

## GUIDELINES

# EUROPEAN SOCIETY OF ENDODONTOLOGY

## Undergraduate Curriculum Guidelines for Endodontology

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### Abstract

Undergraduate education should accomplish graduates who are skilled to provide quality care for patients, who are aware of their scope of practice, competency level and limits and who are open to referring patients whose needs are beyond their own skills and experience. They should also become self-efficacious. Quality performance begins with good diagnosis and decision-making. Graduates should understand when to treat, why to treat, what to treat and how to treat. These guidelines include a list of capabilities that the graduating student will be expected to have achieved to provide a minimum level of competency in endodontics. Theoretical knowledge, practical skills, understanding and insight should be assessed, with both formative and summative assessment procedures, making use of reflection and feedback. Endodontic procedures should be undertaken within the context of comprehensive patient care and should be evidence based. Students should not perform treatments on patients until they have demonstrated in a pre-clinical setting that they possess the required skills. Only if it is not possible to simulate a specific procedure sufficiently in a pre-clinical setting should students learn this procedure by performing it clinically under close supervision. Clinical endodontics should ideally be supervised by endodontists or by staff with special knowledge, interest and self-efficacy in endodontics. It is advised to ensure that students apply their knowledge and practice their skills periodically throughout the continuum of endodontic education until graduation. A philosophy of lifelong learning and evidence-based practice should be instilled in all dental undergraduates.

### KEYWORDS

education, Endodontology, guidelines, undergraduate

**Further contributions** ADEE Executive Committee member James Field; ESE Education and Scholarship Committee members Maria Pigg, Roula Abiad and Vytaute Peculiene; and ESE Executive Board members Lise-Lotte Kirkevang and Hal Duncan.

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## PROCESS

Earlier editions of the European Society of Endodontology (ESE) Undergraduate Curriculum Guidelines for Endodontology were published in 1992, 2001 and 2013 and formed a benchmarking reference for dental schools and regulatory bodies. The ESE undergraduate curriculum guidelines are constantly under review in light of developments in clinical and educational practice. The Education and Scholarship Committee of the ESE seeks to publish updated guidelines which are compatible with recommendations of the Association for Dental Education in Europe (ADEE) and based on available scientific evidence on a 10-year cycle; the current edition is built on the previous one.

In the previous edition, the focus of the revision was on the content of the curriculum and defining recommended levels of competence. In the current edition, the authors and other members of the Education and Scholarship Committee of the ESE reconsidered and adapted the list of capabilities that the graduating student will be expected to have achieved to provide a minimum level of competency. In the current edition, the authors also aimed to elaborate on factors that are important to facilitate efficient and effective learning to prepare students for their role as dentists, to reach and maintain the required level of competence, to accomplish professionalism and to build self-efficacy in endodontics. The authors based the changes they made on the available literature and consulted the other members of the Education and Scholarship Committee of the ESE to check whether they regarded the revision relevant and whether they thought that dental schools throughout Europe and beyond would be able to comply with the current edition. To align with the ADEE, publications of the ADEE and an Executive Committee member of the ADEE were consulted. The Executive Board members of the ESE were invited to provide final remarks. These guidelines may therefore be regarded as a consensus statement from a diverse group of senior European dental educators, commissioned by the European Society of Endodontology.

## PREAMBLE

Undergraduate education in Endodontology remains essential to prepare students for their role as dentists. Innovative materials and methods may facilitate endodontic treatment, however, it is still the 'craftsmanship' that gets the job done, highlighting the need for both knowledge and skills training in undergraduate education. Providing quality care to patients requires relevant knowledge and diagnostic, technical, problem-solving and patient management skills. Performing quality treatment

is important for clinical success (Ng et al., 2011) and public health and contributes to sustainability by reducing the number of additional treatments that would be necessary (Duane et al., 2020). Quality performance begins with good diagnosis and decision-making. Proper awareness of the aetiology of pulpal and periapical disease and the process of how it develops is essential. Dentists should understand when to treat, why to treat, what to treat and how to treat. It is important to ensure that undergraduate training is undertaken to a level that encourages deep understanding of the clinical and technical factors important for clinical outcomes. Undergraduate education should accomplish graduates who are skilled to provide quality care for patients, who are aware of their scope of practice, competency level and limits and who are open to referring patients whose needs are beyond their own skills and experience. It is recognized that resources to deliver the endodontic curriculum vary from school to school and that students may reach the point of graduation with varying levels of knowledge and experience (ESE, 2018). It is also recognized that options for patient referral may differ from country to country and that this may influence the end point of undergraduate education. Ideally, post-graduate education should be available and accessible to ensure that the full scope of endodontic care can be available for patients (Kirkevang, 2021).

