cavitated enamel and dentin” (Murdoch-Kinch & McLean 2003). In our survey, 76.77% of the respondents answered that they were aware of the concept of CEA. Despite that minimally invasive endodontics and conservative access is an emerging concept in the field of endodontics, there were still 23.23% of general dentists who were not aware of the CEA concept. This result suggested that the introduction of CEA should be considered to be part of the curriculum in dental school.

Preference for CEA over TEA

When examples of CEA and TEA prepared teeth were provided to the respondents, 81% answered that they would prefer to restore a tooth which had received a CEA preparation. One respondent of a paper survey who answered that they would prefer to restore a TEA prepared tooth wrote in the margin of the survey that “they like larger access preparations so that it is easier to remove the cotton pellet.” Additionally, 31% of the general dentists reported that they often receive a case back from an endodontist which they believe had performed an “excessively large” access preparation on their referred patients tooth.

With a CEA preparation, often times the axial walls of the preparation are convergent thus complete removal of the temporary restoration may be hindered without illumination and magnification. The implications of CEA on general dentists’ ability to remove the inter-appointment temporary filling has not been investigated to date and future studies are needed to address this topic.

Current Referral Patterns and the Effect of CEA on Endodontic Referrals

Our survey showed that currently, 25% of respondents refer all their cases, 35% refer more than half of their cases, and 40% refer less than half of their endodontic cases to endodontists. A previous investigation on endodontic referrals reported on average, general dentists referred less than one-half (46%) of their endodontic cases (Abbott *et.al.*, 2011). The referral pattern can be varied based on the availability of endodontics in the regions, the educational background of general dentists, and the percentages of difficult cases etc.

Previous study also reported that a majority of general dentists (63%), routinely refer to 2 or 3 different endodontists (Abbott *et.al.*, 2011). Endodontists therefore may be looking for ways to distinguish themselves in order to enhance their relationship with referring general dentists. Interestingly, while the general dentists surveyed preferred CEA over TEA, only 33% considered it a determining factor for their endodontic referrals. However, while not necessarily a determining factor for their referrals, 58% of the respondents would be more likely to refer patients to an endodontist who performs CEA.

CEA and the Preservation of Tooth Structure

In our study, CEA preparation (with and without CBCT) resulted in a significant lower prepared surface area ratio than TEA. The mean surface area ratios for Group A (TEA), Group B (CEA), and Group C (CEA + CBCT) were 1.37, 0.88, and 0.65. Our data clearly demonstrated that TEA (with surface area ratios greater than 1) resulted in

access preparations with parallel to slightly divergent axial walls whereas CEA (with surface area ratios less than 1) resulted in access preparations with convergent axial walls.

When comparing mean differences of surface area ratios, Group B (CEA) resulted in a 35.77% less prepared surface area ratio than Group A (TEA) and Group C (CEA + CBCT) resulted in a 53% less prepared surface area ratio than Group A (TEA).

CEA Does Not Prolong Operation Time

CEA preparation does not prolong the operation time. No statistical difference was found regarding operation time for Group A (TEA), Group B (CEA), and Group C (CEA + CBCT). This was unexpected as it was commonly thought that CEA preparation is more time-consuming than TEA. No significant differences in operation time could be resulted in large variations among samples within a group as well as that once the operator became more experienced, the time spent had been reduced in all three groups. Our data suggested that the operation time should not be considered as an disadvantage of CEA when compared to TEA.

CBCT Guidance Enhances the Accuracy of CEA Preparation

We found that CEA preparation with CBCT resulted in a tendency for more tooth structure preservation. In our study, there was a strong tendency for a reduced prepared surface area ratio of Group C (CEA + CBCT) when compared to Group B (CEA) at a p-value of 0.054. The lack of statistical significance in this case, may have been due to the sample size and future studies may consider taking this into account. This data suggests

that CBCT has a great potential to guide more consistent CEA preparation, leading to more tooth structure preserved.

