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Utilization of a new web-based application for case difficulty assessment as a predictor for procedural errors in nonsurgical root canal treatment

Watraat Unmona Hasanat
u_hasanat@u.pacific.edu

Utilization of a New Web-Based Application for Case Difficulty Assessment as Predictor of Procedural Errors in Non-Surgical Root Canal Treatment

Watraat Hasanat, DDS

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Arthur A. Dugoni School of Dentistry

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Approved by:

Ove Peters, DMD, MS, PHD
Thesis Committee Member

Johnah Galicia, DMD, MS, PhD
Thesis Committee Member

Craig A. Dunlap, DDS,
Interim Graduate Program Director
Mentor

Abstract

Introduction: There are currently no established guidelines to determine which cases general practitioners should refer to an endodontist for root canal treatment. The American Association of Endodontists (AAE) has developed the EndoCase mobile application (ECA), which utilizes either a full or abridged rubric to assign case difficulty level and provide referral guidelines to general practitioners and dental students. **Objective:** The objective of this study was to determine whether the abridged criteria of the EndoCase application can help predict the incidence of procedural errors in nonsurgical root canal treatment of mandibular molars in an undergraduate dental clinic based on the difficulty level. **Methods:** A list of patients who received primary root canal treatment on mandibular first molars in the undergraduate dental clinic from 2015-2020 was obtained. Ninety patients qualified for inclusion. Case difficulty level was assessed using the ECA by three providers with differing levels of experience. Incidence of procedural errors was determined from post-operative radiographs by two calibrated independent observers. **Results**: The most common endodontic mishaps were errors during access cavity preparation followed by the presence of voids in the root filling, with an incidence of 54.4% and 45.6%, respectively. There were no significant differences regarding case difficulty level and the incidence of total procedural errors nor number of treatment visits. Of the individual error types, the presence of obturation >2mm short of the radiographic apex was weakly correlated with case difficulty level ($r = 0.226$, $p < 0.05$). **Conclusion:** There is minimal correlation between the difficulty level of mandibular molars determined by the ECA and the number of treatment visits or overall incidence of procedural errors.

Key Words

American Association of Endodontists case difficulty assessment, EndoCase application, endodontic mishaps, procedural errors, reciprocating WaveOne file system, root canal instrumentation

Introduction

The goal of endodontic therapy is the prevention and treatment of apical periodontitis (1). In the United States, approximately 70-75% of endodontic treatment is performed by general practitioners. In addition, a large number of endodontic procedures are performed annually by dental students in academic settings (2, 3). However, the knowledge, ability, and experience vary between general dentists, dental students, and endodontic specialists.

Procedural errors increase the risk of treatment failure, especially in teeth with necrotic pulps and apical periodontitis. However, many procedural errors are preventable and are typically due to several factors including a lack of understanding of the root canal anatomy, the principles of instrumentation, and periapical tissue response (4). Case difficulty forms may aid in the detection of difficult clinical cases, and proper case selection may reduce the incidence of procedural errors (5). Protocols for determining case difficulty may help the general practitioner determine indications for referral to a specialist for endodontic treatment.

Retrospective studies have found a strong association between apical periodontitis and poor technical quality of root canal treatment (6). In addition, technical errors such as iatrogenic perforation, patency at apical terminus, and extrusion of root fillings are associated with decreased outcomes. Obturation within 2mm of the radiographic apex, and dense obturations free of voids are associated with better clinical outcomes (7-11).

There are currently no validated guidelines to help general practitioners determine the need for referral to an endodontist. However, multiple national associations have created case difficulty forms to assist dental providers. The American Association of Endodontists (AAE) developed a Case Difficulty Assessment Form, which received favorable reviews regarding user experience and relevance based on feedback from general dentists and dental students in a retrospective study (5). Another study compared two different classification systems: Endodontic Treatment Classification (ETC), an adjusted system developed by the Canadian Academy of Endodontists, and the Dutch Endodontic Treatment Index (DETI). Users found that both classification systems were helpful in differentiating between complicated and uncomplicated cases, although there were more variables in the latter system, leading to differences in the difficulty score obtained (12). To date, these tools have not been validated for their ability to determine procedural error as related to case difficulty.