At the end of undergraduate training, students should not only *be* prepared but also *feel* prepared for their roles as dentists, a state referred to as self-efficacious. Self-efficacy is the belief and self-assurance that, despite the prevailing circumstances, a practitioner will be able to perform specific tasks successfully. Self-efficacy determines whether an individual will use the academic capabilities they have achieved and be able to apply them successfully during the performance of demanding work-related tasks (Gist & Mitchell, 1992; Pajares & Miller, 1994; Zimmerman, 2000).

The European Society of Endodontology aims to promote standards of scientific education and clinical training across a broad undergraduate curriculum in Endodontology. This includes but is not limited to diagnostic and treatment procedures for the prevention and management of pulpal and periradicular disease, and for the preservation, restoration and monitoring of pulpally compromised teeth that would otherwise be lost. It is implicit that the procedures defined should be exercised within a model of holistic, evidence-based patient care and should be undertaken to support the oral and general health of patients.

This document represents a guideline for an undergraduate curriculum and cannot be exhaustive. The underlying principle must be that a minimum level of competence and self-efficacy is reached prior to graduation, a level that is sufficient for novice dentists to manage in practice, and

that an ethos of continuing professional development is instilled in the graduate. It is important to make both students and staff aware of the level of competence to be acquired during undergraduate training (Field et al., 2017). Schools may develop their undergraduate curricula with reference to this guideline document and work progressively towards the competence of their students. The methods and tools employed in undergraduate education should ensure that students gain and retain the assigned level of competence and build self-efficacy. A diverse and broad range of educational methods may be successfully employed (Field et al., 2017); however, more research to reveal which methods are best, or most efficient or effective, is needed. Besides, further innovation and implementation of contemporary learning resources to enhance the acquisition of skills, knowledge, deep understanding and self-efficacy are encouraged. Collaborations between academics and commercial innovation-led organizations should be encouraged to develop intelligent systems that will facilitate pre-clinical skills training in endodontics and provide instantaneous feedback on performance. Those systems should provide variety and mimic real-life settings well. Sharing good practices with the ESE Education and Scholarship Committee is welcomed.

In the end, professionalism is essential to optimize endodontic care. Professional action involves not only knowledge and skills but also attitudes (Passi et al., 2010). It is important to recognize that in addition to the theory and methods taught, the example demonstrated by staff influences the practice of endodontics (Chevalier et al., 2021; Field et al., 2017). For teaching and learning professionalism, role modelling is important, hence the culture of the institution and the personal actions of its staff (Cruess et al., 2008; Passi et al., 2010). Against this background, and since not everything is certain in Endodontology, acknowledging perceptions of inevitable uncertainty by staff combined with openness to reflect together with the students may benefit student development (Pigg et al., 2022; von Bergmann & Shuler, 2019).

## CURRICULUM

The curriculum is presented as a list of capabilities that the graduating student will be expected to have achieved. These provide a minimum level of competency and are defined by a baseline consensus of the Education and Scholarship Committee of the ESE, a diverse group of clinical educationalists. Whilst the time and resources given to endodontic education will vary from school to school, the committee has sought to develop a curriculum that can be delivered by most of the dental schools in Europe. The curriculum includes relevant scientific and

interdisciplinary topics to emphasize the scientific foundations of Endodontology and its critical relationships with other clinical disciplines. However, the curriculum does not include guidelines for which theories or methods should be taught; schools should ensure that the content of their education and the protocols they employ for providing endodontic patient care are aligned with current evidence-based approaches (Field et al., 2017). The ESE provides quality guidelines and position statements on several topics that may be used to accomplish this (<https://www.e-s-e.eu/for-professionals/resources-for-clinicians/>). A capabilities-based curriculum allows constructive alignment. Levels of competence and learning outcomes are defined to assist student assessment and the process of course review.

