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Case complexity of root canal treatments accepted for training in a secondary care setting assessed by three complexity grading systems: a service evaluation.

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Introduction

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In the United Kingdom (UK), most root canal treatments are performed in primary care by general dental practitioners (GDPs) (Tickle *et al.* 2008). Complex root canal treatment cases are a large part of referrals to secondary care (Ghotane *et al.* 2015). The availability of specialist skills influences the setting where the cases are managed. Guidelines are therefore in place to aid referrers and specialists in determining the suitability of root canal treatments for either primary care, enhanced endodontic settings (intermediate services) or specialist and secondary care services (Ghotane *et al.* 2015). Various postgraduate training grades may be involved in treatment within these settings.

Three popular guidelines have been used for assessing complexity of root canal treatments and provide a framework for assessing multiple patient and treatment factors which help determine the skill level required to effectively treat a particular endodontic patient. These guidelines are, the most recent introduced, English commissioning standard for restorative dentistry (ECS), the American Association of Endodontists (AAE) case complexity form and the restorative index of treatment need (RIOTN).

The AAE case complexity form has been available since 2005 and was revised in 2006. It uses a number of patient and treatment factors to categorise cases by complexity. Initially, the form was designed for use in endodontic curricula and was offered for educational purposes only. An overall score is calculated to assist clinicians in evaluating the difficulty associated with treating a patient. The form assesses 17 factors and is divided into three parts: 1) patient considerations, 2) diagnostic and treatment considerations, and 3) additional considerations such as trauma, previous treatment, and periodontal disease ([https://www.aae.org/specialty/wp-](https://www.aae.org/specialty/wp-content/uploads/sites/2/2019/02/19AAE_CaseDifficultyAssessmentForm.pdf)

[content/uploads/sites/2/2019/02/19AAE_CaseDifficultyAssessmentForm.pdf](https://www.aae.org/specialty/wp-content/uploads/sites/2/2019/02/19AAE_CaseDifficultyAssessmentForm.pdf)). For educational purposes, each factor is given a score based on its complexity; minimal (1), moderate (2) and high (5). An overall score of 20 points or less indicates minimal complexity suitable for treatment by a dental student, 24 points indicates moderate complexity suitable for treatment by an experienced and skilled dental student with very close supervision, whereas a score above 40 points indicates high complexity suggesting that the patient should

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be referred to a graduate student or endodontist (<https://www.aae.org/specialty/wp-content/uploads/sites/2/2017/06/educatorguidetocdaf.pdf>). The case complexity form was revised in 2006 and has since been used to assist practitioners with root canal treatment planning, referral decisions and record keeping (Ree *et al.* 2003 a & b; Alan & Law 2005) but with limited surveillance across settings. This revised system simplifies the categorization of cases into minimal, moderate and high difficulty. A study of 1,000 patients treated by fourth- and fifth-year undergraduate students has been published and it found that cases classed as high difficulty were most likely to have iatrogenic errors following treatment (Alamoudi *et al.* 2020).

The RIOTN has been available since 2001. It is freely accessible and easy to use (<https://www.rcseng.ac.uk/dental-faculties/fds/publications-guidelines/clinical-guidelines/>) (Falcon *et al.* 2001). This index was developed by the Royal College of Surgeons of England (RCS Eng) to help dentists evaluate the need for referral to specialist restorative dentistry services, including endodontics. The index comprised three main components: 1) Patient identified need for treatment; 2) Complexity of treatment, assessed by clinicians and 3) Priority for treatment (also assessed by clinicians). The initial development of the index has had some success (Falcon *et al.* 2001) but lacks studies to evaluate its practicality. Literature reports one study has evaluated this system of grading the complexity of root canal treatment. It found the system to be incomplete to evaluate the data derived from all endodontic referrals to a department of restorative dentistry in a district general hospital within a period of 2001 and 2002 (Muthukrishnan *et al.* 2007). Authors revealed that whilst easy to use, interpretation of root canal patency, root morphology, canal curvature, and significant medical history remained ambiguous with poor to moderate reproducibility between practitioners (Muthukrishnan *et al.* 2007).

The ECS was introduced more recently, in 2019, to help stratify provision of endodontic treatment based within the framework of the National Health Service (NHS) in England and it is also freely available on the internet (<https://www.england.nhs.uk/publication/commissioning-standard-for-restorative-dentistry/>).

This system correlates complexity to the skill-level required for provision of care which is based on a three-tiered approach encompassing primary care setting, an intermediate level that requires practitioners with enhanced endodontic skills or thirdly, specialist care. Currently, there is paucity of literature evaluating the use of the ECS prescribed criteria for endodontic treatments that are undertaken within the secondary care setting and the application of this system of complexity grading remains yet unreported.

The present comparative evaluation assessed the complexity of root canal treatments accepted for treatment by postgraduate training grades at Cardiff University Dental Hospital (CUDH) using the ECS in comparison with the AAE and the RIOTN grading systems.

Methodology

The service evaluation was carried out at the Department of Restorative Dentistry, CUDH and approved by the audit committee (registration number: 6816). Sample size calculation was based on previously published work (Muthukrishnan *et al.* 2007). Case records of 200 consecutive patients waiting for root canal treatment (named allocated cases in this service evaluation) with dental core trainees (DCT, $n=86$ patients) and Master's in Clinical Dentistry in Endodontology (MCD, $n=114$ patients) postgraduate students, between May 2018 and January 2020, were assessed using the AAE, RIOTN and ECS. The patients had already been through specialist new patient assessment clinics prior to being placed in the waiting lists. Interpretation of the guidelines were discussed and agreed where ambiguity existed (Table 1). The data evaluated included medical history and periapical radiographs present in the referral sent by the GDP to CUDH. To achieve a consistent determination of canal curvature in this service evaluation, a standardised method was agreed by investigators and measured on the radiographic patient archiving and communicating system (Synapse, Fujifilm Corporation, Japan) (Schneider, 1971). Further data was also collected from patient notes and periapical radiographs available and entered anonymously onto a spreadsheet (Microsoft Excel, Washington DC, WA, USA). Each of the criteria had different nomenclature for describing complexity. The RIOTN used 'complexity' (1, 2 & 3) and ECS use 'level' (1, 2 & 3).