CBCT Guidance Enhances the Efficacy of CEA Preparation for Inexperienced Operators

Our preliminary data showed a reduced operation time for CEA preparation with CBCT guidance. However, this effect decreased with operator experience. Time to complete access preparation for the last five samples in all groups was markedly reduced and was similar in all three groups. This was found to be due to the operators' experiences. As the operator gained experience in performing CEA preparations, operation time for Group A (TEA), Group B (CEA), and Group C (CEA + CBCT) were found to be not statistically different.

Our data also suggests that while not statistically different, CEA preparation with CBCT guidance resulted in a more consistent CEA preparation with a smaller standard deviation and narrower confidence interval. This effect was even more pronounced when sample 1.21 from Group C (CEA + CBCT) was removed from analysis. This sample was very calcified and was a severe statistical outlier in our analysis.

CEA Preparation in Calcified Teeth

Endodontic treatment on calcified root canal systems is challenging. While CBCT guidance provides valuable insight as to the location and number of root canals present, access preparation and canal identification remain challenging, especially when pulp stones were present. Most of endodontists utilize ultrasonic instruments to remove

attached pulp stones in the pulp chamber (Plotino et al., 2007). The technique involves separating the pulp stone from the edges of the pulpal floor and removing the stone coronally. This was found to be especially challenging after a CEA preparation was performed due to the contracted working space and convergent axial walls. Therefore, CEA preparation may require modification and/or enlargement in such cases.

CBCT Guidance Reduces Procedure Errors

Perforation of the pulp chamber floor is an iatrogenic error that can result in treatment failure (Seltzer et al., 1967). Perforation has been reported to occur most often with inadequate access preparation and/or misdirection of a bur (Alhadainy 1994). While perforation can be repaired using a variety of materials, the prognosis can be compromised based on the timing of repair, the location and the size of perforation (Fuss & Trope 1996). One lower molar sample (sample 2.3) in Group B (CEA) was perforated at the pulp chamber floor. This procedure error occurred during the search for root canal entrances. No such error occurred in either Group A (TEA) or Group C (CEA + CBCT). While this was not a common occurrence in the samples prepared, it may be possible that CBCT guidance could help reduce the occurrence of perforation during non-surgical endodontic treatment.

Another common cause of endodontic failure is unable to locate and adequately treat the root canal system in its entirety. A recent study showed that the incidence of missed canals for upper first molars were 46.5% for tooth #14 and 41.3% for tooth #3 (Karabucak *et al.*, 2016). After access preparation of all samples, preoperative CBCT images were reviewed and occurrence of missed canals was recorded. One sample, a

maxillary molar (sample 1.11), in Group B (CEA) had a missed MB2 canal. No missing canals were found in Group C (CEA+CBCT), suggesting that CBCT guidance could help reduce the occurrence of missed canals during non-surgical endodontic treatment.

Adequate Pulpal Debridement with CEA Preparation

One of the concerns of the CEA preparation has been that adequate pulpal debridement (especially in infected root canal systems) may be hindered because of the convergent cavity walls. With the traditional access preparation, greater than 35% of the root canal walls remain untouched after chemo-mechanical debridement shown by a micro-CT study (Peters *et al.*, 2001). A more recent study reported that the percentage of untouched canals ranges from 59.6%-79.9% (De-Deus *et al.*, 2015). The percentage of untouched-walls in CEA prepared teeth has been investigated and a compromised canal instrumentation efficacy (over 60% of canal walls untouched) was found only in the distal canals of mandibular molars when a “contracted endodontic cavity was performed” (Krishan 2013). With the advances of modern endodontics technology, including ultrasonics, microscopes and irrigation systems, we believe that the concern of inadequate debridement in CEA prepared teeth may be overcome.