Terms incorporated within these guidelines follow a pattern adopted by the ADEE in their Profile and Competencies of the Graduating European Dentist (Cowpe et al., 2010) and their New Undergraduate Curriculum Framework (Field et al., 2017). They defined competencies in their New Undergraduate Curriculum Framework (Field et al., 2017) as follows:

### Competences

Professional behaviours and skills required by a graduating dentist in order to respond to the full range of circumstances encountered in general professional practice (Cowpe et al., 2010). Competence is very much a professional construct.

For the capabilities expected of a student at graduation, Cowpe et al. (2010) discerned three levels of competence that could be assigned:

#### Be competent at

A dentist should on graduation demonstrate a sound theoretical knowledge and understanding of the subject together with an adequate clinical experience to be able to resolve clinical problems encountered independently or without assistance.

#### Have knowledge of

A dentist should on graduation demonstrate a sound theoretical knowledge and understanding of the subject, but need/have only a limited clinical/practical experience.

#### Be familiar with

A dentist should on graduation demonstrate a basic understanding of the subject but need not have clinical experience or be expected to carry out procedures independently.

The Education and Scholarship Committee of the ESE recognizes that for some endodontic capabilities the

level of 'be competent at' can be reached by training in a pre-clinical setting, provided that students have adequate clinical experience in providing general dental care. Understanding and insight are very important; they facilitate transfer of skills (Perkins, 1991).

For all capabilities, the ADEE advises formulating learning outcomes. They defined learning outcomes in their New Undergraduate Curriculum Framework (Field et al., 2017) as follows:

### Learning outcomes

A series of individual and objective outcomes, with shared ownership between students and staff, designed to facilitate the learning and assessment process. Learning outcomes are very much an educational construct.

The ADEE differentiates among 'Clinical Learning Outcomes', 'Supporting Clinical Learning Outcomes' and 'Fundamental Learning Outcomes':

**Clinical Learning Outcomes (Clinical LO)** – directly observable within a clinical or skills environment.

**Supporting Clinical Learning Outcomes (Supporting Clinical LO)** – directly observable within a clinical or skills environment, through case-based discussion or written assessment.

**Fundamental Learning Outcomes (Fundamental LO)** – assessable through discussion or written assessment.

## STRUCTURE OF TRAINING

Endodontic procedures should be practised with the required level of skill and based on sound scientific knowledge. A holistic endodontic curriculum, therefore, requires knowledge-based input and the acquisition of required skills in a suitably equipped pre-clinical environment that simulates clinical reality as closely as possible and integrates knowledge and skills. This should be followed by the consolidation of knowledge and skills, and the building of self-efficacy, through supported clinical practice. The taught approach for endodontics should be one that can be safely applied to relevant cases and provide students with a solid base that they can simply use and safely build on following graduation (Baaij, 2023). It is acknowledged that the time and resources devoted by schools to endodontic education vary widely (Sacha et al., 2021), and it has not been possible to define a minimum level of knowledge- or skills-based input. Neither is it possible nor desirable to provide definitive directions to schools on how they plan and deliver their courses.

However, it is advised to ensure that students apply their knowledge and practice their skills periodically throughout the continuum of endodontic education until graduation (Baaij, 2023; Field et al., 2017).

## CLINICAL EXPERIENCE

Endodontic procedures should be undertaken within the context of comprehensive patient care. The breadth of endodontic procedures is reflected by their integration with aspects of Cariology, Conservative dentistry, Periodontology, Prosthodontics, Restorative Dentistry, Surgical Dentistry, Oral Medicine, Orofacial pain and jaw function, Special Care Dentistry, Paediatric Dentistry and Dental Traumatology. Whilst some schools may have dedicated endodontic clinics, it is recognized that many do not, and that the conduct of endodontic procedures in mixed clinics may in fact encourage holistic care. Although undergraduate students may benefit from teaching and clinical supervision by endodontists or dentists with enhanced skills and knowledge in Endodontology (Baaij & Özok, 2018), it is acknowledged that this is unrealistic in many schools (Sacha et al., 2021). However, the teaching and supervising staff should ideally have a special interest in Endodontology and be able to integrate knowledge and skills in the clinical setting. At the very minimum, they themselves must be self-efficacious in endodontics (Cruess et al., 2008; Passi et al., 2010).