The 2006 version of the AAE system was used in this service evaluation which describes the 'difficulty' levels as 'minimal' (all factors scoring minimal difficulty), 'moderate' (1 or 2 factors scoring moderate difficulty) & 'high' (1 factor scoring high difficulty or 3 factors scoring moderate difficulty) rather than the AAE points-based system (https://www.aae.org/specialty/wp-content/uploads/sites/2/2017/10/2006casedifficultyassessmentformb_edited2010.pdf). For simplicity, we used 'level' 1, 2 & 3 to describe the complexity of each guideline, level 1 being the simplest and level 3 being most complex.

During the initial phase of evaluation, 65 patient records were analysed independently by a Dental Core Trainee DCT (RL) and a consultant in restorative dentistry (also a specialist in endodontics) (AD) applying the complexity score assigned for each guideline. A Kappa score was not calculated due to small sample sizes in some categories, which would result in instability. Instead, inter-examiner variation was assessed, and a percentage agreement calculated for each guideline. In cases where scores differed, patient notes were presented to a third restorative dentistry consultant (specialist in endodontics) (MT, MV) for a final decision. Data was then gathered from a further 135 patient records and complexity was graded by RL. Intra-examiner variation was then calculated for RL. Fifty patient records were reassessed and percentage agreement was calculated. As with the inter-observer variation, Kappa scores could not be calculated due to small sample sizes in some categories. Descriptive analysis was performed using Microsoft Excel to calculate frequency distributions and relationships.

Results

Inter-examiner agreement was high, and the percentage agreements were 95.4% for the AAE, 92.3% for the RIOTN and 93.8% for the ECS. Intra-observer agreement for AAE was 100%, followed by ECS (88%) and RIOTN (84%).

Most of the cases were level 3 complexity. The highest percentage of cases were identified as level 3 when using the AAE criteria (99.5%, $n=199$) in contrast to the ECS (55.5%, $n=111$)

which scored the lowest number of cases with the highest complexity. RIOTN scored 132 (65.5%) cases level 3 (Figure 1).

When using the AAE, the factor 'endodontic treatment history' was the most common reason for a case to score a level 3 complexity ($n=184$). This was followed by 'canal and root morphology' ($n=59$) and 'radiographic appearance of canals' ($n=29$) (Figure 2).

When using the RIOTN guidelines, the pre-modifying factor responsible for the most level 3 cases was 'iatrogenic damage or pathological resorption' ($n=33$). This was followed by canal negotiability ($n=32$) and canal obstructions ($n=20$). Presence of modifying factors (RIOTN guidelines) led to a 17.5% increase in level 3 cases and 11% increase in level 2 cases. The factor 'endodontic retreatment' was the most common modifying factor [70.5% of the cases ($n=141$)] (Figures 3, 4 & 5).

When using the ECS, the factor 'quality of root filling' led to the most level 3 complexity scores ($n=54$). This was followed by 'iatrogenic damage or pathological resorption' ($n=33$) and whether the 'canal was considered negotiable' ($n=27$) (Figure 6).

The AAE scored 67 cases higher than RIOTN and 89 cases higher than ECS. The AAE factor 'endodontic treatment history' was identified in 78% of these cases when compared with RIOTN, and 64% of these cases when compared with ECS (Figures 7A, 7B).

The ECS scored 13 cases higher than RIOTN. The ECS factor quality of root filling ('quality of obturation') was identified in 85% ($n=11$) of these cases and the ECS factor 'attempt to locate and instrument canals' in the remaining 15% ($n=2$) (Figure 7C). RIOTN scored 64 cases higher than ECS. The RIOTN modifying factor 'history of previous root canal treatment' ('endodontic retreatment') was identified in 74% ($n=47$) of these cases (Figure 7D).

Discussion

A simple and reliable method is desirable to determine the complexity of root canal treatment and therefore the most suitable level of clinician within post-graduate training (at an educational level, a mix of simple as well as cases along a gradient of complexity may be treated depending on the level of experience of the operator – undergraduate or postgraduate

training - and degree of clinical supervision). Allocating cases to the appropriate level of care is therefore made easier by first determining case complexity. Comparison of the recent ECS with other well-recognised complexity guidelines seems essential to determine their suitability for use within endodontology, both within postgraduate training in the UK and beyond. However, there is lack of evidence in literature regarding the comparison between existing endodontic complexity guidelines. The complexity of root canal treatments completed in secondary care environments across the world is also under reported. This service evaluation therefore assessed the complexity of root canal treatments of 200 consecutive cases managed by postgraduate training grades at CUDH using the most recent and ECS guideline in comparison with the AAE and RIOTN. The relationships between these three guidelines were also evaluated.

Even though the 2006 AAE system has been designed to evaluate case complexity in endodontic curricula, it lacks objectivity on the precise number and combination of moderate difficulty level factors that would lead to a high difficulty score. For this service evaluation, a combination of at least three "level 2" factors was scored as a "level 3" (complex). The 'points-based scoring' system was not used in this service evaluation as the AAE recommends that this score system should be restricted for undergraduate educational purposes only. The present service evaluation focused on postgraduate training grades at CUDH and was applied exclusively to determine the complexity of cases that had been allocated for treatment in this setting.

The RIOTN serves as an historic UK reference standard for complexity determination. Despite still being available online, it has now been placed in archive by RCS Eng. One of the main problems with this index is that it allows latitude in interpreting criteria such as 'root canal obstruction' and 'difficult root canal morphology'. The former could mean gutta-percha, posts, silver points or broken instruments. The investigators agreed on the interpretation of these statements to grade the level of difficulty (Table 1). Gutta-percha root filling was excluded as an obstruction as the RIOTN accounts for this within the modifying factors named 'retreatment'. Although 'retreatment' (more precisely 'history of root canal treatment') is

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included in the modifying factors, the quality of the previous root filling is not assessed in this system and is a drawback. These findings are consistent with other published work regarding the evaluation of the RIOTN (Muthukrishnan *et al.* 2007). Root canal negotiability is also difficult to interpret using periapical radiographs. Whilst canal lumen visible on periapical radiographs along their length may be considered negotiable, the converse is not always true (Kuyk & Walton, 1990). When evaluating case complexity via case notes, information on clinical negotiability before specialist treatment intervention can only be assessed based on the content of the referral. Canal accessibility may vary according to the referring dentists' endodontic skills and equipment available. It is difficult, or even impossible, to establish if canals are negotiable without clinical examination of pulp chamber and attempting canal negotiation.

The ECS describes difficulties with local anaesthetic that cannot be addressed by routine measures as complexity level 2. However, the ECS guideline does not define these measures. This information could only be assessed based on the referral. In this service evaluation, the supra-periosteal injection (local infiltration) or nerve block (e.g. inferior alveolar nerve block, IANB) were classed as routine measures.