The Effects of CEA Preparation on Fracture Resistance

Endodontically treated teeth do not have a lower modulus of elasticity or lower fracture resistance (Fusayama & Maeda 1969). However, there is a direct relationship between the amount of remaining coronal tooth structure and the resistance to occlusal forces (Vale 1956). More coronal dentin preserved reduces the incidences of tooth

fracture. CEA preparation in molars has been shown to provide a 2.5-fold greater fracture resistance (Krishan 2013). Furthermore, the fracture resistance of premolars and molars that received a contracted endodontic cavity was comparable to that of intact teeth whereas teeth prepared with a traditional endodontic cavity had less fracture resistance than intact teeth (Krishan 2013). CEA preparation is also advantageous in cases that root canal treatment has to be completed through the existing prosthetic restoration (ie. crowns, bridges, etc.) as significant reduced load to fracture has been shown in certain all-ceramic prosthetic materials after endodontic access preparations (Bompokai *et al.*, 2015).

Study Limitations

Limitations of this study include that there were some differences in the numbers of calcified teeth in three groups (one sample in Group A, two samples in Group B, and three samples in Group C). We did not exclude the calcified teeth in this study which may result in large variations in operation time required during access preparation. Additionally, a single operator prepared all samples. This was done in order to limit operator variability however in doing so, extrapolation of the results to all endodontic residents may or may not be possible. More residents could be included in future studies so the results are more likely to be applied to its effectiveness, on resident training. Finally, our survey responses only account for dentists in the state of Connecticut.

Future Studies

CBCT machines for endodontic use have different resolution and radiation

exposure. In this study, we used xxx CBCT which provides xxx field of interest / dosage/ resolution. Future studies on CBCT guided CEA preparation may include comparison of various CBCT units and dose protocols to determine the most effective protocol with the least amount of ionizing radiation exposure to the patient.

Our survey looking into the effect of CEA preparation on endodontic referral patterns only included dentists in the state of Connecticut. While doing so helped obtain a relatively high response rate, the data obtained may not be applicable to other sample populations of general dentists and future studies will expand to a broader population.

CBCT-guided endodontic access have been evaluated by *in-vitro* studies, *ex-vivo* studies, and multiple case reports (Zehnder *et al.*, 2015; Buchgreitz *et al.*, 2016). These techniques usually involve cases with extreme root canal calcification where CAD/CAM generated jigs have been used as a guide during access preparation to help find a root canal that is only present apically in the root structure. While promising, more research needs to be done in order to determine the effectiveness and feasibility of this technique for widespread clinical use.

VI. Conclusions

Despite above mentioned limitations, we found that while many general dentists in Connecticut are aware of and prefer CEA preparation, only 33% of them consider the form of access preparation a determining factor for their endodontic referrals. CEA preserved more coronal tooth structure than TEA without significantly more operation time. Moreover, CBCT can aid beginners in CEA preparation by enhancing the efficacy (less operation time) and accuracy (reduced prepared surface area ratio).

VII. Appendix

Appendix 1: Survey questionnaire

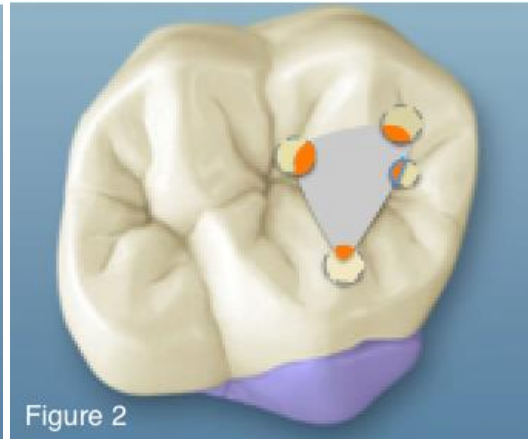
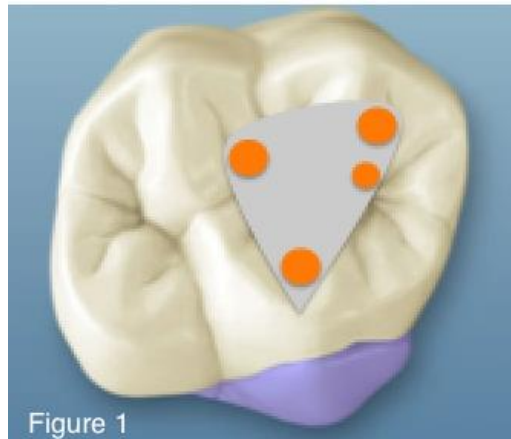
UConn Health
Division of Endodontology

Does conservative endodontic access (CEA) matter?

