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Research Article

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

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Abstract

Aims: Conservative endodontic access (CEA), which removes the least tooth structure necessary, has become a popular alternative to traditional endodontic access (TEA). This study aims to examine whether CEA affects endodontic referrals and whether CBCT can guide CEA.

Methodology: A survey of general dentists (n=129) was conducted to determine the impact of CEA on endodontic referrals. To assess the effects of CBCT on CEA, 45 extracted molars were accessed by TEA (group A), CEA (group B) or CEA with pre-operative CBCT images provided (group C). The ratios of surface areas of coronal access to pulp floor were quantified and the time for access preparation was recorded. Statistics was performed using Graph Pad Prism 5.

Results: While 81% of general dentists preferred CEA, only 33% considered it a determining factor for their endodontic referrals. TEA resulted in statistically significantly more coronal dentin removed than CEA with or without CBCT (surface area ratio: groups A: B: C= 1.37±0.38*: 0.88±0.42: 0.65±0.14; mean ± SD, *p<0.05, one-way ANOVA). There was no difference in operation time among three groups.

Conclusions: CBCT has great potential to guide CEA preparation for beginners and CEA is a preferred access form to general dentists but is not a determining factor on endodontic referrals.

ABBREVIATIONS

CBCT: Cone Beam Computed Tomography; CEA: Conservative Endodontic Access; TEA: Traditional Endodontic Access

INTRODUCTION

Endodontic therapy prevents or treats apical periodontitis. The first step is gaining access to the root canal orifices. Two techniques used are the traditional endodontic access (TEA) and conservative endodontic access (CEA). TEA follows the "straight line access" principle, resulting in complete visualization of all canal orifices from an occlusal view. CEA complies with the concept of "minimally invasive dentistry" and emphasizes the importance of the coronal structure preserved.

TEA exerts less strain on instruments and allows for more consistent working length measurements [1,2]. Disadvantages of TEA include lower resistance to fracture and significant weakening of prosthetic restorations [3-5]. In contrast, CEA preserves more coronal tooth structure [6] and provides a greater resistance to fracture. Thus is advantageous in cases with existing prosthetic restorations [3,4]. CEA also reduces visibility, which potentially leads to untreated anatomy [4]. Other concerns of CEA include increased strain on instruments, increased operation time, and compromised disinfection. In addition, CEA may not be feasible in cases with extensive restoration or cavity and CEA may have negative impact on endodontically treated teeth which require intracoronal bleaching [7].

CBCT can be used to identify the number of root canals and their location. CBCT has higher specificity and sensitivity when compared to intraoral radiographic assessments in the detection of the MB2 canal [8]. Thus, it is conceivable that CBCT technology can better guide CEA preparation by providing relevant information for pre-access analyses.

Whether CBCT images increase the efficacy of CEA and whether CEA affects endodontic referrals of general dentists remain unknown. We hypothesized that CEA is the preferred access by general dentists and can be better guided with CBCT. To test this hypothesis, a survey amongst general dentists was conducted and access preparations in extracted molars with or without the aid of CBCT was performed.

MATERIALS AND METHODS

A survey consisting of eight questions was designed (Table 1). The definition of CEA was described as "a technique of endodontic access with minimal size of access opening". Images of CEA and TEA preparations were provided to the respondents.

To increase the response rate, our survey was limited to general dentists in the State of Connecticut. The survey was distributed using the online platform "Survey Monkey" (www.surveymonkey.com) (112 surveys) and a paper version (17 surveys). A reminder was periodically sent to respondents. The response rate was 77.52% (100 out of 129).

Collection of extracted teeth

Forty-five human extracted upper and lower molars were collected. Exclusion criteria were teeth with caries beyond class I, teeth with extensive fillings/crowns, atypical crown morphology, previously root canal treated teeth and third molars. Extracted teeth were divided into three groups (n=15 per group), group A (TEA), group B (CEA), and group C (CEA with CBCT images provided pre-operatively to the operator), using a random group allocation online software (www.ramdomlists.org).

CBCT imaging

Custom jigs for radiographic imaging were made using poly-vinyl siloxane (PVS) bite registration material Correct-Bite (Pentron, Orange, CA) (Figure 1A). Briefly, the PVS material was injected, using an impression gun (Dentsply Sirona, York, PA) and syringe, into preformed plastic wells. While unset, extracted teeth were introduced to the level of the cementum-enamel junction (CEJ) and left for two minutes allowing the material to set. The jig was labelled according to the sample number.