Recommendations are not made on the appropriate number of procedures such as pulp caps, pulpotomies and root canal treatments required for a student to reach a threshold of competence. Recommendations for successful completion of endodontic training should not be made on the quantity of exposure. Indeed, a competency-based approach to training implies that the quality and consistency of student performance are more important than simply the quantity of exposure. Levels of expected expertise are intimated by the descriptors (be competent at, have knowledge of and be familiar with) assigned to each competency or behaviour-based learning outcome. It is essential within an endodontic curriculum that students gain the assigned level of competence for the entire span of endodontic care. This includes examination, diagnosis, differential diagnostics, decision-making, vital pulp therapies, root canal treatment, nonsurgical retreatment, surgical procedures, the management of endodontic emergencies and the management of dental trauma. Students should not perform treatments on patients until they have demonstrated in a pre-clinical setting that they possess the required skills. However, it may not always be possible currently to simulate all procedures sufficiently in the pre-clinical setting, and in these cases, closely



supported learning should be facilitated in the clinical setting. Equally, sometimes it may not be possible for students to be exposed to all procedures in the clinical setting within their undergraduate training and simulation may be the only way to practice the relevant capabilities. Although undergraduate training should ideally provide extensive clinical experience in endodontic procedures (Baaij et al., 2020), it is recognized that more limited clinical experience before graduation, provided this is at a competent level, may be adequate for graduates to practice as a novice dentist (Baaij et al., 2021).

For root canal treatment, students should be competent to undertake the treatment of uncomplicated anterior and posterior teeth, including molars. Hence, they should gain adequate experience in the treatment of anterior, premolar and molar teeth in the pre-clinical environment. Extracted human teeth and/or artificial replicas can be used for this pre-clinical training (Tchorz et al., 2015). Subsequently performing root canal treatment in patients is considered important for building self-efficacy, and this is most effective when started with primary treatments of anterior or premolar teeth before proceeding with molar treatment or even retreatment (Baaij et al., 2020). Whilst it has historically been advised that students should gain clinical experience in the treatment of uncomplicated anterior, premolar and molar teeth, it is recognized that this may be unrealistic in many schools. Performing more complicated treatments on patients in the early stages of clinical experience is not recommended as this may have a negative impact on student self-efficacy (Baaij et al., 2020) and may also undermine an essential message that dentists should practice within their skill set and refer patients for treatments that are beyond their experience and skill (Baaij, 2023).

## CLINICAL DECISION-MAKING

Students should not simply be trained as technicians or 'root canal therapists'. Students should be encouraged to consider all options for the management of compromised teeth and justify the case for tooth preservation by watchful waiting, vital pulp therapy, root canal treatment or nonsurgical/surgical retreatment followed by adequate coronal restoration and balance this against tooth loss and prosthetic/implant-supported replacement based on the prevailing scientific evidence. Education in Endodontology may be integrated with education in Implantology, Prosthodontics and Restorative Dentistry to achieve unbiased decision-making (Pineda et al., 2018). The foundational nature of endodontic procedures, the importance of assessing the overall prognosis of teeth including the periodontal status and the restorability preoperatively, and of planning the restorative strategy before

embarking on treatment should be emphasized. Against this background, students should gain the assigned level of competence in assessing endodontic treatment complexity and risks. They should be aware of the factors associated with treatment success and tooth survival and be able to implement these within their decision-making. Since uncertainty is an unavoidable component of the complex discipline of Endodontology, they should learn to manage uncertainty too (Pigg et al., 2022). Students should equally be encouraged to reflect on their own skills and knowledge in case assessment and recognize when referral would be in the best interests of their patients.

## ASSESSMENT

Assessment for and assessment of learning ensures that the knowledge and skills learned are reinforced and that a standard of competence is achieved by the end of training. The demonstration of competence should involve both formative and summative assessment. It should be ensured that assessments are valid and fair; this would be beneficial to the students' learning since it provides them with the opportunity to improve when necessary, and this is a duty of care to students, to their future patients and to our profession (Bush et al., 2013; Field et al., 2017; Monrouxe et al., 2011; Scholes & Albarran, 2005).