Previous retrospective clinical studies utilized a printable version of the AAE Case Difficulty Assessment form in order to evaluate the quality of root canal treatment. A study completed in an undergraduate dental setting demonstrated a significant association between case difficulty and iatrogenic errors, with molars exhibiting the highest frequency of errors of any group (7). A similar study conducted in a post-graduate dental clinic found a statistically significant difference between the length of root canal filling and level of difficulty, but no statistically significant differences between homogeneity of root canal filling and case difficulty (13). In comparing instrumentation method, number of treatment visits, and case difficulty level, a prior study completed in an undergraduate dental clinic found that endodontic treatment mishaps were significantly associated with cases in the high difficulty category (14).

The AAE recently developed the EndoCase mobile application (ECA), which aims to be a more practical and user-friendly version of the previous, two-page Endodontic Case Difficulty Assessment Form. The ECA mobile application utilizes a full or abridged rubric to assign case difficulty level and serve as a useful tool with which to make referral decisions. The assessment form is divided into four categories of considerations: patient, diagnostic, treatment, and additional considerations. Guidelines are given for each level of difficulty to help determine whether the case is appropriate for general dentists and students or the patient needs to be referred to an endodontic specialist. Users have the option of a full or abridged version of difficulty criteria. The latter excludes the following individual patient criteria present in the full version: medical history, anesthetic difficulties, patient compliance, maximum opening, gag reflex, emergency conditions, radiographic difficulties, and history of trauma.

To date, there have been no studies evaluating the use of the abridged ECA in determining the association between case difficulty level and endodontic treatment mishaps when compared by the experience of provider – endodontist vs. general dentist vs. dental student. The objective of this study is to determine whether the abridged version of the ECA can help evaluate the incidence and type of endodontic procedural errors during nonsurgical root canal treatment of mandibular first molars in an undergraduate dental clinic. The null hypothesis is that the ECA is unable predict the occurrence of procedural errors based on the difficulty level of a nonsurgical root canal treatment case.

Materials and Methods

This study was completed at the University of the Pacific Arthur A. Dugoni School of Dentistry (San Francisco, California, USA). All data was collected after exemption was obtained

from the university's Institutional Review Board (IRB #2020-97). A list of patients who received root canal treatment in the undergraduate dental clinic were recovered from the University's electronic health record (Axium). The DDS program includes one year of preclinical training and two years of clinical training, and all operators recruited for the study were enrolled in their second or third year of predoctoral education. Endodontic treatment was always supervised by an endodontic faculty member or post-graduate resident.

All treatments were performed in the undergraduate dental clinic and followed the University's standard protocol of treatment as follows: after rubber dam isolation, access was achieved, canals orifices were located, and working length was determined with the use of an electronic apex locator (Root ZX II, J Morita, Tokyo, Japan) and digital periapical radiographs. Hand instrumentation was performed to create a glide path using consecutive K-files up to size #20 (Dentsply, Tulsa, Oklahoma, USA). Following establishment of a glide path, rotary instrumentation was completed using WaveOne Reciprocating files (Dentsply, Maillefer, Switzerland). Canals were irrigated continuously with 5.25% sodium hypochlorite solution using a side-vented passive irrigation syringe. For all interappointment visits, calcium hydroxide was used as an intracanal medicament (Ultracal XS, Ultradent Products, Inc, South Jordan UT). Obturation was completed using AH Plus Sealer and a cold lateral condensation technique (Dentsply, Tulsa, Oklahoma, USA). A temporary restoration was placed, and final post-operative periapical radiographs were taken.

Because previous studies identified molars as the tooth type with the highest frequency of procedural errors, a list of all patients who have had primary root canal treatment completed by dental students on tooth #30 during the years 2015-2020 was obtained.

Inclusion and Exclusion Criteria

Individuals that received primary nonsurgical root canal treatment of mandibular right first molars (tooth #30) by dental students were recruited for this study. All patient records must have contained the following digital radiographs during endodontic treatment: 2 pre-operative periapical radiographs, 1 pre-operative bitewing radiograph, and 2 post-operative radiographs for evaluation. Patients under the age of 18, patients receiving nonsurgical treatment of all other teeth, nonsurgical retreatment, surgical retreatment, and patients treated in the postgraduate clinic were excluded from this study.

Case difficulty assessment and evaluation

From a total of 356 patients who received root canal treatment on tooth #30 in the undergraduate dental clinic, 90 patients qualified for the study. Because the case assessment application is meant for use by general dentists and dental students to determine the appropriate level of care and indications for referral, difficulty level was determined by three different provider types who are likely to use the app for its intended purpose: a dental student, a general dentist, and an endodontist (Table 1). Case difficulty level was assessed and recorded using the abridged version of the ECA, which is currently freely available (https://www.aae.org/specialty/clinical-resources/treatment-planning/case-assessment-tools/).

