Title page

Title:	A web-based endodontic case difficulty assessment tool
Authors:	PK Shah, BS Chong
Institution:	Institute of Dentistry, Barts & The London School of Medicine & Dentistry, Queen Mary University of London, London, UK
Running Title:	Web-based endodontic case difficulty assessment tool
Keywords	case difficulty assessment, endodontic treatment, treatment risks, web-based tool.

Correspondence: Pratik Shah,
Institute of Dentistry,
Barts & The London School of Medicine and Dentistry,
Turner Street,
London E1 2AD,
UK.
Tel.: +44 7894492460
e-mail: kiboko1@gmail.com

Abstract

Objective: To develop a web-based tool to facilitate identification, evaluation and management of teeth requiring endodontic treatment.

Materials and Methods: Following a literature search and thorough analysis of existing case difficulty assessment forms, the web-based tool was developed using an online survey builder (Qualtrics, Qualtrics Lab, UT, USA). Following feedback from a pilot study, it was refined and improved. A study was performed, using the updated version (EndoApp) on a cohort (n=53) of dental professionals and dental students. The participants were e-mailed instructions detailing the assessment of five test cases using EndoApp, followed by completion of a structured feedback form. Analysis of the EndoApp responses was used to evaluate usage times, whereas the results of the feedback forms were used to assess user experience and relevance, other potential applications, and comments on further improvement/s.

Results: The average usage time was 2 minutes 7 seconds; the average times needed for the last three (Cases 3-5), was significantly less than the preceding two (Cases 1 & 2), test cases. An overwhelming majority of participants expressed favourable views on user experience and relevance of the web-based case difficulty assessment tool. Only two participants (4%) were unlikely or very unlikely to use EndoApp again. The potential application of EndoApp as an 'educational tool' and for 'primary care triage' were deemed the most popular features and of greater importance than the secondary options of 'fee setting' and as a 'dento-legal justification tool'.

Conclusions: Within the study limitations, owing to its ability to quantify the level of difficulty and provide guidance, EndoApp was considered user-friendly and helped facilitate endodontic case difficulty assessment. From the feedback, further improvements and the development of a Smartphone App version are in progress.

Clinical relevance: EndoApp may facilitate treatment planning, improve treatment cost-effectiveness and reduce frequency of procedural errors by providing appropriate guidance on endodontic case management.

Introduction

Endodontic treatment, like any healthcare procedure, is not risk-free. Inadequate instrumentation, insufficient disinfection and incomplete obturation of the root canal system may result in an unfavourable treatment outcome and persistence of disease; in addition, during delivery of endodontic treatment, instrument separation, perforation and other procedural errors may occur resulting in the need for revision or even tooth loss [1-6]. Such procedural errors may be influenced by the level of operator knowledge, skill and experience in managing variables in patient- and treatment-related prognostic factors [7-13].

Outcome studies have shown that endodontic can have high success rates when performed optimally, following accepted treatment protocols and techniques [1,10-13]. However, there is variance in knowledge, skills and experience between operators, including between general dental practitioners (GDPs) and endodontic specialists [9,10]. Hence, the delivery of endodontic treatment, especially if challenging, may be beyond the skill and experience of some operators. There may also be a greater risk of procedural errors if it is beyond an individual operator's capabilities. If there is a tool available to help assess the risks and difficulties of a particular case, the operator can then decide whether to undertake the treatment or refer it onwards, including for specialist management. When a case is correctly assessed and appropriately managed, it is more likely to lead to a favourable treatment outcome and reduction in the need for treatment revision or even tooth loss; this translates into savings in term of financial outlay, pain and suffering for patients. Ultimately, the patient's gain is the preservation of a tooth, which would otherwise have been lost.

Ree et al. [14] noted that GDPs must be capable of determining the complexity of treatment and, in order for them to refer patients requiring complicated endodontic treatment, specialist services must be available. In many countries, endodontics is yet to be recognised as a specialty. Furthermore, even in those countries where the specialty is recognised, there are insufficient specialists to service the increasing endodontic treatment demands of patients.