The inter-examiner and intra-examiner reliability scores were calculated and reliability was high for both scores. Kappa scores were not calculated due to the small numbers of cases being identified as levels 1 or 2, particularly when using the AAE guidelines.

Severe canal curvatures account for increased complexity in all systems, and these are generally estimated rather than measured (Muthukrishnan *et al.* 2007). The assessment of canal curvatures, angles and apex diameter are subjective and can vary due to radiographic images and individual interpretation. As an attempt to reduce subjectivity during the determination of canal curvature in this evaluation, a standardised method was agreed by investigators and measured on the radiographic viewing system. Another problem with the determination of these parameters is the lack of uniformity in the definitions for severe curves amongst the guidelines [$>30^\circ$ (AAE), $>40^\circ$ (RIOTN) or $>45^\circ$ (ECS)]. This lack of consistency and scientific evidence makes this process inconsistent, leading to difference in complexity

scores. Similar concerns exist for the AAE assessment for canal apex (1 mm diameter for minimal difficulty, 1.5 mm and > 1.5 mm for moderate and high difficulty respectively).

Negotiation of curvatures and shaping such canals has now become more predictable with files made from newer heat-treated nickel-titanium alloys which may account for the evolution of threshold standards between the grading systems (Locke *et al.* 2013, Thomas *et al.* 2013). However, the adoption of newer instrumentation varies across different dental settings and severely curved canals may still pose a challenge for the GDP (Locke *et al.* 2013, Thomas *et al.* 2013). The influence of the radius of canal curvature has not been considered in conjunction with angle of curvature in any guideline used in this service evaluation and it should be adopted for any future work in this area.

There is little published data outlining the most common reasons for endodontic referral in the UK. Between 2015 and 2018, the demand for specialist endodontic services was highlighted in Wessex, England. The data showed that the demand for endodontic treatment was greater than any other restorative dentistry treatment (<https://www.dorsetlhc.org/wp-content/uploads/2019/10/Wessex-Restorative-Needs-Assessment.pdf>). Large scale studies in other parts of the world have shown that the most common reasons for endodontic referral include post-treatment disease with canal obstructions (presence of posts, broken instruments), perforation or resorption, difficulties with diagnosis and persistent signs or symptoms, the need for root canal retreatment or periradicular surgery and trauma (Abbott 1994, Peciuliene *et al.* 2010, Kim 2014, Lishen *et al.* 2019). In order of frequency, root canal retreatments were required in many cases allocated for postgraduate treatment at CUDH. This was followed by an 'attempt to repair iatrogenic damage', 'pathological resorption' and to overcome difficulties such as 'canal location/negotiation'. Canals with obstructions were present in only 4% of cases included in this data set as patients with broken instruments or posts were of higher educational demand and allocated for treatment soon after being seen on the consultant clinic rather than joining the waiting list which was used for analysis in this service evaluation. Whereas this early allocation helps fulfil educational training needs at the dental hospital and school, data was not available to include in this service evaluation. For

similar reasons, there were fewer cases of dental trauma or periradicular surgery in this service evaluation which highlights the limitations of a retrospective analysis and should be taken into consideration for future evaluation service projects.

Root canal retreatment competency is not explicitly discussed within the General Dental Council learning outcomes for the graduating dental students in the UK (GDC, 2015). Therefore, root canal retreatments may be considered complex by many GDPs. However, poorly filled root canals with the appearance of radiographic canal patency beyond the root filling have been considered level 1 treatment (based on ECS), and thus within the remit of a primary care practitioner in England. Educational trends in endodontology indicate that many dental schools in the UK now also teach root canal retreatment to their undergraduate students to help prepare them for general dental clinical practice (Al Raisi *et al.* 2019). In future studies, it would be interesting to evaluate the degree of complexity of the root canal treatments that GDP's manage in general practices and their views on the cases that require more complex management to benefit patients and society.

Almost all cases scored as complex (level 3) with AAE were because of 'history of root canal treatment' ('endodontic treatment history'). However, this does not distinguish between previously initiated root canal treatment and presence of a previous root filling (or more precisely, presence of post-treatment disease). This led to a higher complexity score with the AAE. In the RIOTN, 'presence of root canal treatment' ('endodontic retreatment') was also the most prevalent 'modifying factor'. However, it's description is less specific than the ECS which differentiates the quality of the existing root filling and influences complexity grading. Most of the cases that were scored higher by the ECS than the RIOTN were due to a good quality root filling ('quality of obturation'). Poorly condensed gutta percha (GP) short of appropriate length is easier to remove than well condensed GP to an appropriate length (Virdee & Thomas, 2017). Single cone root fillings were considered poorly condensed in this service evaluation, even when extending to length, and thus scored level 1 with ECS. Densely compacted root fillings improve the outcome of primary root canal treatment (Ng *et al.* 2008), but single cones with bio ceramic sealers have been used for root fillings (Chybowski *et al.* 2018) and make

Accepted Article
root canal retreatment more time consuming because of the difficulty removing the root filling (Romeiro *et al.* 2020). This may need to be considered when using the ECS in the future.

Of the cases scored higher by the ECS as compared with RIOTN, 15% were due to a failed attempt to locate canals by the GDP leading to a level 2 complexity score by the ECS. These cases only scored level 1 when using the RIOTN as the criteria does not acknowledge previous attempts at canal location. The RIOTN does mention difficulties with canal negotiability. However, in this present evaluation, difficulties with canal location were not grouped with non-negotiable canals. Canals are often missed due to a poor access cavity design. Therefore, it is important to distinguish between difficulty with canal location and non-negotiable canals (Adams & Tomson, 2014).

Results of this service evaluation show minor differences in complexity scores given by ECS and RIOTN regarding “non-negotiable canals”. The complexity definition regarding negotiation has been more comprehensively described by the ECS as compared with the RIOTN which accounts for this difference. The former guideline scores complexity 3 only when canals are considered non-negotiable beyond the coronal third of the root. Within the specialist setting, using illumination, magnification, ultrasonic tips and more recently CBCT-guided endodontics, management of sclerosis within the root canal can be overcome more predictably.

Of the three complexity guidelines used in this evaluation, according to the ECS authors’ opinion, this guideline was the most user friendly and recent. It provided the most clarity when assessing complexity of endodontic retreatment which was important since 70.5% of the cases assessed required this therapy. It also gave the most comprehensive description of non-negotiable canals and distinction from ‘difficulties with canal location’ in addition to a more modern approach for defining complexity. The ECS was also quick to apply and does not use a complicated points-based system which makes it more acceptable for use by a busy general dentist. Whilst designed for use in England, its efficacious structure for complexity grading related to skills levels could be translated for use across most healthcare systems internationally.