In order to familiarize each observer with the ECA, each evaluator was required to practice rating five sample cases with the primary author of the study. Three evaluators participated in the pre-operative cases difficulty assessment: a general dentist with 2 years of postgraduate clinical experience in a private practice who completes root canal treatment on a weekly basis, a dental student in his final year of clinical training who has completed at least 5 nonsurgical root canal treatments, and an endodontist with two years of postgraduate clinical experience . When disagreements occurred on answers to the questionnaire, a consensus was

reached after discussion. Following this process, an anonymized set of three digital pre-operative radiographs, including a bitewing, and two periapical radiographs, were independently presented to each observer for each of the ninety cases who were blinded to the postoperative radiographs and occurrence of procedural errors.

Two endodontists who were blinded to the difficulty level were involved in the evaluation of the two post-operative radiographs for each case. The method of viewing the radiographs was standardized using an evaluation form to record the number of visits as well as incidence and type of procedural errors for each case. Both evaluators independently evaluated radiographs and recorded endodontic mishaps. If there was disagreement on presence or absence of errors in any case, agreement was achieved after discussion.

The following procedural errors were considered in this study: errors during access leading to deviation from standard access form or gouging of tooth structure, canal transportations and ledge formation deviating from the radiographic apex, coronal and radicular perforations, obturation more than 2mm short of the radiographic apex (underfilling), obturation beyond the apical foramen (overfilling), excessive taper compromising root dentin, and lack of density or homogeneity of root filling with the presence of voids. The incidence and type of procedural errors were determined from post-operative radiographs by two calibrated independent observers. If there was disagreement, an agreement was reached after discussion.

Statistical Analysis

For the case difficulty level, the numerical score was obtained by the ECA and was used for all statistical analysis rather than using corresponding the categorical value of minimal, moderate, or high difficulty. Pearson's Correlation Coefficient was used to determine the

correlation between case difficulty obtained by each scorer, as well as the average difficulty score, and the total number of procedural errors and treatment visits for each case. A Point Biserial Correlation Coefficient was used to determine the correlation between the average case difficulty level and each individual type of procedural error included in the study. Linear regression was performed to estimate the effect of average case difficulty level and total number of procedural errors. An independent samples t-test was used to determine if there was a statistically significant difference between the case difficulty levels determined by the observers. Data was analyzed using SPSS v. 20.0 (SPSS Inc., Chicago, USA). The p-value was set at 0.05.

Results

Based on the average difficulty scores from all three scorers, 74% of the cases were allocated to the "moderate" difficulty and 26% of the cases were allocated to the "high" difficulty category.

Procedural errors occurred in all but 3 out of 90 cases, giving a 96.6% incidence of at least one procedural error. There were no cases with separated instruments.

Missed canals accounted for the least common procedural errors with an incidence of 8.9%, accounting for 4.0% of the total number of procedural errors that occurred. The most common were errors during access and inadequate obturation density, with an incidence of 54.4% and 45.6% respectively. Errors during access and inadequate obturation density accounted for 24.6% and 20.6% of all procedural errors, respectively. Transportation had an incidence of 36.7% and accounted for 26.6% of all procedural errors. Inadequate or excessive taper of preparation and overfilling each had an incidence of 24.4% and accounted for 11.1% of procedural errors. Underfilling had an incidence of 15.6% and accounted for 7.0% of all

procedural errors. Perforations had an incidence of 11.1% and accounted for 5.0% percent of all errors (Figure 1).

There were no statistically significant correlations between case difficulty level and the incidence of procedural errors, at the individual scorer level or using a pooled average of all scorer's difficulty levels (Figure 2; Table 2). There was a statistically significant low degree of positive correlation ($r = 0.226$, $p < 0.05$) between average case difficulty score and the presence of underfilling, defined as obturation more than 2mm short of the radiographic apex. There were no other correlations between average case difficulty level and the remaining individual error types included in the study (Figure 3; Table 3). There were no significant correlations between case difficulty level and number of treatment visits, or between the number of treatment visits and incidence of procedural errors (Figures 4 and 5; Table 4).

Discussion

This study demonstrates that endodontic case difficulty as determined by the ECA does not correlate with the total incidence of procedural errors or number of visits in the treatment of mandibular molars in an undergraduate dental clinic. Individual error types were not associated with difficulty level except for obturation >2mm short of the radiographic apex, which demonstrated a weakly positive correlation with increased difficulty level. There were no correlations between number of visits and total number of errors or individual error type. These findings are in contrast with other studies that showed that increased case difficulty was associated with more procedural errors and number of treatment visits (7, 14). With regard to practitioner experience level, there was no statistically significant difference in the averages of the case difficulty scores that were determined by each of the three evaluators. This suggests that

the format and criteria of the ECA are accessible and able to be used by multiple provider types to predict case difficulty level with similar results.