This may be partly fulfilled by having sufficient numbers of dentists with extended skills/special interest in endodontics (DwESEs) in addition to registered endodontic specialists (SpEs). In the UK, DwESE are GDPs who have chosen to receive further training to provide enhanced endodontic services [15,16]. Therefore, within the limits of their competency, they can accept referrals from dental colleagues, treat moderately complex cases, and refer more complicated cases for specialist management [15]. However, any solution to meeting the increasing endodontic treatment demands of patients is reliant on accurate determination of treatment complexity, to ensure an individual case is managed by an operator of the appropriate skill-set.

Case difficulty assessment forms, based on pre-treatment clinical and radiographic examinations, may assist in determining the complexity of endodontic treatments. Examples of case difficulty assessment systems and forms include:

- Restorative Dentistry Index of Treatment Need (RIOTN) [17]. The RIOTN categorises the level of difficulty for teeth requiring root canal, periodontal, and/or prosthetic treatment into three complexity grades that are reflective of the skill and experience level of the operator (dental graduate, experienced dentist, or specialty trained dentist) [17]. An overall complexity score is obtained by selecting the discipline with the highest grade. Modifying factors, for example patient management concerns, medical problems, and presence of atypical facial pain, are considered if the overall score is below the maximum grade of complexity.
- University of California at San Francisco (UCSF) endodontic case selection system [18]. The UCSF form is composed of two charts: one to assess various criteria by rating the complexity as ‘uncomplicated’, ‘moderately complicated’, or ‘complicated’; and the other to determine the overall level of difficulty by collectively reviewing the complexity grades deduced earlier, whereby a referral may be indicated if one or more ‘moderately complicated’ criteria or a single ‘complicated’ criterion is recorded.

- Canadian Academy of Endodontists (CAE) case-classification system [19]. The CAE form grades and numerically quantifies the risk levels of 13 criteria and subcriteria as: average – 1 unit; high – 2 units; or very high – 5 units. The final score is categorised reflecting the level of difficulty as Class I (15 – 17 units), II (18 – 25 units) or III (more than 25 units). Certain very high risk variables are assigned inevitably as Class III.
- American Association of Endodontists (AAE) case assessment difficulty form [20]. The AAE form was originally formulated for endodontic case selection for undergraduate teaching and care in 1999 [21,22] and a revised version of the form was released in 2006 for use by GDPs. It was based on the CAE form, with similar difficulty rating (mild, moderate, and high) of 17 criteria and subcriteria. The AAE Educator Guide [23] can be used with the AAE form for numerical quantification of difficulty levels; however, its validity has not been tested for use by GDPs.
- Dutch Endodontic Treatment Index (DETI) and Endodontic Treatment Classification (ETC) form [14]. The DETI is a short screening questionnaire designed to identify uncomplicated and complicated endodontic treatment cases [14]. If a complicated case is detected, then further analysis using the ETC form may be performed to determine the level of difficulty and appropriate treatment route [14]. The ETC is similar to the CAE form in grading and numerical quantification of 16 criteria. The levels of difficulty are categorised as Class I (15 – 19 units), II (20 – 25 units) or III (more than 25 units).

However, these systems and forms have several and specific limitations including:

- An absence of a quantification system - RIOTN [24], UCSF and AAE forms.
- Reliance on a manual quantification system that prolongs usage times - CAE and ETC forms.
- Lack of comprehensiveness - RIOTN [24] and UCSF forms.