Pre- and post-operative CBCT scans were taken using a 3-D Accuitomo (J. Morita USA, Inc., Irvine, CA). Scan parameters were set to 90 kVP and 2.0 mA, at a field of view of 150x100 mm at the "Hi-Fi" setting. Molars mounted in PVS custom jigs were scanned in groups of five samples per scan. The operator was only allowed to access CBCT images from teeth in group C. CBCT images were analyzed using CB Works software (OnDemand3D Technology, Inc., Irvine, CA). The CBCT image for each sample was analyzed independently, without knowing the grouping information.

Access preparations

All teeth were accessed by a third-year endodontics resident (J. G.) under a microscope with 6.4x magnification (Leica M320, Leica Microsystems). Access preparations for group A were performed with the goal of achieving straight-line access. Teeth in group B were prepared for CEA. Access preparations for group C were performed with the aid of CBCT images. In upper molars for example, access to the largest canal (palatal canal) was performed first using #2 and #4 carbide round burs (Brasseler USA Dental, Savannah, GA). The mesiobuccal canal was then accessed using CBCT images as a guide for approximate distance and orientation from the palatal canal. Next, the distobuccal canal was identified and finally any remaining canals indicated in CBCT images were located.

For all three groups, access preparations were completed when all root canal orifices could be visualized and accessed by a size-10 k-file (Dentsply Sirona, York, PA). The operation time was recorded.

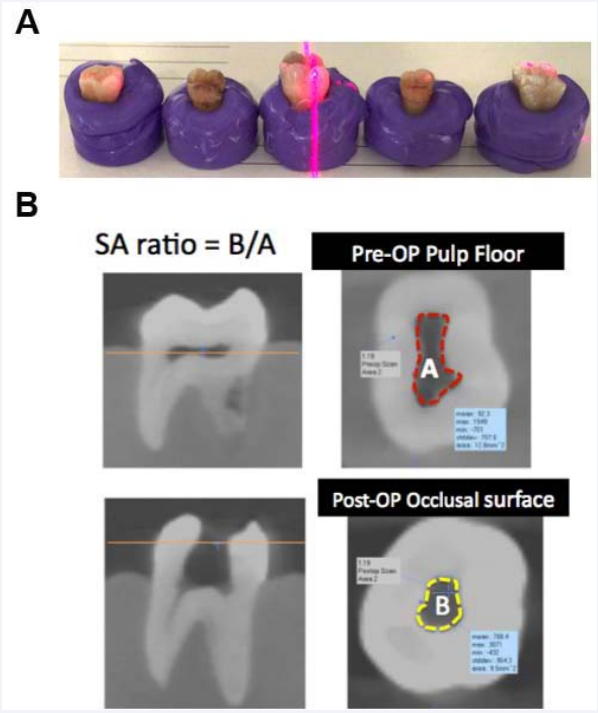

Figure 1 A) Molars embedded in custom-made PVS jigs. Only coronal structures above CEJ were exposed. Laser (pink light) centering prior to CBCT scan. Five teeth were scanned at one time.
B) The representative pre-operative (top panel) and post-operative (bottom panel) CBCT images showing axial planes of molars, pre-OP pulp floor and post-OP occlusal surfaces. The surface area (SA) ratio was calculated using the formula: surface B (yellow dotted circle) divided by surface A (red dotted circle).

Table 1: Summary of survey questionnaire.

Questions	Response
Are you aware of the concept of CEA?	Yes (76.77%); No (23.23%)
Which access preparations of endodontically treated teeth would you prefer to restore (images given)?	CEA (81%); TEA (19%)
How much do you agree with the concept of CEA?	Strongly agree (35%); Somewhat agree (60%); Disagree (5%)
How often do you find that endodontically treated teeth have excessively large access preparations?	Always (2%); Often (31%); Sometimes (60%); Never (7%)
What percentage of your patients who need endodontic treatment do you refer out to a specialist?	100% (25%); More than 50% (35%); Less than 50% (40%)
Which type of access cavity do you prefer endodontists to prepare for your patients?	TEA (7%); CEA (32%); Accept both forms (61%)
Would you be more likely to refer to an endodontist who performs CEA?	Yes (58%); No (42%)
Would the size of access opening be a determining factor for your endodontic referrals?	Yes (33%); No (67%)