The AAE was chosen for this service evaluation because it is the most well recognised and well utilised system for grading endodontic complexity in the world and has been developed to evaluate endodontic curricula, therefore well aligned with the educational needs in the discipline. The RIOTN was also used as it is contemporaneous and well recognised within the UK where this service evaluation was carried out. Prior to the introduction of the ECS, the RIOTN was a commonly used system available for grading complexity of endodontics in the UK. The ECS is a modern system introduced recently in England. The ECS is a successor to the RIOTN which has now been placed into archive by the RCS Eng. The ECS has no published data on its use, and prior to this service evaluation, has not been compared to the older systems. There are other tools available for assessing endodontic complexity. In 2018, a web-based tool termed 'EndoApp' was developed after combining several different complexity grading systems (Shah & Chong, 2018). It was found to be user friendly and merits further investigation regarding its correlation with commissioning standards (Shah *et al.* 2020). The Dental Practicality Index (DPI) helps decision-making for a tooth from the restorative, periodontal, endodontic, and patient perspective, including determination of need for referral (Dawood & Patel, 2017). However, it may be difficult to commission enhanced and specialist services based on this index as it is difficult to distinguish between complexity levels 2 and 3. More work is required in this context to relate numerical scores of DPI to the complexity levels of ECS. Most recently, the Endodontic Complexity Assessment Tool (E-CAT) has been proposed and should be explored for its appropriateness for grading referrals within the NHS setting specifically, and relating this to practitioner skill level on a wider international basis (Essam *et al.* 2021). Further research is required comparing the ECS to 'Endo App', DPI and E-CAT. A combination of these more modern systems may provide the most effective tool for determining endodontic complexity. Despite efforts, there will be always limits to establishing universal guidance to measure complexity of cases due to the following main factors: (a) lack of common consensus on definitions and parameters used for data collection, (b) natural variation of the ethnic groups/populations and (c) postgraduate training varies internationally in terms of structure and skill level required at each level of training, and (d) how the complexity

rating is then used would depend on the health care system or educational programme it is being used within. However, it would be valuable to start by gaining a universal consensus on a standard protocol for case complexity assessment to facilitate efficient allocation of patients to appropriate operators.

Conclusions

Within the limitations of this service evaluation, it was possible to conclude that high proportion of cases treated by training grades at postgraduate levels at CUDH were of a high complexity level (level 3) using the three guidelines (ECS, AAE, and RIOTN). This is appropriate for secondary care training which involves managing challenging cases (under various levels of supervision). The ECS scored cases lower than the RIOTN and AAE. The AAE and RIOTN were less specific than the ECS. For example, the quality of the existing root filling requiring retreatment was not considered by the AAE or RIOTN.

Declaration of Interests

Authors have no conflict of interest to declare.

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Table legend:

Table 1. Investigator interpretation of complexity guideline ambiguities

Figure legends

Figure 1. Overall percentage of complexity of cases identified by AAE, RIOTN and ECS guidelines ($n=200$).

Figure 2. Complexity level identified when using the AAE criteria for each patient/treatment factor ($n=200$).

Figure 3. Complexity level for each patient and treatment when using the RIOTN ($n=200$).

Figure 4. Complexity scores assigned when using the RIOTN pre- and post- modifying factors ($n=200$).

Figure 5. RIOTN modifying factors per number of cases ($n=145$).

* named “endodontic retreatment” by authors.

Figure 6. Complexity score assigned when using the ECS for each patient/ treatment factor ($n=200$).

Figure 7. A. AAE Factors causing an increase in complexity when compared with RIOTN. **B.** AAE factors causing an increase in complexity when compared with ECS. **C.** ECS factors causing an increase in complexity compared with RIOTN. **D.** RIOTN factors causing an increase in complexity grading compared with ECS.

Table 1. Investigator interpretation of complexity guideline ambiguities

Ambiguity highlighted	Guideline	Interpretation
canal curvature	AAE	Schneider's method (Schneider 1971)
determination		angle calculated on Synapse (Fujifilm,

	RIOTN	Tokyo, Japan)
	ECS	
decision on final complexity level	AAE	minimal difficulty (scored as 1): scores minimal difficulty across all criteria moderate difficulty (scored 2): Scores moderate difficulty once or twice across criteria high difficulty (scored 3) - scores moderate difficulty several times interpreted as 3) across criteria or high difficulty one or more times across criteria.
root canal obstruction	RIOTN	includes post/ fractured post/ fractured instrument/ screw/ silver point
difficult root morphology	RIOTN	developmental abnormalities C-shaped canals S-shaped canals complicated canal anatomy (Vertucci 1984)
routine measures for local anaesthetic	ECS	infiltrations and inferior alveolar nerve block insufficient