- An absence of important criteria and variables, such as obturation material types, quality and extent of root-fillings, and supernumerary roots - CAE, AAE and ETC forms.
- Inclusion of less relevant criteria, such as ‘restorability’ - USCF form; and ‘emergency condition’ - AAE form.
- Use of inappropriate terminology, such as ‘pathological resorption’, ‘damaged access’, ‘difficult root morphology’, ‘recurvature’, ‘long curve’, ‘peripheral calcification’, ‘supra-osseous’, ‘sub-osseous’, ‘I’ and ‘J’ shaped canals - RIOTN, UCSF, CAE, AAE, and/or ETC forms [14,24].
- Use of clinically indistinct measures for angles of inclination, rotation or curvature, or extent of mouth opening - RIOTN, CAE, AAE, DETI and ETC forms.
- Undervaluation of risk levels for opened apices, S-shaped canals, C-shaped root canal systems, and bifurcating canals in the apical/middle third - CAE and ETC forms.

Therefore, given there is potential for improvements, the aim of this study was to create an endodontic case difficulty assessment tool using an electronic, web-based platform; to comprise of fundamental criteria and variables, clinically compatible measures, and a computerised quantification system, which would be more practical and user-friendly. Computational power of web-based algorithms can simplify the assessments and ubiquity of internet-enabled mobile devices can facilitate paperless access. Additionally, a web-based tool can operate across multiple platforms and devices, and be easily distributed, maintained, and updated.

Materials and Methods

Following a literature search and thorough analysis of existing case difficulty assessment forms (RIOTN, UCSF, CAE, AAE, and DETI/ETC), a new case difficulty assessment questionnaire, comprising improved criteria and variables, was incorporated into a web-based tool using online software (Qualtrics, Qualtrics Lab, UT, USA), which also permitted a flowchart arrangement of criteria-based questions with simple integration of a scoring system. A web-based structured feedback form, in a standard course evaluation format, was also developed to allow for quantitative assessment of the feedback responses on user experience and relevance, and other potential uses. A comments section was included to allow qualitative feedback analysis of user experiences, and gather improvement suggestions.

Following feedback from a pilot study [25], this was refined and improved; the updated version (EndoApp) was designed to be concise, followed a structured flow chart format, and contained graphical representations for better user engagement (Figure 1). The EndoApp questionnaire included various criteria logically arranged and linked, such as tooth location, number of canals, tooth length, root curvature, coronal restoration type, anatomical considerations, presence of dental resorption, and patient-related factors. An analogous branch of retreatment questions also assessed the type of obturation material, extent of obturations, and various procedural errors. The questionnaire comprehensively covered the various criteria by first assessing criteria concerning tooth morphology and need for retreatment, followed by other tooth- and patient-related factors. Answers for each question were weighed according to their individual risk levels as: low – 1 unit; medium – 2 units; high – 5 units; and exceptional – 9 units. Exceptional items were graded to signify the extreme level of difficulty that would require special attention. These included opened apex, S-shaped canal, C-shaped root canal system, bifurcating canals in the apical/middle third, supernumerary root, external cervical root resorption, long obturation, paste root-filling, and cement root-filling. After completion of the questionnaire, a cumulative score and a

matching recommendation would be generated advising the user to either perform the treatment, or refer the case onwards for management. The final score ranges for the levels of difficulty were deduced by calculating the minimum units for each level (Table 1).

For simulation and testing of complex treatment challenges, five cases were created from available patient data; consent was obtained prior to usage and sensitive patient information was anonymised to maintain confidentiality. Each test case contained patient, tooth, and treatment challenges; details of the presenting complaint, history, and clinical examination, including results of any special tests, were supported by clinical photographs and radiographs. Study participants would thus diagnose the presenting problem before assessing the level of difficulty with EndoApp for each test case, similar to clinical scenarios. A summary of treatment challenges for each test case is shown in Table 2 and an example of a test case used in the study is shown in Figure 2.