- 1) Are you aware of the concept of conservative endodontic access (CEA)?
 - a) Yes
 - b) No

**Different from traditional straight-line preparation, CEA is a technique of endodontic access with minimal size of access opening.*

- 2) Which of the access preparations below would you prefer to restore after endodontic therapy was completed?



- a) Figure 1
 - b) Figure 2
- 3) How much do you agree with the concept of CEA?
 - a) Strongly agree
 - b) Somewhat agree
 - c) Disagree
 - 4) How often do you find that teeth that you are restoring which have received endodontic treatment have had excessively large access preparations?
 - a) Always
 - b) Often
 - c) Sometimes

- d) Never
-
- 5) What percentage of your patients who need endodontic treatment do you refer out to a specialist?
 - a) 100%
 - b) More than 50%
 - c) Less than 50%
 - 6) Would the size of access opening be a determining factor for your endodontic referrals?
 - a) Yes
 - b) No
 - 7) Which type of access cavity do you prefer endodontists to prepare for patients?
 - a) TEA (traditional endodontic access/straight line access) as in Figure 1
 - b) CEA (conservative endodontic access) as in Figure 2
 - c) Accept both forms
 - 8) Would you be more likely to refer to an endodontist who performs CEA?
 - a) Yes
 - b) No

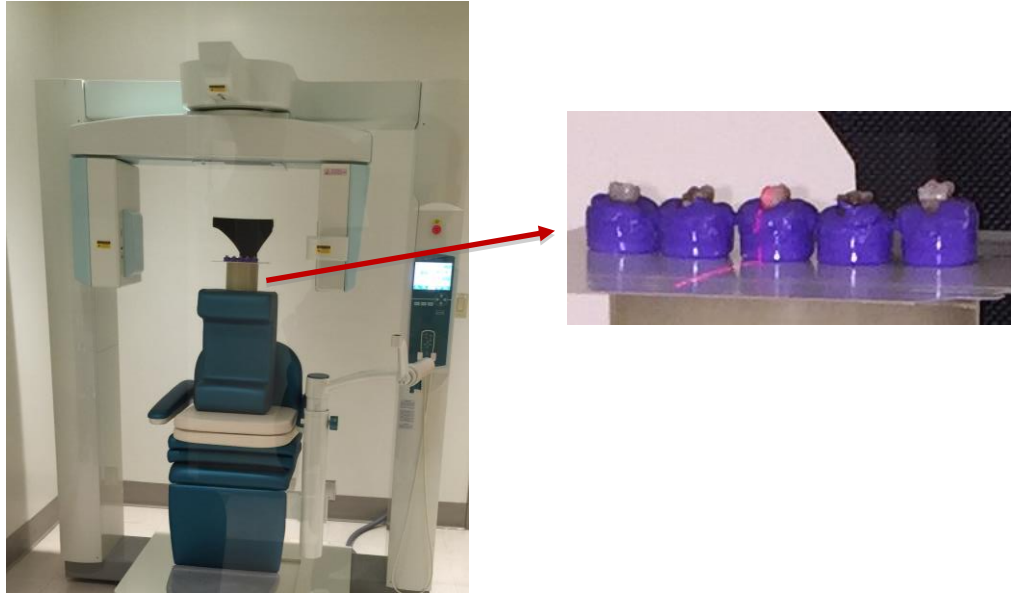
Appendix 2: The use of CBCT to guide access preparation

Fig. 17: Five teeth at a time were mounted and scanned by 3D Accutomo (J. Morita, USA). Red arrow indicated the magnified image showing sample placed and ready for CBCT scan (top panel).