Development against a defined benchmark and using reflection is recommended (Field et al., 2017). Students should know the factors that are important for the outcome of endodontic treatment, and they should be able to apply this knowledge to the treatments they perform. Both during and following treatment, students should reflect on the process: during the treatment, they should use reflection to adapt the treatment if necessary to improve quality, and following treatment, they should use reflection to determine the prognosis of the tooth and consider how they manage future cases more effectively (Baaij, 2023). Exercises of this sort should be conducted as 'whole task' assessments, assessing the entire performance and with opportunities for student self-assessment and reflection.

### Formative assessment

When skills are practised without feedback or evaluation, errors are reinforced rather than corrected (Dunnington et al., 1994). Both skills and theoretical knowledge, as well as understanding and insight, and the integration of scientific evidence should be assessed. Rubrics can be developed, corresponding to the capabilities included in this guideline document. Direct observation has been shown to

be a good method of assessing performance. This method may be difficult to standardize, but rubrics with precise criteria can improve consistency and reliability. For understanding and insight, to stimulate professional action and to encourage the use of scientific evidence, students should be encouraged to provide a reflective narrative to be assessed with their pre-clinical or clinical work – what went well and why they reached their conclusions, what went not so well and what were the reasons, what would they do differently or better next time, what would be the expected prognosis if their treatment had been conducted on a patient and what they have learned. Formative assessment can only work if there is effective and structured feedback. The level of competence should be emphasized. Normative feedback, however, can influence feelings of competence and hence self-efficacy not only positively but also negatively (Gist & Mitchell, 1992; Wulf et al., 2010), and it is considered important that teaching and supervising staff are aware of that. Formative feedback should be constructive and encourage self-assessment and reflection to enhance understanding and control and is relevant when set against specified criteria in rubrics. Formative feedback should whenever possible be provided immediately. Staff:student ratios should ideally be high to ensure safe practice, close interaction and guidance of students in the learning process (Al Raisi et al., 2019). Six endodontic treatments are normally considered the maximum that a staff member should supervise simultaneously. For clinical training, however, a maximum of four is recommended.

The assessment of performance by direct observation with multiple episodes of assessment may be ideal but is resource intensive and impractical for many schools. The criterion-based assessment of treatment stages (i.e. diagnosing, decision-making, isolation, access, etc) has advantages over the simple evaluation of postoperative radiographs (ESE, 2018). Suitable methods for formative assessment of clinical skills include the objective structured clinical examination (OSCE), structured clinical operative test (SCOT) and procedural observation tests such as direct observation of procedure skill (DOPS) and mini-clinical evaluation exercise (mini-CEX) tests (Fromme et al., 2009; Kogan et al., 2009). These can involve the assessment of complete procedures or lengthy procedures – such as root canal treatment – can be separated into smaller, defined elements. Students can be encouraged to undertake these when they wish to present themselves as competent. Typically, students are observed during the procedure and also perform self-assessments using the same criteria as the supervising clinician. When the procedure is completed, the student and supervisor meet to discuss the exercise, provide reflection and feedback and agree on grading. It is acknowledged that such methods of

assessment and feedback are resource intensive and may be challenging to achieve in some schools.

Peer support and parity may be used (Field et al., 2017). When students are trained in dyads, enhanced retention and transfer of skills may be achieved (Wulf et al., 2010). Besides, resources may be used more optimally when peer-assisted learning and reflection methods are used.

Not only theoretical and technical skills should be tested but also the student's professional attitude. This may be included in the assessment of endodontic competencies and behaviour-based learning outcomes, or form part of a broader assessment of generic skills and professional development and include compliance with local regulations on matters such as cross-infection control, radiation protection, record keeping, communication skills and aspects of patient management. To stimulate professional identity formation, encourage feedback-seeking behaviour and for clinical assessment of students' learning and their development, entrustable professional activities (EPAs) may be used (Bremer et al., 2022). The selection of items included in the assessments employed will indicate to students what is considered important. E-portfolios, for example, should thus include markers of professionalism in addition to clinical skills.

## Summative assessment

The competence of students to reach the correct diagnosis and perform vital pulp therapies and root canal treatment on uncomplicated anterior and posterior teeth should be formally assessed before allowing them to graduate. This may take the form of a practical examination, or ideally evidence from the management of a collection of cases (portfolio of completed pre-clinical and clinical work) with accompanying reflective narratives, assessed by teachers against standardized criteria. Formal examination of the other capabilities may be done by standard-set written (in paper and pen or online), practical or oral examinations or the objective assessment of completed pre-clinical or clinical work. Consideration should be given to providing examinations specifically in Endodontology, and students should be given the opportunity to demonstrate their integration of endodontic knowledge and skills within broader summative assessments.