To assess usage times, user experience and relevance, views on other potential applications, and to obtain comments for further improvement, EndoApp was tested on a cohort of participants consisting of:

- GDPs;
- NQPs - undergraduate dental students and recently qualified dentists;
- ESPs - DwESEs, SpEs, and postgraduate endodontic students;
- NESPs – non-endodontic specialists and postgraduate students pursuing non-endodontic specialities (e.g. periodontics, prosthodontics)

A sample size calculation was performed to determine the minimum number of participants required for the cohort. Based on the pilot study data [25], the confidence level required for this study was 95%, with a degree of precision of ±12%, standard error (SE; 12/1.96) of 6.122, and proportion (P) of 75%. The minimum sample size (N) was determined using the calculation below:

$N = (P(100\% - P))/(SE)^2 = (75(100 - 75))/(6.122)^2 = 1600/53.217 = 50$ participants.

The cohort recruited for the study included 53 participants. Instructions, test cases, and hyperlinks for EndoApp, which included the feedback form, were emailed to participants. They were instructed to:

- assess and diagnose the problem for each test case before using EndoApp;
- complete all five test cases sequentially before submitting their overall feedback.

Data Analysis

The usage times and feedback responses for EndoApp were collected utilising the Qualtrics data collection facility, and analysed. The feedback responses also enabled demographic categorisation of participants by professional group (GDPs, ESPs, NQPs, and NESPs) and post-qualification period (number of years since attaining a primary dental degree), to permit further analysis.

For each test case, the average usage time was determined by dividing the sum of usage times by the number of participants to complete the assessment process. The overall average usage time was determined by calculating the mean value of the average usage times for all test cases.

From the feedback responses, the user experience and relevance were determined by measuring five parameters (ease of use; likelihood of reuse; suitability for case difficult assessment; accuracy of recommendation; and influence on decisions to treat/refer) based on a favourability scale (strongly favourable, somewhat favourable, neutral, somewhat unfavourable strongly unfavourable). For each parameter, the scores on the favourability scale was converted into percentages. A list of other potential applications of EndoApp was converted into percentage to determine popularity of each application. Analysis of the comments highlighted the potential improvements that may be incorporated into the next version of EndoApp.

Results

Demographics

GDPs were the largest professional group (n=22), followed by ESPs (n=15), NQPs (n=11), and NESPs (n=5), whereas 'under 10 years' were the largest group to have attained a primary dental qualification (n=27) followed by '10 - 20 years' (n=16), and 'over 20 years' (n=10). Since the participant numbers for each category were non-representative, further analysis was not performed; hence, results based on the usage times and feedback responses were collectively analysed.

Usage times

The overall average usage time for EndoApp was 2 minutes 7 seconds based on 249 responses (Figure 3). Sixteen responses, mainly from GDPs and NQPs, were excluded to minimise skewing of the average usage times. For these, case difficulty assessment was aborted early by the participants as the problems were not diagnosed for Test Cases 1, 3, & 5. The average usage time for Test Cases 3, 4 & 5 was considerably less than the preceding Test Cases 1 & 2.

User experience and relevance

The overwhelming majority perceived EndoApp favourably (Figure 4) with respect to ease of use (97%), suitability for case difficulty assessments (97%), accuracy of the recommendation (87%), influence on decisions to treat/refer (68%), and likelihood of reuse (70%). Only two participants (4%) were unlikely or very unlikely to use EndoApp again.

Other potential applications

With regards to other potential applications of EndoApp (Figure 5), its use as 'educational' (94%) and 'primary care triage' (92%) tools were considered the most popular. Favourable

support for ‘secondary care triage’ (64%), ‘research’ (60%), and ‘record keeping’ (57%) was also noted. However, the use of EndoApp as a ‘fee setting’ (15%), ‘informed consent’ (30%) or ‘dento-legal justification’ tool (32%) was considered secondary.

Suggestions for improvement

The suggestions offered focused on integrating a specialist referral service, refining the scoring system/retreatment criterion to improve scoring accuracy, modifying the flow structure and incorporating a differential diagnosis function.