There was a 96.6% incidence of at least one type of error in the cases included in this study. This is a higher incidence than those reported in previous studies which have found a range of 13% to 66% incidence of mishaps in undergraduate dental clinics (15-18). This can be explained by the inclusion of one tooth type in this study; whereas previous studies have examined multiple tooth types, including anterior teeth which are associated lower incidences of procedural errors. In addition, there is significant variation in practitioner skill and case assignment in an academic setting.

Eight different procedural error types were selected that may affect the quality of root canal treatment, which in turn may affect the prognosis of root canal treatment. In this study, the most frequent endodontic mishaps were errors that occurred during access cavity preparation (54.4%), inadequate obturation density with the presence of voids (45.6%), and canal transportation (36.7%). Balto et al reported similar findings with regard to the most common types of errors, with ledge formation present in 14% of cases and apical transportation occurring in 7% of cases. However, they found a lower overall incidence of procedural errors due to the inclusion of different tooth types in the study (17). Other authors have reported higher rates of transportation or ledge formation, with incidences ranging from 39% to 52% of all cases (19, 20). Anterior teeth and premolars exhibit transportation and ledge formation less frequently, while molars often exhibit thin, curved, or mineralized canals that may make endodontic treatment more difficult. The inclusion of multiple tooth types in this study may have resulted in a lower incidence of procedural errors.

Combining the frequency of overfilling and underfilling, procedural errors related to obturation length control comprised 18% of all errors in this study. The quality and length of root canal treatment has been associated with endodontic outcomes. Ng et al found that homogeneity of fill with the absence of voids and length of root canal obturation within 2mm of the radiographic apex were increased with higher rates of success (8). The specific anatomy of mandibular molars, such as their curved root structure, may make length control difficult. While this study demonstrated a statistically significant correlation between the case difficulty level and the incidence of underfilling, there were no significant correlations with overfilling. However, since transportation was a frequent occurrence in this study, it may have played a minimal role in the occurrence of obturation that was >2mm short of the radiographic apex.

Perforations had an incidence of 11.1% and accounted for 5% of all procedural errors in this study. Other studies have found a similar occurrence of perorations, accounting for 1.9-2.5% of all procedural errors in an undergraduate dental clinic (7, 19). Although short term outcome studies have shown favorable prognoses with perforations repaired with MTA, systematic reviews and metanalyses have found that the incidence of perforations reduces the success rate to approximately 80% after repair with MTA (8, 21, 22).

Outcome studies have demonstrated that the presence of separated files does not result in a lowered prognosis of endodontic treatment without the radiographic presence of a periapical lesion (23, 24). There were no cases of separated instruments in the study, which may be related to the instrumentation method of completing final cleaning and shaping of all canals with WaveOne Gold reciprocating files. In vitro studies have shown that reciprocating file systems exhibit significantly higher torsional resistance and cyclic fatigue compared to instrumentation with rotary nickel titanium files (25-27). Other studies have demonstrated similarly low

incidences of separated instruments in cases completed in undergraduate dental clinics, ranging from 1.9 to 3% of cases (7, 28).

Patients treated in an academic setting are often treated in multiple visits. In this study, there were no significant correlations between number of treatment visits and case difficulty level or the incidence of procedural errors. Endodontic literature has conflicting studies concerning outcomes of single versus multiple visit endodontic treatment. Two prospective studies have shown an association with the risk of flare ups and an increased number of visits (29, 30). However, other studies do not demonstrate an association between these two factors, instead attributing greater risk of postoperative pain for those patients who presented with pre-operative pain (31).

This study includes several inherent limitations. Future research projects would benefit from a larger sample size and inclusion of multiple tooth types. Molars have been shown to be the single tooth type associated with the most procedural errors and, currently in the United States, only 20% of molars are reported to be endodontically treated by general practitioners (2, 7). This study aimed to investigate if the case difficulty level would be able to predict procedural errors, and thus aid general practitioners in case selection for molar teeth. However, all molars included in the study were graded as moderate or high difficulty with scores greater than or equal to 10 points (Table 1). This would suggest the ECA has limited potential for application for the general dentist or dental student in determining whether to treat a molar tooth, as these difficulty levels indicate referral or at least consideration of referral to an endodontist for treatment. To determine where the abridged ECA can be applied to teeth of multiple difficulty levels, teeth with a larger range of difficulty, such as anterior teeth and premolars, could be included in future studies.