## CAPABILITIES EXPECTED OF A GRADUATING EUROPEAN DENTIST IN ENDODONTOLOGY

The following pages present a list of capabilities that the European Society of Endodontology considers essential

for a graduating dentist in Europe. Capabilities are presented in two domains:

Domain 1: Knowledge of the scientific and evidence base of endodontic practice.

Domain 2: Behaviour-based learning outcomes and competencies for endodontic practice.

2a: Endodontic disease and nonsurgical endodontic treatment.

2b: Post-treatment endodontic disease and surgical endodontic treatment.

Each domain includes a list of major capabilities which is followed by a list of learning outcomes – the elements of the curriculum that will allow students to achieve the desired level of competence. The learning outcomes provided could be broken down by the dental schools into more specific learning outcomes according to their philosophies.

### Domain 1: Knowledge of the scientific and evidence base of endodontic practice

All undergraduates should be adequately grounded in basic and applied science for the safe practice of clinical dentistry (including endodontics). For the safe practice of clinical endodontics, undergraduates should *have knowledge of*:

1 Development, structure, function, physiology and ageing of oral and dental tissues.

2 Anatomy of the head and neck region.

3 Dental anatomy.

4 Pathology of oral and dental diseases of endodontic relevance.

5 Microbiology and immunology of endodontic relevance.

6 General medicine and surgery as applied to the management of dental (including endodontic) patients.

7 Pharmacology and therapeutics as applied to the management of dental (including endodontic) patients.

8 Biomaterials science and adjunct therapies as applied to endodontics.

9 Diagnostic investigations and imaging.

10 Epidemiology, public health measures and biostatistics.

#### *Fundamental learning outcomes:*

In order to meet these capabilities, the dental curriculum should provide learning opportunities for students to be able to:

1 *Have knowledge of the development, structure, function, physiology and ageing of oral and dental tissues:*

1.1 Bony maxilla and mandible.

1.2 Teeth.

1.2.1 Dental hard tissues, including enamel, dentine and cementum.

1.2.2 Dental pulp/dentine complex.

1.3 Tissues adjacent to the teeth, including gingiva, periodontal ligament, alveolar bone and alveolar mucosa. *and be familiar with:*

1.4 The potential of stem cell therapies for tissue repair and regeneration.

2 *Have knowledge of the anatomy of the head and neck region:*

2.1 Gross anatomy of the head and neck.

2.2 Innervation, vascular supply and lymphatic drainage of the teeth, jaws and adjacent structures.

2.3 Communications between the pulp and periodontium.

3 *Have knowledge of dental anatomy:*

3.1 Crown, root and pulp morphology of primary and permanent teeth.

3.2 Morphological changes in response to ageing and disease.

4 *Have knowledge of the pathology of oral and dental diseases of endodontic relevance, including:*

4.1 Dental caries.

4.2 Tooth wear.

4.3 Marginal periodontal disease.

4.4 Cracked and crazed teeth.

4.5 Pulp reactions to caries, trauma, tooth wear, operative procedures and dental materials.

4.6 Mechanisms of dental pain.

4.7 Classification of pulp and periapical conditions.

4.8 Pulpitis.

4.9 Periapical disease of endodontic origin, including localized and spreading infections.

4.10 Dental resorptions, including external cervical resorption, replacement resorption, surface resorption, internal resorption and inflammatory root resorption.

4.11 Pulp–periodontal inter-relationships.

4.12 Odontogenic and nonodontogenic lesions of the jaws.

4.13 Wound healing in dental and oral tissues.

5 *Have knowledge of microbiology and immunology of endodontic relevance:*

5.1 Oral colonization and biofilm formation.

5.2 Dental caries.

5.3 Marginal periodontal disease.

5.4 Ecological niches in the oral environment, including the dental root canal.

5.5 Pulpitis and periapical disease of endodontic origin.

5.6 Cross-infection control, disinfection and sterilization.

*and be familiar with:*

5.7 Microbiological sampling and identification.

6 *Have knowledge of general medicine and surgery as applied to the management of dental (including endodontic) patients:*