Discussion

The widespread availability of electronic devices has created opportunities for improved patient and treatment management through web-based tools or Smartphone applications (Apps). This proof of concept study was carried out to aid the efficient development and allowed the testing of a new case difficulty assessment questionnaire using, initially, a web-based platform.

The cohort (n=53) used to assess EndoApp consisted of dental professionals and dental students with differing levels of experience and skill-set. Whilst this provided variety and ensured that all levels of dental healthcare professionals are catered for, not unexpected, the interpretation of clinical and radiographic test case data varied, and the feedback opinions were qualitative and hence subjective. There may be a bias towards a particular dental discipline depending on the participants' background or interest. Although future studies of this nature will also rely on subjective responses, the variation and bias may be reduced by focusing on dental professional groups most likely to benefit from the web-based tool, for example, NQPs or GDPs. In addition, using a larger representative cohort, more test cases of similar complexity levels for standardisation and calibration of the assessment process, and/or more realistic simulation of clinical scenarios, including actual patients, may help to moderate the variation and bias.

The average usage times for Test Cases 1 & 2 were higher than the overall average as participants needed time to be familiar and, being new, were more critical when undertaking the assessment exercise, needing to review the test cases more often. As participants became more familiar with the operational flow, structure, and assessment, their usage times improved significantly (Test Cases 3, 4 & 5). Thus, with an overall average usage time of 2 minutes 7 seconds, using EndoApp may be time-saving for a busy clinician.

The positive views on user experience and relevance of EndoApp may be attributed to the use of an automated scoring system, graphical representations, and concisely structured

case difficulty assessment. Only two participants (4%) were unlikely or very unlikely to use EndoApp again; these participants were comfortable performing difficulty assessments unaided or were not involved in provision of endodontic services. Thus, the web-based tool may be more beneficial for dental students and less endodontically-experienced dental practitioners.

Other potential applications of EndoApp, for example, in 'dental education' can help improve understanding of technical challenges such as complex root canal anatomy and treatment limitations. Thus, it may be used as an adjunct to reinforce practical aspects of endodontic knowledge and encourage endodontic skill development. If used for 'triage', it may help to deliver more cost-effective primary and secondary care services. In the UK, endodontic failures in the National Health Service-funded General Dental Services contract have led to increased referrals to secondary care providers [26,27]. EndoApp may help mitigate the excessive demand for secondary care services by filtering and diverting referrals appropriately to practice-based DwESEs, where available. In teaching/secondary care environments, the web-based tool may be used to triage incoming referrals according to student/staff skill and experience. Additionally, EndoApp may help to maintain accurate records, and assist in standardising teeth for research purposes. Potential application for 'dento-legal justification', 'informed consent' and 'fee setting' may be considered controversial due to ethical concerns.

In the UK, there is, currently, no restriction on the type or level of difficulty a qualified and registered dental practitioner is allowed to undertake. However, given the inexorable rise in dental litigation [28], this may change. For example, there is already guidance published by the UK's regulatory body on the standards [29] expected of, and the scope of practice [30] for, the whole dental team. By assisting dentists in identifying complex cases beyond their capabilities, helping patients to appreciate the intricacies of endodontic

treatment, and recording the various determinant criteria, dento-legally, EndoApp may benefit both dentists and patients.

From the results from this study and the feedbacks, further improvements are in progress along with the development of a Smartphone App version. A Smartphone App for endodontic case difficulty assessment would be more versatile, make distribution and support easier, and overcome the constraints inherent in the web-based tool. The Smartphone App may also offer the possibility of developing additional functionalities related to case difficulty assessment such as analysis of digital/digitised radiographs to determine root curvatures and tooth length, self-generating referral forms, targeting location-based referral services, programmed triaging, and more accurate record keeping. Additional studies are planned with larger cohorts to deliver a representative sample sizes consisting of NQPs and/or GDPs.