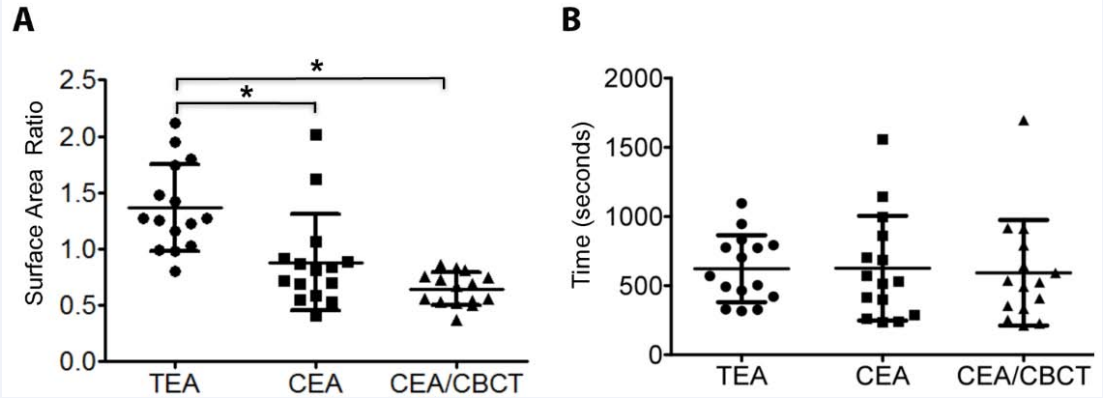

Figure 2 Histograms of A) surface area ratio of group A (TEA), group B (CEA), and group C (CEA + CBCT). B) Operation time required in group A, group B, and group C. Data presented are mean ± SD. N=15 per group. *p<0.05 by one-way ANOVA.

Calculating the ratio of surface area

All measurements were taken in the axial view of CBCT images. 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 1B). The level chosen for post-operative measurements 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 CBCT software tool and measured in square-millimeters (mm^2). Each surface area was measured three times consecutively in the same manner. The means of the surface area measurements were calculated. The surface area (SA) ratios were calculated using the following formula:

SA ratio= mean surface area of access (post-operative occlusal view) / pulpal floor

Statistical analysis

Both, the SA ratio and the operation time required to complete access preparations were subjected to statistical analysis using Prism5 software (Graph Pad Software, La Jolla, CA) with one-way ANOVA. Statistically significant difference was reached for *p*-value < 0.05. Data presented as mean ± standard deviation (SD).

RESULTS AND DISCUSSION

Survey questionnaire collection

The responses of this survey are summarized in Table 1.

The concept of CEA was common knowledge among the respondents. Only 5% of general dentists disagree with this concept. Approximately one third of general dentists reported that they often or always found endodontically treated teeth with excessive large access preparation. Many general dentists (81%) prefer to restore endodontically treated teeth with CEA preparation. Although endodontic referral is common and more than half of the respondents would be more likely to refer to an endodontist who performs CEA, type of access is not a determining factor for referrals.

Comparison of SA Ratio between TEA and CEA

To investigate the coronal structure preserved after CEA or TEA preparations, we calculated the SA ratio in each group. We showed that the mean of the SA ratio in Group A was larger than one, indicating a divergent cavity form whereas the SA ratios in groups B and C were less than one, suggesting a convergent cavity form. The SA ratios in group B (CEA) and group C (CEA + CBCT) were statistically significantly smaller than the ones in group A (TEA), while no significant difference was found between group B and group C (Figure 2A). However, a p-value of 0.0504 was detected between groups B and C, which indicates a tendency for reduced SA ratio when CBCT is utilized for CEA preparation. In addition, the standard deviation in group C is smaller than that of group B suggesting that with the aid of CBCT, a more consistent CEA preparation is obtained.

Operation Time for TEA vs. CEA Preparation

To investigate the efficiency of the different access cavity preparation techniques, the operation time, the time until all canal orifices were identified, of each sample was examined. There was no statistically significant difference among three groups (Figure 2B).

DISCUSSION

Performance of root canal treatment through a more conservative access (CEA) has been advocated (9). This concept aims to achieve minimally invasive endodontics as well as minimally invasive dentistry. Although the concept of conservative endodontic access is becoming more accepted, the knowledge gaps in this field include: 1) guidelines for performing CEA are mostly missing in endodontic residency programs; 2) the effects of CBCT on CEA preparation remain unknown although the use of CBCT in endodontics is on the rise, and 3) a lack of studies whether CEA preparation serves as a determining factor to endodontic referral patterns of general dentists. These questions were addressed in this study by conducting a survey to general dentists in the State of Connecticut and by performing access preparations in extracted molars with or without the aid of CBCT images.