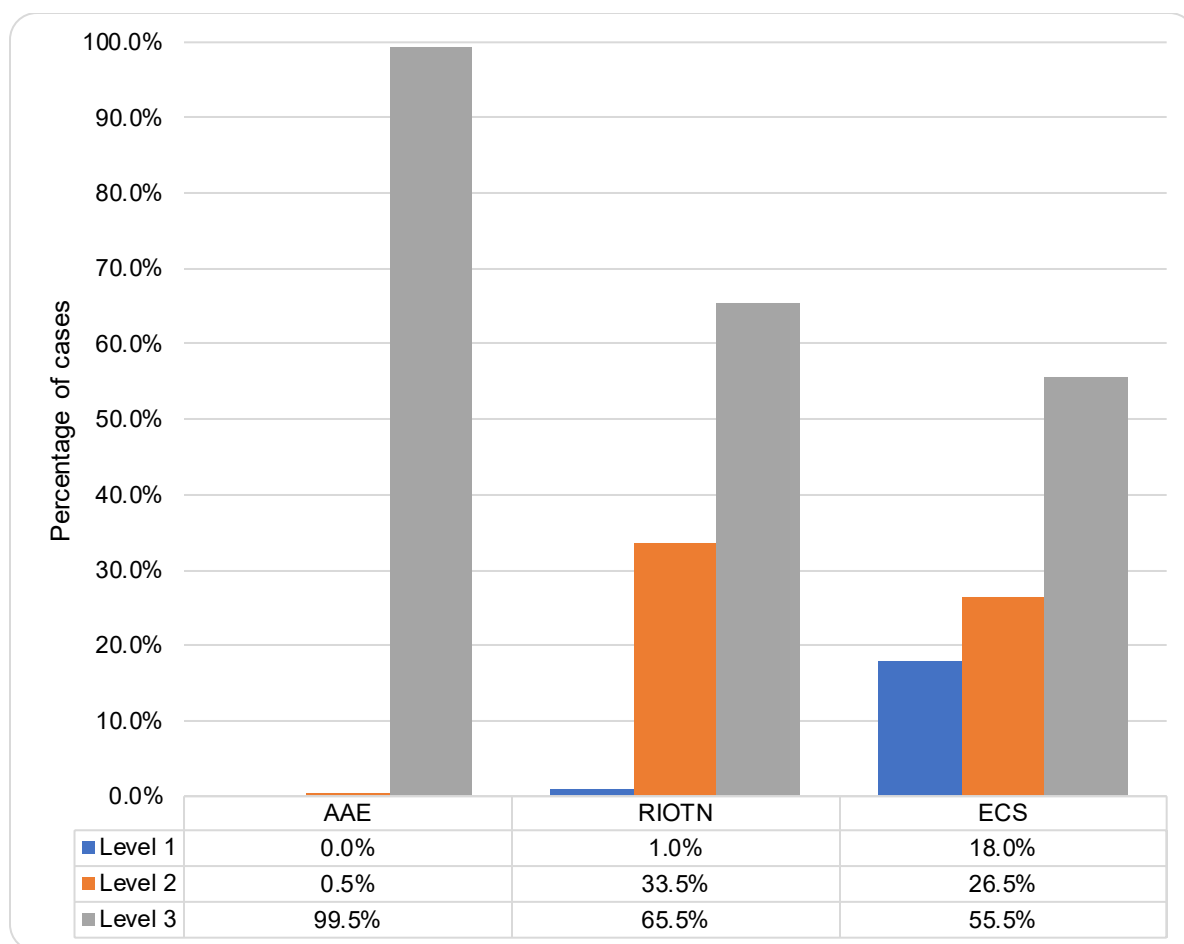


Figure 1. Overall percentage of complexity of cases identified by AAE, RIOTN and ECS guidelines ($n=200$).

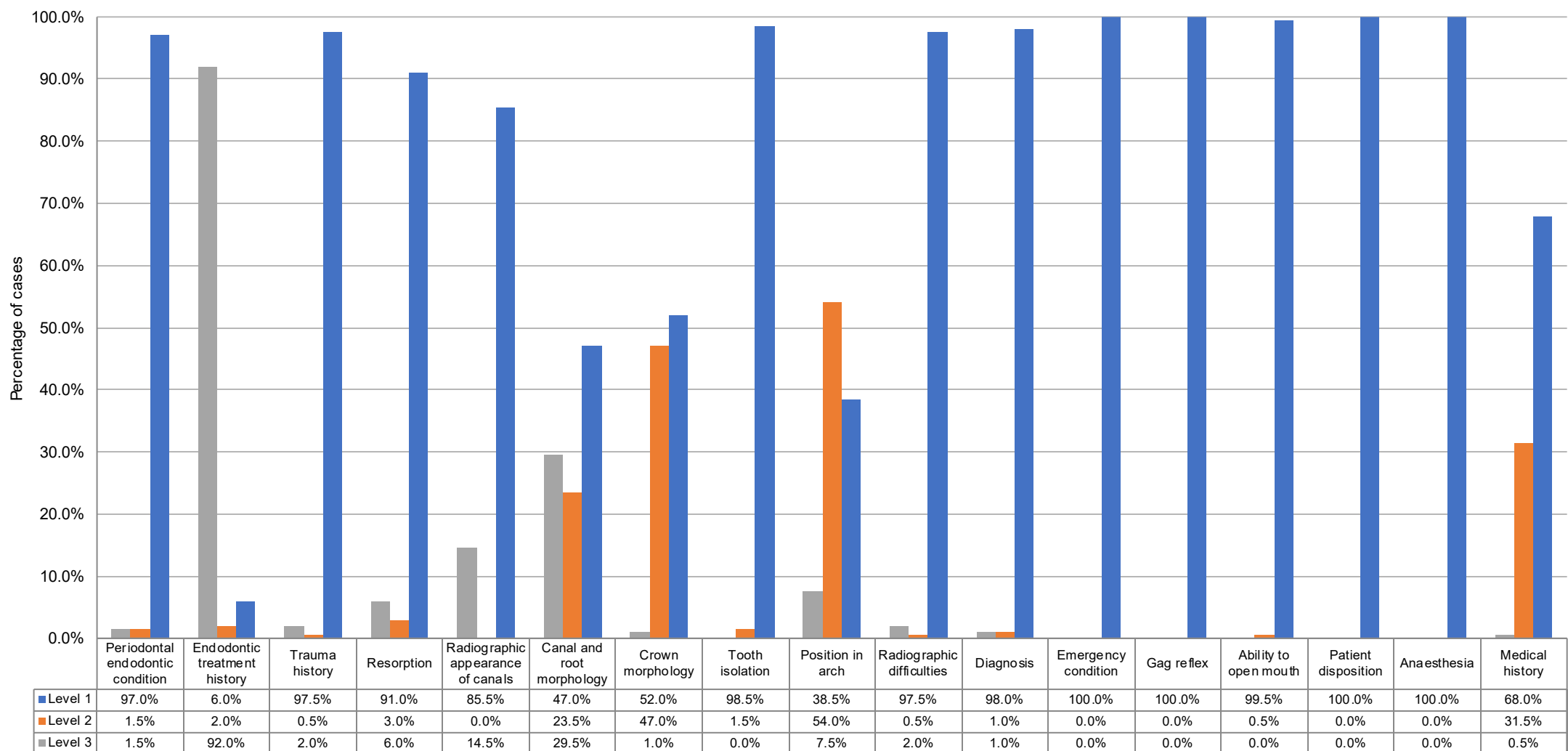


Figure 2. Complexity level identified when using the AAE criteria for each patient/treatment factor ($n=200$).