Ultimately, by facilitating and quickly identifying treatment challenges, aiding management of cases matching a practitioner's level of skill or, if necessary, advise referring difficult cases onwards for management, EndoApp will help prevent procedural errors, improve treatment outcome and reduce the need for further, especially, re-intervention. This will represent savings not just in term of financial cost but also pain and suffering; it also means the preservation rather than the loss of many teeth that are potentially treatable but beyond or constrained by the skill, knowledge and abilities of an individual clinician.

Conclusions

Within the limitations of the study, the web-based tool, owing to its ability to quantify the level of difficulty and provide guidance, was considered to be user-friendly and helped facilitate endodontic case difficulty assessment. The potential application as an 'educational tool' and for 'primary and secondary care triage' were deemed the most popular features and of greater importance than the secondary options of 'fee setting' and as a 'dento-legal justification tool'.

Compliance with Ethical Standards

Conflict of Interest: PK Shah declares that he has no conflict of interest.

BS Chong declares that he has no conflict of interest.

Funding: No funding was received to write this manuscript or publish this paper.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent: For this type of study, formal consent is not required.

References

1. Sjögren U, Hägglund B, Sundqvist G, Wing K (1990) Factors affecting the long-term results of endodontic treatment. J Endod 16:498-504.
2. Chugal NM, Clive JM, Spångberg LS (2003) Endodontic infection: some biologic and treatment factors associated with outcome. Oral Surg Oral Med Oral Path Oral Radiol Endod 96:81-90.
3. Ruddle CJ (2004) Nonsurgical retreatment. J Endod 30:827-845.
4. Lin LM, Rosenberg PA, Lin J (2005) Do procedural errors cause endodontic treatment failure? J Am Dent Assoc 136:187-193.
5. Ng Y-L, Mann V, Gulabivala K. (2011) A prospective study of the factors affecting outcomes of non-surgical root canal treatment: part 2: tooth survival. Int Endod J 44:610-625.
6. Di Filippo G, Sidhu SK, Chong BS (2014) Apical periodontitis and the technical quality of root canal treatment in an adult sub-population in London. Br Dent J 216:E22.
7. Pettiette MT, Delano O, Trope M (2001) Evaluation of success rate of endodontic treatment performed by students with stainless-steel K-files and nickel–titanium hand files. J Endod 27:124-127.
8. Sonntag D, Delschen S, Stachniss V (2003) Root canal shaping with manual and rotary Ni-Ti files performed by students. Int Endod J 36:715-723.
9. Yared G, Bou Dagher F, Kulkarni K (2003) Influence of torque control motors and the operator's proficiency on ProTaper failures. Oral Surg Oral Med Oral Path Oral Radiol Endod 96:229-233.
10. Friedman S (2008) Treatment outcome: the potential for healing and retained function. In: Ingle JI, Bakland LK, Baumgartner J (eds) Ingle′s Endodontics, 6th edn. BC Decker Inc., Hamilton, Ontario, pp 1162-1232. :

11. Ng Y-L, Mann V, Rahbaran S, Lewsey J, Gulabivala K (2008) Outcome of primary root canal treatment: systematic review of the literature – part 2. Influence of clinical factors. Int Endod J 41:6-31.
12. Ng Y-L, Mann V, Rahbaran S, Lewsey J, Gulabivala K (2008) Outcome of secondary root canal treatment: a systematic review of the literature. Int Endod J 41:1026-1046.
13. Ng Y-L, Mann V, Gulabivala K (2011) A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. Int Endod J 44:583-609.
14. Ree MH, Timmerman MF, Wesselink PR (2003) An evaluation of the usefulness of two endodontic case assessment forms by general dentists. Int Endod J 36:545-555.
15. Al-Haboubi M, Eliyas S, Briggs PF, Jones E, Rayan RR, Gallagher JE (2014) Dentists with extended skills: the challenge of innovation. Br Dent J 217:E6.
16. Ghotane SG, Al-Haboubi M, Kendall N, Robertson C, Gallagher JE (2015) Dentists with enhanced skills (Special Interest) in Endodontics: gatekeepers views in London. BMC Oral Health 21:110.
17. Falcon FC, Richardson P, Shaw MJ, Bulman JS, Smith BGN (2001) Developing an index of restorative dental treatment need. Br Dent J 190:479-486.
18. Rosenberg RJ, Goodis HE (1992) Endodontic case selection: to treat or to refer. J Am Dent Assoc 123:57-63.
19. Canadian Academy of Endodontics (1998). Standards of Practice. Canadian Academy of Endodontics, Winnipeg, Manitoba.
20. American Association of Endodontists (2006) AAE Endodontic Case Difficulty Assessment Form and Guidelines. American Association of Endodontists. https://www.aae.org/uploadedfiles/clinical_resources/guidelines_and_position_statements/2006casedifficultyassessmentformb_edited2010.pdf Accessed 18 June 2017.