A previous investigation on endodontic referrals reported that, on average, general dentists referred less than one-half

(46%) of their endodontic cases to endodontists and a majority of general dentists (63%), routinely referred to only 2 or 3 different endodontists (10). Our survey showed that most general dentists in the State of Connecticut tended to refer their cases to endodontists. While the majority of dentists preferred to restore a tooth with CEA preparation, one respondent preferred to restore a TEA-prepared tooth because "larger access preparation makes it easier to remove the cotton pellet". The implications of CEA on the easiness for general dentists to remove the inter-appointment temporary filling should be considered in clinical practice. Although CEA is not necessarily a determining factor, 58% of the respondents would be more likely to refer patients to an endodontist who performs CEA. Being capable of preparing CEA may become a necessary skill for endodontists. Although minimally invasive endodontics and conservative access is an emerging concept in the field of endodontics we found that 23.23% of general dentists were not aware of the CEA concept. This result suggests that the introduction of CEA should be considered part of the curriculum in dental schools.

Our data clearly demonstrate that TEA resulted in access preparations with parallel to slightly divergent axial walls whereas CEA resulted in access preparations with convergent axial walls. 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, respectively. Furthermore, it was shown that CEA preparation does not prolong the operation time. This was unexpected as it is commonly thought that CEA preparation is more time-consuming than TEA. No significant differences in operation time for samples within a group were found. As the operator became more experienced, operation time was reduced in all three groups. Our data suggest that the operation time should not be considered a disadvantage of CEA when compared to TEA.

Clinical implications of CBCT in CEA preparation are: 1) to enhance the accuracy of CEA; 2) to enhance the efficacy of CEA for inexperienced operators; 3) to reduce procedure errors during CEA preparation. When comparing data between group B (CEA) and group C (CEA with CBCT), CBCT has a strong tendency to guide more consistent preparation. Although time required to complete access preparation for the last five samples was markedly reduced in all three groups, the first 10 samples of group C required less time compared to those in group B. Longer operation time in some samples of group B and C was associated with the severity of calcification in the pulp chamber. CBCT images also provided additional advantages preventing procedural errors including perforation and missing canals. Perforation has been reported to occur most often with inadequate access preparation and/or misdirection of a bur [11]. A recent study showed that the incidence of missed canals for upper first molars was46.5% for tooth #14 and 41.3% for tooth #3 [12]. In our study we had one pulpal floor perforation in a calcified lower molar in group B where CBCT was not used. No such error occurred in group C. After access preparation of all samples, preoperative CBCT images were reviewed and occurrence of missed canals was recorded. One sample in group B (CEA) had a missed MB2 canal. No missed canals were found in group C.

A thorough radiographic assessment assists the operator in determining the location and angulation of the root canal system. The American Association of Endodontists (AAE) and the American Academy of Oral and Maxillofacial Radiology (AAOMR) released their joint position statement in 2016 regarding the use of CBCT in endodontics, including better detection of root canal morphology. A recent survey of 1083 endodontists found that 50.69% of the respondents had access to CBCT imaging on-site. The general concerns for the use of CBCT include resolution limitations, radiation exposure and cost to the patient [13]. Clinicians should stay with the concept of "as low as reasonably achievable" and constantly consider to use a limited field of view, which allows small volume scans with high resolution and reduced radiation exposure [14]. CBCT should only be used if there is a benefit for patient treatment. Taken together, we recommend performing CBCT-aided CEA in cases with high risks of fracture, procedural errors or missed canals.

One of the concerns of the CEA preparation has been that adequate pulpal debridement may be hindered because of the convergent cavity walls. With the TEA preparation, greater than 35% of the root canal walls remain untouched after chemo-mechanical debridement as shown by a previous micro-CT study [15]. A more recent study reported that the percentage of untouched canals in TEA prepared teeth ranges from 59.6%-79.9% [16]. When comparing the instrumentation efficiency between CEA and TEA, the percentage of untouched-walls was only significantly higher in the distal canals of molars with CEA and not significantly different in maxillary incisors, mandibular premolars and other canals of molars [4]. Future studies will be needed to investigate whether CEA negatively affects long-term clinical outcome due to possible compromised canal instrumentation efficacy.

Limitations of our study include that there were some differences in the number of calcified teeth within the 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 therefore have resulted in larger variability in operation time. Future studies should separate teeth with or without calcifications to obtain more homogeneous groups. Referral patterns may vary based on the availability of endodontists in a region, the training background of general dentists, and the percentage of difficult cases etc. Our survey was geographically limited to dentists in the State of Connecticut. Future studies may benefit from including a geographically broader dentist population.

CONCLUSION

Our study found that while CEA is a preferred access by general dentists, it is not a determining factor for endodontic referrals in the State of Connecticut. We suggest that CBCT images will especially benefit inexperienced operators and may be a tool to train residents to perform CEA.

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