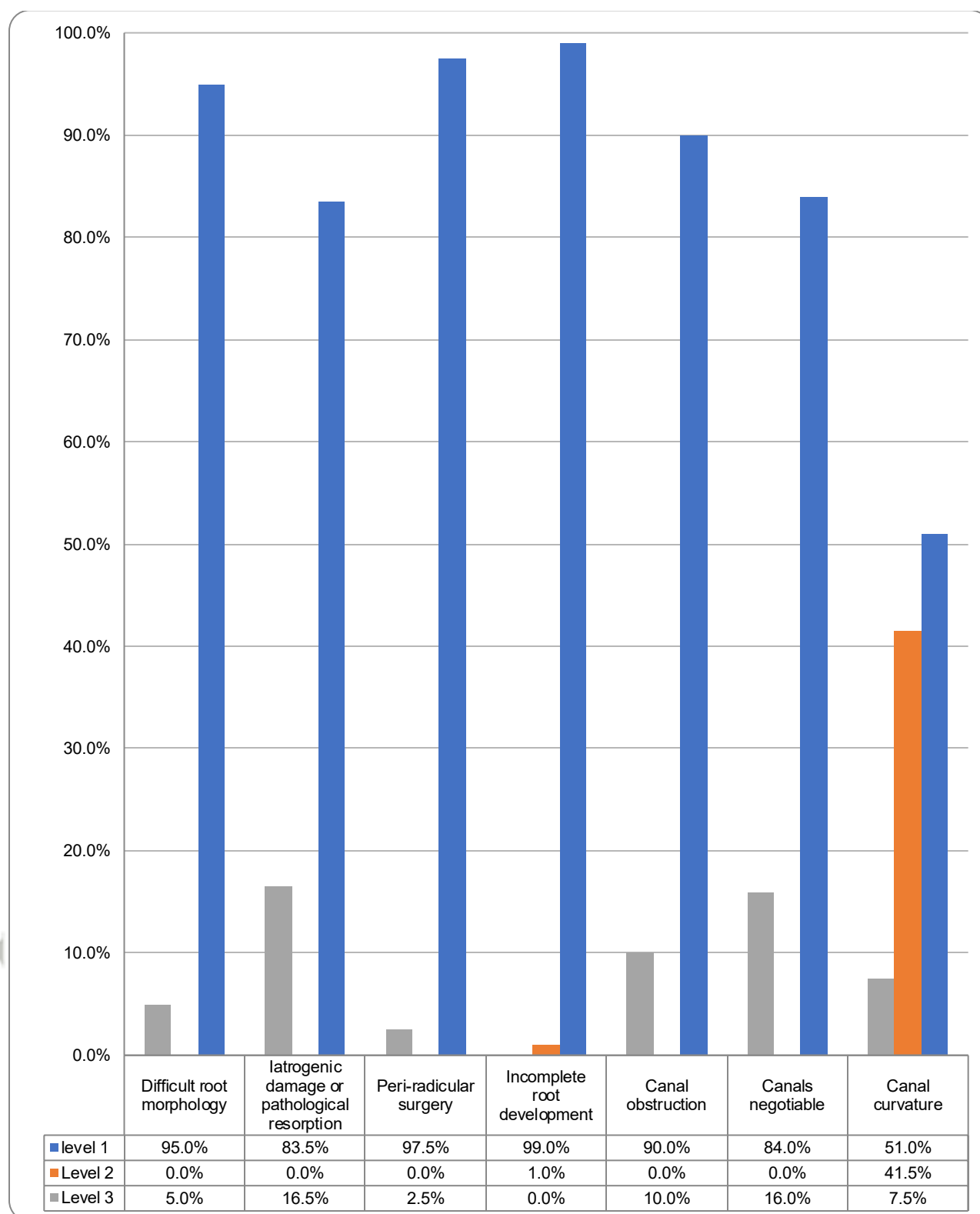


Figure 3. Complexity level for each patient and treatment when using the RIOTN ($n=200$).

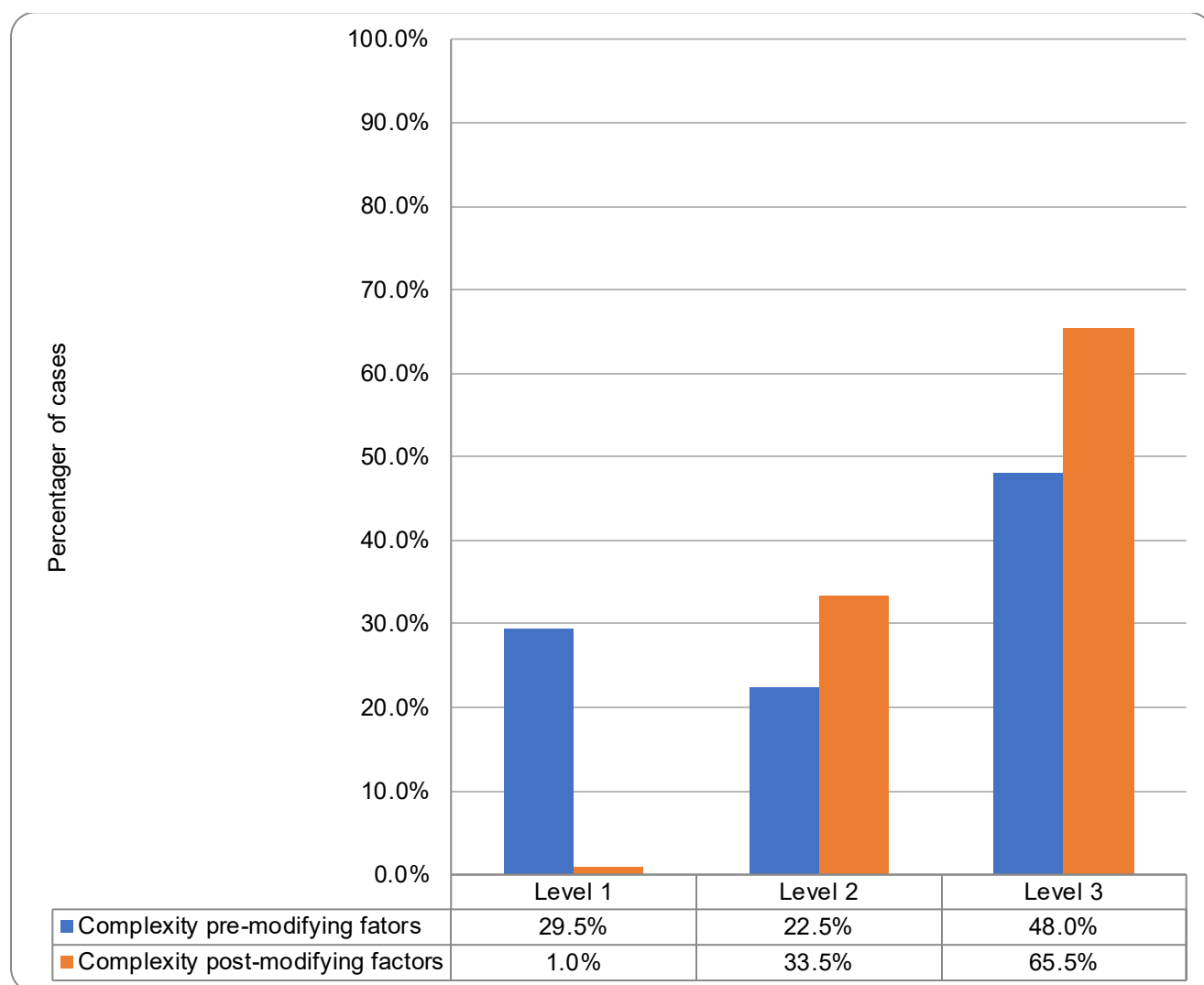


Figure 4. Complexity scores assigned when using the RIOTN pre- and post- modifying factors ($n=200$).