Appendix 3: Workstation for access cavity preparation.



Fig 18: Workstation for access cavity preparation with surgical operating microscope (M320, Leica Microsystems)

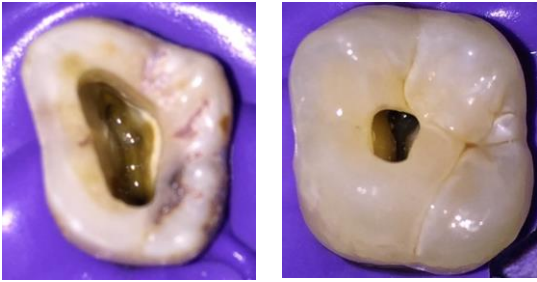
Appendix 4: CEA and TEA preparation examples

Fig 19: TEA (left panel) versus CEA (right panel) preparation of upper molars.

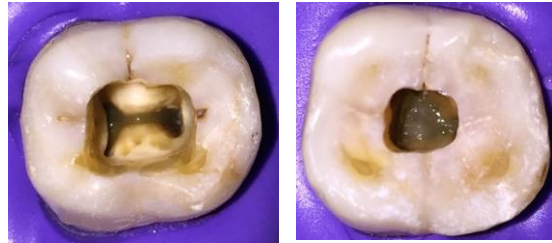


Fig 20: TEA (left panel) versus CEA (right panel) preparation of lower molars.

Appendix 5: Raw data of operation time of Gr. A (TEA), B (CEA) & C (CEA + CBCT)

Samples in Gr. A	Time (sec.)	Samples in Gr. B	Time (sec.)	Samples in Gr. C	Time (sec.)
1.2	772	1.1	1142	2.1	916
2.2	775	1.7	860	1.3	525
1.5	503	2.3	995	1.4	791
1.10	793	1.11	513	1.6	592
1.12	420	1.14	529	1.8	537
1.13	945	1.16	1557	1.9	492
1.17	704	2.5	399	2.4	911
1.20	831	1.19	571	1.15	408
2.6	464	2.7	287	1.18	641
1.22	570	2.8	685	1.21	1696
1.24	492	1.25	703	1.23	213
1.26	1095	1.27	414	2.10	252
1.28	316	1.29	235	2.11	227
2.9	329	2.12	260	2.14	354
2.15	326	2.13	239	2.16	333

Appendix 6: Raw data of surface area of Gr. A (TEA)

Sample	SA Pre 1 (mm)	SA Pre 2 (mm)	SA Pre 3 (mm)	SA Pre mean (mm)	SA Post 1 (mm)	SA Post 2 (mm)	SA Post 3 (mm)	SA Post mean (mm)	SA ratio
1.2	20.3	20.0	20.4	20.2	20.3	20.2	19.6	20.0	0.99
2.2	14.3	14.4	14.4	14.4	20.3	19.9	21.0	20.4	1.42
1.5	7.0	6.9	7.1	7.0	12.6	11.7	12.4	12.2	1.74
1.10	11.2	10.6	11.0	10.9	10.5	10.7	10.9	10.7	0.98
1.12	9.6	9.0	8.7	9.1	10.8	11.4	11.4	11.2	1.23
1.13	16.5	17.1	18.2	17.3	13.6	14.0	13.6	13.7	0.80
1.17	13.3	13.4	13.3	13.3	16.5	17.1	17.1	16.9	1.27
1.20	13.0	12.8	12.9	12.9	16.7	16.0	16.6	16.4	1.27
2.6	14.9	15.0	15.2	15.0	22.2	22.2	22.5	22.3	1.48
1.22	14.1	14.7	14.6	14.5	16.5	17.1	16.8	16.8	1.16
1.24	13.4	14.1	14.3	13.9	14.2	14.1	14.6	14.3	1.03
1.26	12.2	12.6	12.2	12.3	22.5	22.0	21.7	22.1	1.80
1.28	9.2	9.8	9.2	9.4	20.0	19.2	20.6	19.9	2.12
2.9	14.1	13.0	14.3	13.8	17.3	17.2	17.1	17.2	1.25
2.15	9.7	10.1	9.5	9.8	18.7	19.5	19.2	19.1	1.95