There is also significant variation in practitioner skill and case assignment in an academic setting. Students often receive faculty help in clinical procedures, which may decrease the number or type of procedural errors that may occur. In this type of retrospective study, it is not possible to determine the extent of faculty involvement that was required for each case. In order to better categorize incidence of procedural errors, experience level and academic year of the operator should be considered, as procedural errors would likely be more frequent in less experienced operators. A prospective study would allow case difficulty criteria and procedural errors to evaluated at the time of treatment as well as the level of faculty intervention.

Conclusion

The ECA is a valuable tool for general dentists and dental students. However, the application has limitations. While the ECA allows providers to determine case difficulty level, this study demonstrates that the tool does not allow providers to reliably predict procedural errors for molar primary root canal therapy. In order to do so, additional criteria may need to be added or the scoring of tooth difficulty may need to be addended within the tool. Future studies should include multiple tooth types and control for provider skill level in order to determine if the ECA is credible tool with which providers can determine the need for referral to an endodontist.

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Figures

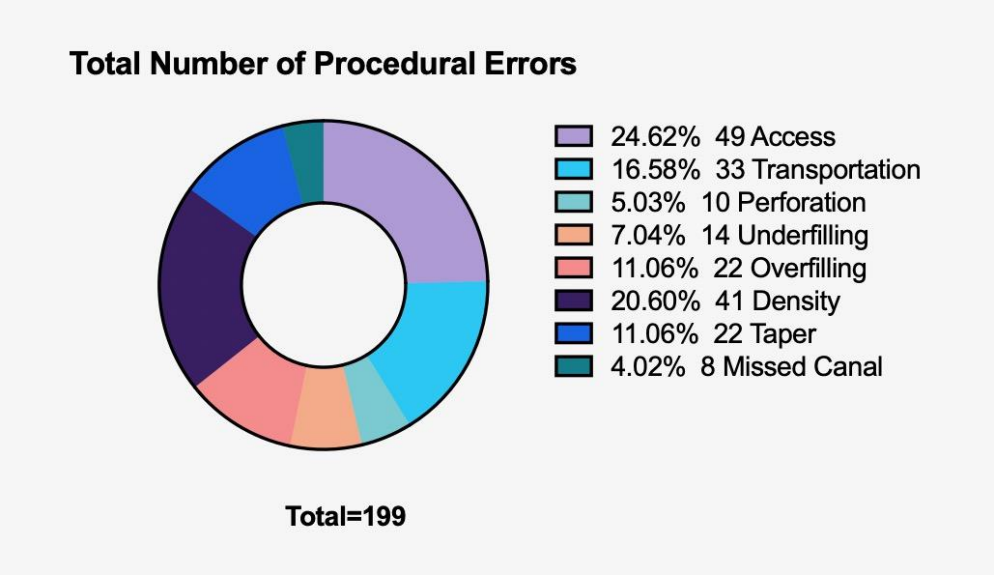

Figure 1: The frequency of individual error types as a percentage of total errors (N = 199 errors).

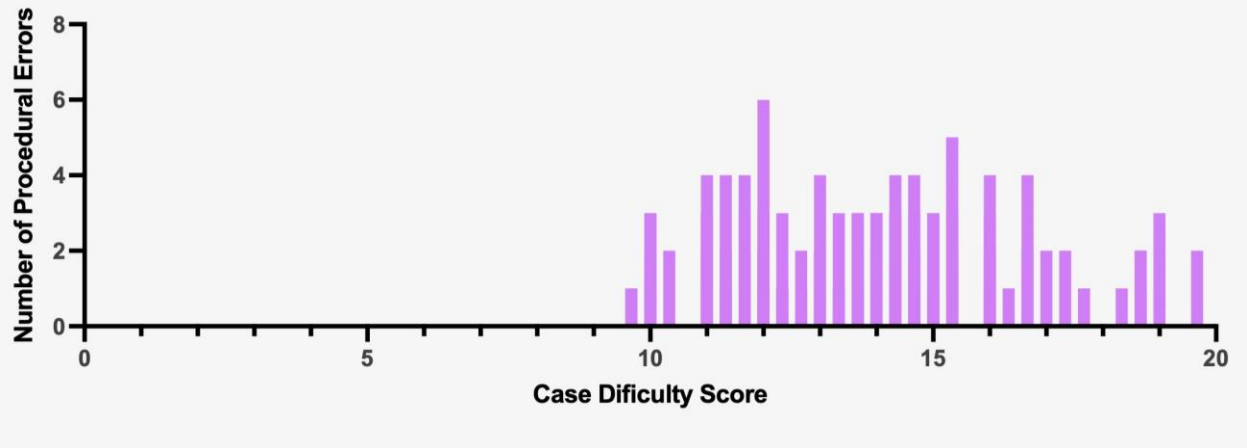

Figure 2: The total number of procedural errors in each case compared to the average difficulty level of each case, based on the pooled difficulty score of all three evaluators who used the ECA.