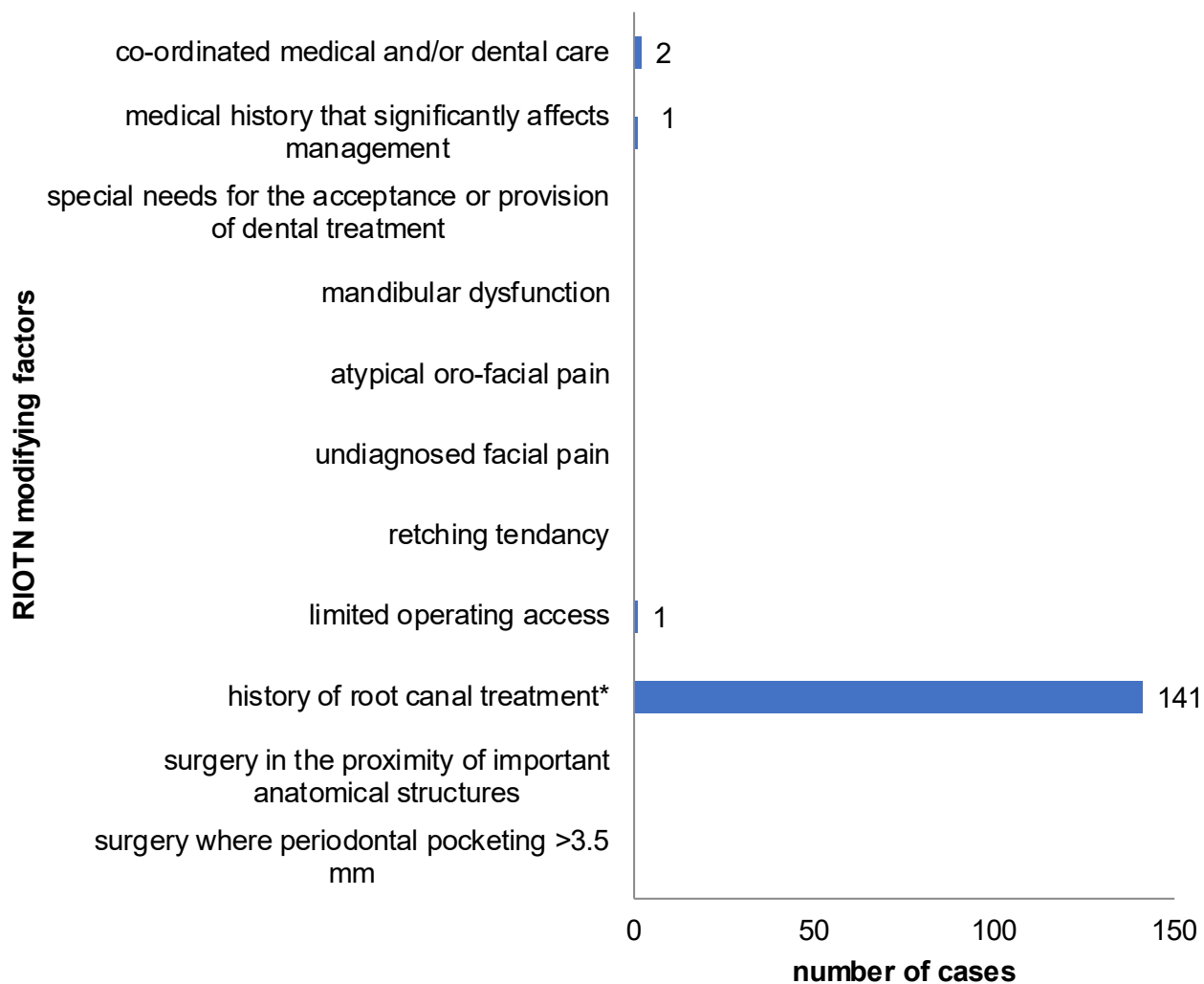


Figure 5. RIOTN modifying factors per number of cases ($n=145$).

* named "endodontic retreatment" by authors.