Appendix 7: Raw data of surface area of Gr. B (CEA)

Sample	SA Pre 1 (mm)	SA Pre 2 (mm)	SA Pre 3 (mm)	SA Pre mean (mm)	SA Post 1 (mm)	SA Post 2 (mm)	SA Post 3 (mm)	SA Post mean (mm)	SA ratio
1.1	10.5	11.4	11.2	11.0	7.9	7.7	8.0	7.9	0.72
1.7	5.8	6.5	5.5	5.9	5.3	5.3	5.6	5.4	0.92
2.3	18.8	18.0	18.4	18.4	14.5	14.9	15.3	14.9	0.81
1.11	9.1	9.5	9.0	9.2	9.8	10.0	9.8	9.9	1.07
1.14	12.7	11.5	11.4	11.9	6.3	6.3	7.1	6.6	0.55
1.16	17.0	17.0	17.6	17.2	7.5	6.8	6.9	7.1	0.41
2.5	15.7	15.5	15.8	15.7	10.6	10.8	11.2	10.9	0.69
1.19	13.0	12.8	12.6	12.8	8.8	9.5	8.4	8.9	0.70
2.7	17.7	18.3	18.3	18.1	10.4	10.4	11.0	10.6	0.59
2.8	4.0	4.3	3.9	4.1	6.6	6.6	6.6	6.6	1.62
1.25	4.4	4.4	4.6	4.5	9.0	9.1	9.3	9.1	2.02
1.27	7.4	7.9	8.2	7.8	6.9	6.9	6.6	6.8	0.87
1.29	8.6	8.2	8.7	8.5	6.9	7.5	6.9	7.1	0.84
2.12	8.6	8.5	8.0	8.4	7.7	7.4	7.4	7.5	0.89
2.13	13.9	12.6	13.6	13.4	7.1	7.1	7.1	7.1	0.53

Appendix 8: Raw data of surface area of Gr. C (CEA + CBCT)

Sample	SA Pre 1 (mm)	SA Pre 2 (mm)	SA Pre 3 (mm)	SA Pre mean (mm)	SA Post 1 (mm)	SA Post 2 (mm)	SA Post 3 (mm)	SA Post mean (mm)	SA ratio
2.1	18.2	17.5	17.7	17.8	9.5	9.2	10.1	9.6	0.54
1.3	5.2	5.5	5.2	5.3	4.4	4.3	4.2	4.3	0.81
1.4	5.6	5.8	6.1	5.8	5.0	5.0	4.9	5.0	0.86
1.6	5.7	6.1	6.1	6.0	4.4	4.4	4.4	4.4	0.73
1.8	10.1	11.2	9.7	10.3	5.2	5.2	5.2	5.2	0.50
1.9	15.2	15.2	15.2	15.2	8.2	7.9	5.7	7.9	0.52
2.4	12.7	12.5	13.3	12.8	9.9	9.2	10.2	9.8	0.76
1.15	12.9	12.1	12.3	12.4	4.7	4.6	4.4	4.6	0.37
1.18	14.4	14.9	14.9	14.7	7.8	7.7	8.1	7.9	0.53
1.21	14.6	14.3	14.1	14.3	7.9	8.4	7.9	8.1	0.56
1.23	10.2	10.9	10.1	10.4	7.7	7.5	7.5	7.6	0.75
2.10	9.5	9.7	9.8	9.7	6.4	6.5	6.6	6.5	0.67
2.11	8.6	8.2	8.7	8.5	5.7	6.0	6.1	5.9	0.69
2.14	10.5	10.7	10.7	10.6	8.5	9.0	8.9	8.8	0.83
2.16	14.3	14.2	14.8	14.4	8.1	8.1	7.8	8.0	0.56

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