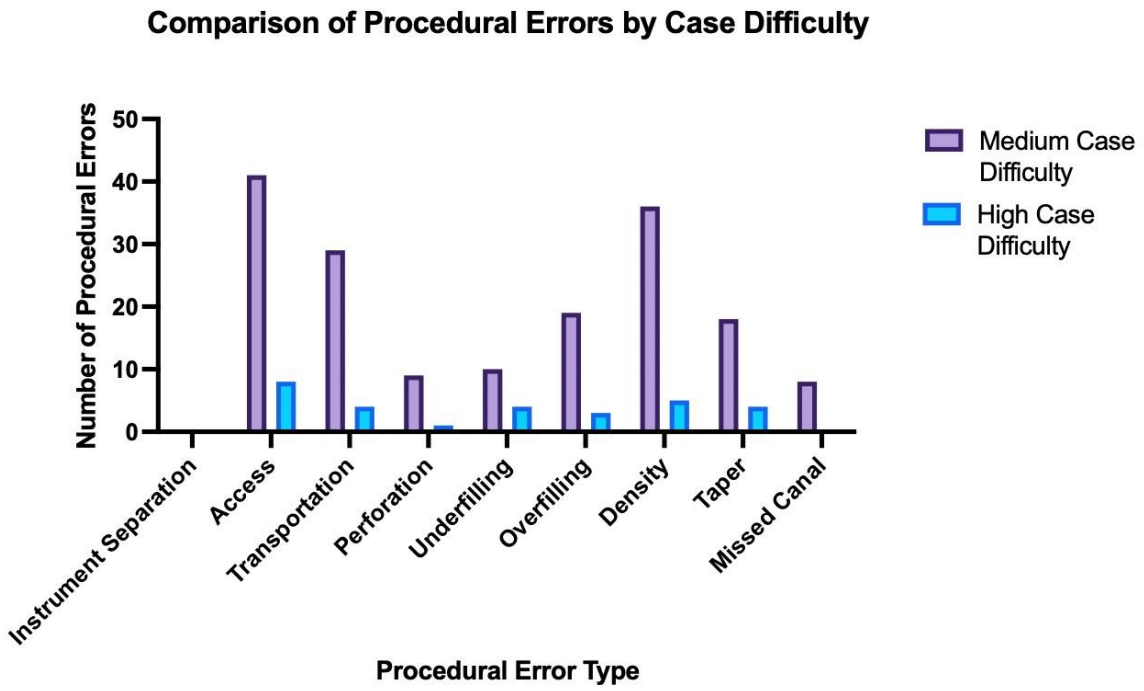

Figure 3: The frequency of individual error types between the moderate and high difficulty categories.