21. Curtis EK, Simon DC (1999) Endodontic case difficulty assessment: the team approach. Gen Dent 47:340-344.
22. Messer HH (1999) Clinical Judgement and Decision Making in Endodontics. Aust Endod J 25:124–132.
23. American Association of Endodontists (2005) AAE Educators Guide. American Association of Endodontists. https://www.aae.org/uploadedfiles/clinical_resources/guidelines_and_position_statements/educatorguidetocdaf.pdf Accessed 18 June 2017.
24. Muthukrishnan A, Owens J, Bryant S, Dummer PMH (2007) Evaluation of a system for grading the complexity of root canal treatment. Br Dent J 202:E26.
25. Shah P (2016) The development of a web-based case difficulty assessment tool for non-surgical root canal treatment. Dissertation. Queen Mary University of London.
26. Steele J (2009) NHS Dental Services in England: An Independent review led by Professor Jimmy Steele. Department of Health, London, UK.
27. Tickle M, McDonald R, Franklin J, Aggarwal V R, Milsom K, Reeves D (2011) Paying for the wrong kind of performance? Financial incentives and behaviour changes in National Health Service dentistry 1992–2009. Community Dent Oral Epidemiol 39:465-473.
28. Chong BS (2015) No win, no fee. ENDO (Lond Engl) 9:155-156.
29. General Dental Council. (2013) Standards for the dental team. General Dental Council, London, UK.
30. General Dental Council. (2013) Scope of practice. General Dental Council, London, UK.

Final score range (units)	Level of difficulty	Recommended treatment route
13	Low	GDPs
14 – 17	Average	DwESEs or GDPs
18 – 25	High	SpEs or DwESEs
> 26	Very high	SpEs

Table 1: The recommendations on treatment route generated by EndoApp corresponding to the levels of difficulty and final score ranges.

Test Case	Tooth*	Main treatment challenges
1	UR2	• Opened apex in a microdontia tooth • Receded pulp chamber
2	LR6	• Retreatment case with procedural errors • Presence of a coronal indirect restoration
3	LL3	• External cervical root resorption requiring surgical intervention prior to endodontic treatment
4	UR6	• Canal location through a coronal indirect restoration. • Receded pulp chamber
5	LR6	• Complex medical history • Perio-endo lesion with external root resorption

Table 2: Tooth requiring endodontic intervention and the main treatment complexities for the five test cases. (* - Palmer notation)

Legends for figures

Fig. 1: Screenshots of EndoApp showing the various assessment criteria and graphical representations.

Fig. 2: Test Case 3 slide displaying patient details, histories, clinical, and radiographic information for the participants to use for case difficulty assessment purposes with EndoApp.

Fig. 3: Average time taken to use EndoApp for each test case and the overall average for 249 responses. (m –minutes; s – seconds)

Fig. 4: Participant views on user experience (ease and reuse) and relevance (suitability, accuracy and influence) of EndoApp.

Fig. 5: Levels of support for other potential applications of EndoApp.