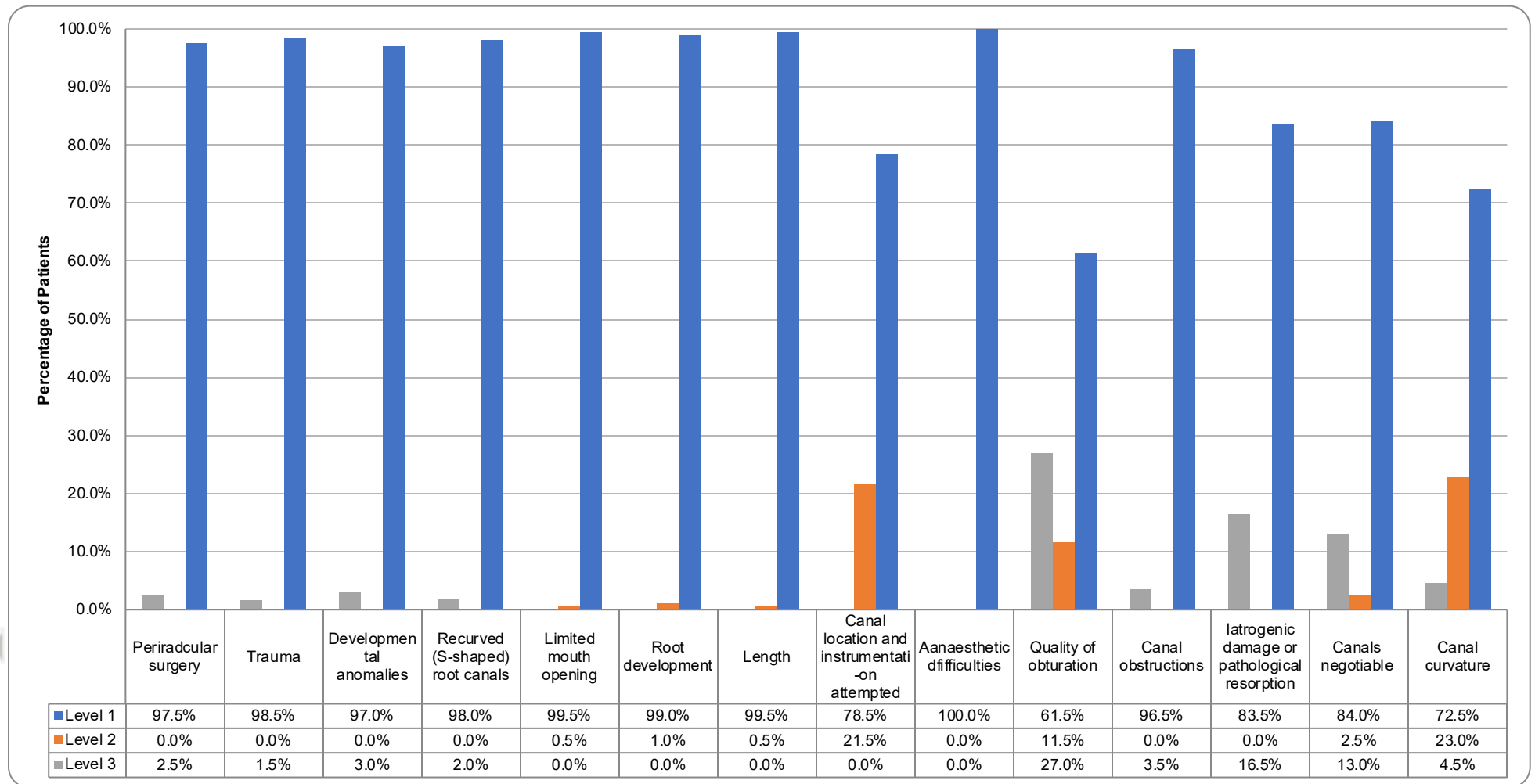


Figure 6. Complexity score assigned when using the ECS for each patient/ treatment factor ($n=200$).

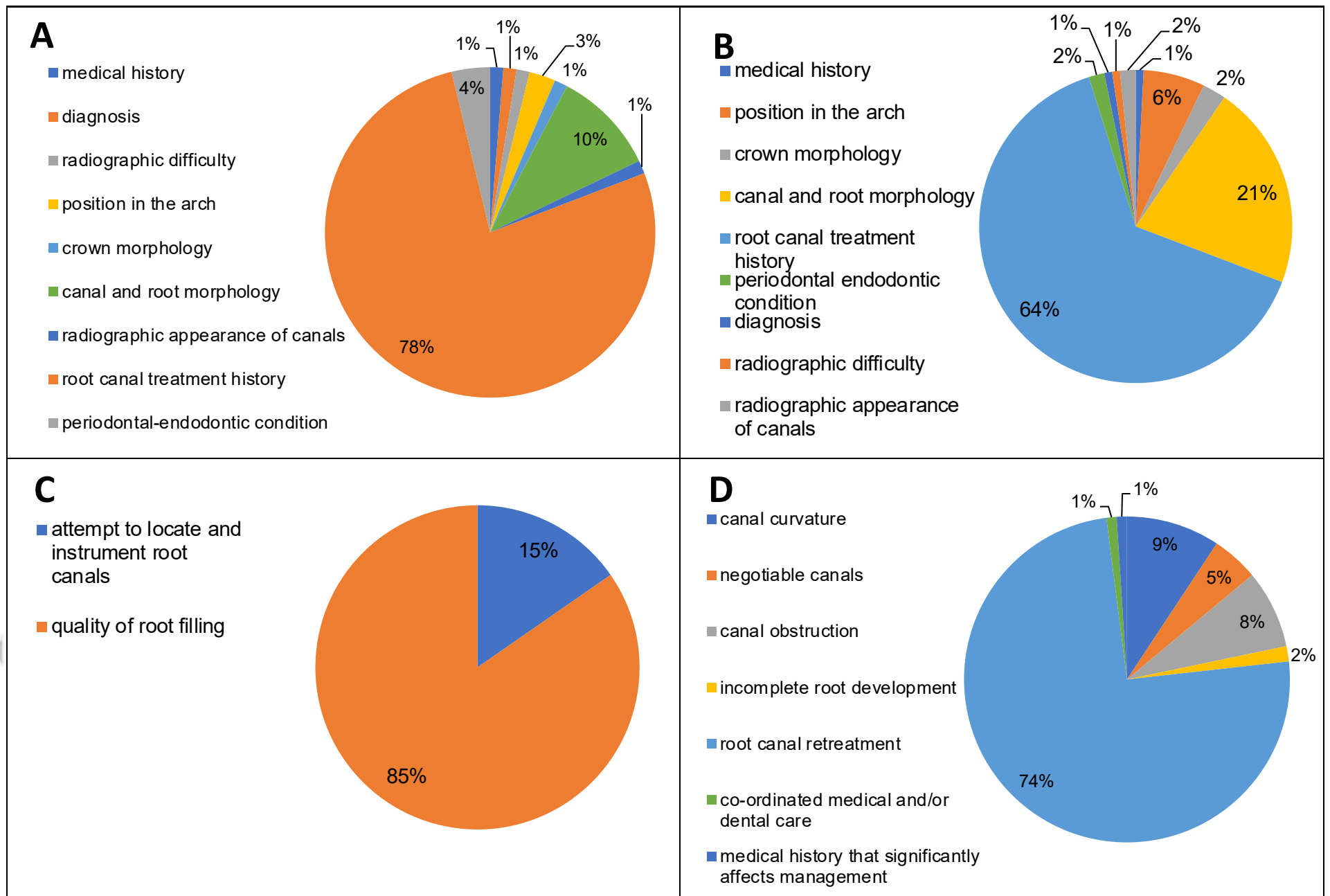


Figure 7. A. AAE Factors causing an increase in complexity when compared with RIOTN. **B.** AAE factors causing an increase in complexity when compared with ECS. **C.** ECS factors causing an increase in complexity compared with RIOTN. **D.** RIOTN factors causing an increase in complexity grading compared with ECS.