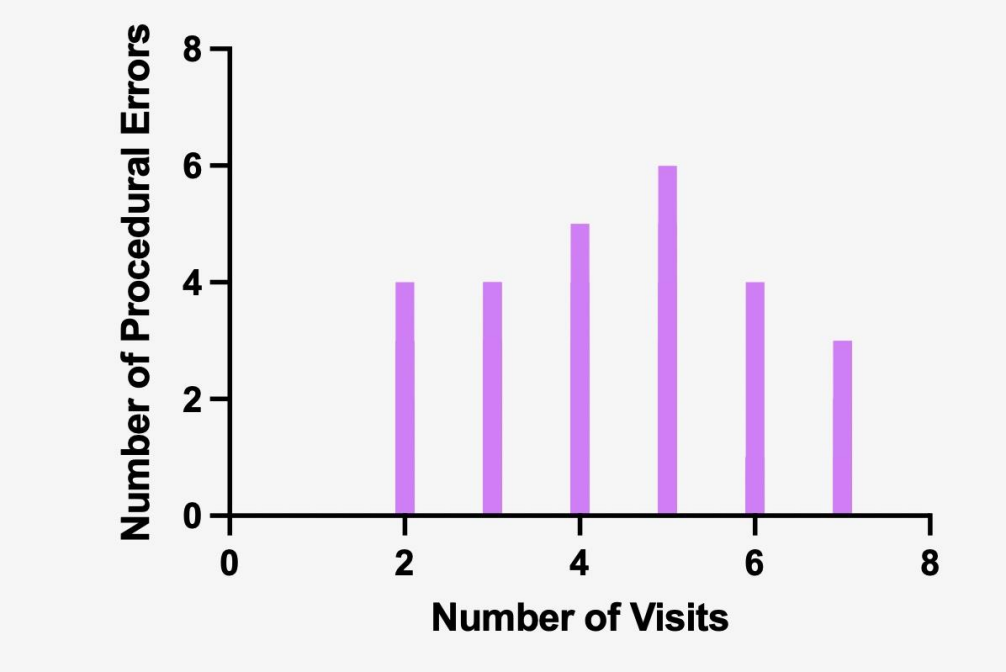

Figure 4: The total number of procedural errors compared to the number of treatment visits.

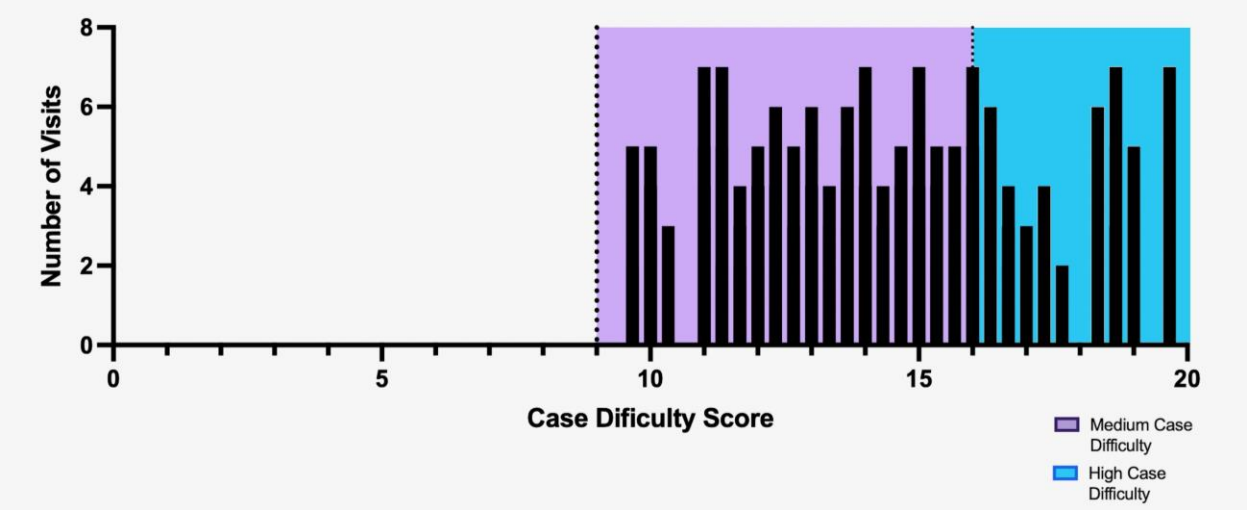

Figure 5: The total number of visits compared to the average case difficulty level, based on the pooled difficulty score of all three evaluators who used the ECA.

Table 1: AAE Recommendation Criteria for the Educator's Guide to using the Abridged ECA

Case Difficulty Score	Recommendations
<10 points Minimal Difficulty Level	Dental student may treat—level of faculty supervision should be tailored to the student's level of experience.
10-16 points Moderate Difficulty Level	An experienced and skilled dental student may treat with very close supervision by an endodontist, or the case referred to a graduate student or endodontist.
>16 points High Difficulty Level	The case should not be treated by a predoctoral dental student. The patient should be referred to a graduate student or endodontist.

Table 2: Case Difficulty Compared to Total Number of Errors

	Pearson's Correlation	**Significance (2-tailed)**
Case Difficulty Level Scorer 1 (Endodontist)	-0.002	0.984
Case Difficulty Level Scorer 2 (General Dentist)	0.091	0.392
Case Difficulty Level Scorer 3 (Dental Student)	-0.039	0.713
Average Case Difficulty Level	0.022	0.841

Results from Pearson's Correlation for case difficulty level determined by evaluator type and average difficulty level correlated with the total number of procedural errors in each case.

Table 3: Individual Error Types Compared to Average Case Difficulty Level

	Pearson's Correlation	Significance (2-tailed)
Instrument Separation	n/a	n/a
Access	-0.071	0.509
Transportation	0.064	0.548
Perforation	0.007	0.948
Underfilling*	0.226	0.032*
Overfilling	-0.062	0.564
Density	-0.021	0.844
Taper	0.059	0.582
Missed Canal	-0.151	0.156

Results from Pearson's Correlation for individual error types and the average case difficulty level based on the pooled difficulty score of all three evaluators who used the ECA. Significant differences are marked as * ($p < .05$).

Table 4: Number of Treatment Visits Compared to Average Case Difficulty Level and

	Pearson's Correlation	Significance (2-tailed)
Average Case Difficulty Level	0.084	0.43
Total Number of Errors	-0.08	0.455

Results from Pearson's Correlation for total number of treatment visits compared to the total number of procedural errors in each case and the average case difficulty level based on the pooled difficulty score of all three evaluators who used the ECA.

Appendix

Abridged Case Difficulty Assessment Form (aCDAF)

american association of endodontists

To use this calculator, enter "1" in the for every criteria that is present in the square boxes. If a criteria is absent, the box MUST be left blank. Each row should have at LEAST one entry.

CRITERIA	MINIMAL DIFFICULTY		MODERATE DIFFICULTY		HIGH DIFFICULTY	
POSITION IN THE ARCH	Anterior / premolar		1st molar		2nd or 3rd molar	
INCLINATION	Slight inclination (<10°)		Moderate inclination (10-30°)		Extreme inclination (>30°)	
ROTATION	Slight rotation (<10°)		Moderate rotation (10-30°)		Extreme rotation (>30°)	
CROWN MORPHOLOGY	Normal original crowm morphology		Full coverage restoration		Restoration does not reflect original anatomy / alignment	
			Porcelain restoration		Significant deviation from normal tooth / root form (e.g. fusion dens in dente)	
			Bridge abutment			
			Moderate deviation from normal tooth / root form (e.g. taurodontism microdens)			
			Teeth with extensive coronal destruction			
CANAL AND ROOT MORPHOLOGY	Slight or no curvature (<10°)		Moderate curvature (10-30°)		Extreme curvature (>30°) or S-shaped curve	
			Crown differs moderately from root axis.		Mandibular premolar or anterior with 2 roots	
					Maxillary premolar with 3 roots	
					Canal divides in the middle or apical third	
					Very long tooth (>25mm)	
APICAL OPENING	Closed apex (<1mm in diameter)		Apical opening 1-1.5mm in diameter		Open apex (>1.5mm in diameter)	
RADIOGRAPHIC APPEARANCE OF	Canal(s) visible and not reduced in size		Canal(s) and chamber risible but reduced in size		Indistinct canal path	
			Pulp stones		Canal(s) not visible	
ENDODONTIC TREATMENT HISTORY	No previous treatment		Previous access without complication		Previous access with complications (e.g. perforation, non negotiated canal, ledge, separated instrument)	
					Previous surgical or non-surgical endodontic treatment completed	

Scores

Counts	MINIMAL DIFFICULTY	0	MODERATE DIFFICULTY	0	HIGH DIFFICULTY	0
Scores	Multiply by a point value of 1	0	Multiply by a point value of 2	0	Multiply by a point value of 5	0
	Total score	0				
	Overall recommendation	*Mild difficulty*				
	General recommendation	*Dental student may treat—level of faculty supervision should be tailored to the student's level of experience.*				

Further Reading

https://www.aae.org/specialty/wp-content/uploads/sites/2/2019/02/19AAE_CaseDifficultyAssessmentForm.pdf
https://www.aae.org/specialty/wp-content/uploads/sites/2/2017/10/educatorguidetocdaf.pdf

LEVELS OF DIFFICULTY

MINIMAL DIFFICULTY

Preoperative condition indicates routine complexity (uncomplicated). These types of cases would exhibit only those factors listed in the MINIMAL DIFFICULTY category. Achieving a predictable treatment outcome should be attainable by a competent practitioner with limited experience.

MODERATE DIFFICULTY

Preoperative condition is complicated, exhibiting one or more patient or treatment factors listed in the MODERATE DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for a competent, experienced practitioner.

HIGH DIFFICULTY

Preoperative condition is exceptionally complicated, exhibiting several factors listed in the MODERATE DIFFICULTY category or at least one in the HIGH DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for even the most experienced practitioner with an extensive history of favorable outcomes.

Review your assessment of each case to determine the level of difficulty. If the level of difficulty exceeds your experience and comfort, you might consider referral to an endodontist.