6.1 Medical emergencies.

6.2 Oral signs of systemic disease.

6.3 Special considerations for young, elderly and medically compromised patients.

6.4 Systemic effects of oral and specifically endodontic infections.

7 *Have knowledge of pharmacology and therapeutics as applied to the management of dental (including endodontic) patients:*

7.1 Oral and systemic effects of drugs.

7.2 Drug interactions.

7.3 Pharmacological pain management.

7.4 Management of microbial infections.

7.5 Mechanisms and significance of antimicrobial resistance.

7.6 Haemostasis.

7.7 Therapeutic agents in the management of pulp and periradicular disease.

*and be familiar with:*

7.8 Pharmacological anxiety management.

8 *Have knowledge of biomaterials science and adjunct therapies as applied to endodontics:*

8.1 Principles of biocompatibility.

8.2 Materials, and their properties, for use in vital pulp therapies.

8.3 Materials, and their properties, for the production of endodontic instruments.

8.4 Materials, and their properties, for the disinfection and debridement of root canals.

8.5 Materials, and their properties, for root canal filling and repair.

8.6 Materials, and their properties, for the temporization and restoration of root-canal-treated teeth.

8.7 Bonding to dental tissues.

8.8 Principles of ultrasound generation and application.

*and be familiar with:*

8.9 Materials used for tissue regeneration.

8.10 Principles of fluid dynamics, mechanics and activation.

9 *Have knowledge of diagnostic imaging:*

9.1 Principles of X-ray generation for conventional and digital systems.

9.2 Principles of 2D- and 3D-imaging modalities, including cone-beam computerized tomography (CBCT).

9.3 Biological effects of ionizing radiation, principles of radiation hygiene and as low as reasonably achievable (ALARA) guidelines.

9.4 Optimizing image quality, including the use of paralleling devices for intra-oral views.

9.5 Processing and storing diagnostic images.

10 *Have knowledge of epidemiology, public health measures and biostatistics:*

10.1 Community prevalence of dental caries, noncarious tooth loss, dental trauma and pulpal and periradicular disease of endodontic origin.

10.2 Prevention and management of dental caries, noncarious tooth loss, dental trauma and pulpal and periradicular disease of endodontic origin.

10.3 Principles of epidemiology and biostatistics in public health.

## **Domain 2: Behaviour-based learning outcomes and competencies for endodontic practice**

### **2a: Endodontic disease and nonsurgical endodontic treatment**

The undergraduate should *be competent at:*

1 Conducting a detailed general and dental history.

2 Conducting a comprehensive clinical examination of a patient with an endodontic-related problem.

3 Reaching a diagnosis and identifying possible differential diagnosis/—es, including their aetiology.

4 Establishing a treatment plan and communicating this to the patient.

5 Performing procedures to retain all or part of the dental pulp in health.

6 Performing good-quality root canal treatment.

7 Restoring endodontically treated teeth.

8 Monitoring and evaluating the outcome of endodontic treatment.

9 Communicating verbally and in writing with dental and medical colleagues.

The undergraduate should *have knowledge of:*

10 The management of dentoalveolar trauma.



*Learning outcomes that should be 'clinical LO' or could be 'supporting clinical LO':*

In order to meet these capabilities, the curriculum should provide learning opportunities including pre-clinical training and clinical experience for students to be able to:

1 *Conduct a detailed general and dental history:*

1.1 *Be competent at* deriving a clear, concise medical and dental history. [Clinical LO].

1.2 *Be competent at* clarifying points of uncertainty without prejudicing the response. [Clinical LO].

1.3 *Be competent at* keeping legible, accurate and concise clinical notes. [Clinical LO].

2 *Conduct a comprehensive clinical examination of a patient with an endodontic-related problem:*

2.1 *Be competent at* conducting a detailed examination of extra-oral and intra-oral tissues and structures. [Clinical LO].

2.2 *Be competent at* prescribing and conducting a range of diagnostic tests of endodontic relevance, including periodontal probing; assessment of tooth mobility; soft-tissue palpation for tenderness and fluctuance; tenderness to tooth percussion; investigation for cracks by differential cusp wedging, transillumination and staining; occlusal examination; pulp sensitivity testing; sinus tract exploration; selective anaesthesia; examination of jaw muscles; intra-oral radiography, including the use of paralleling devices; and extra-oral radiography. [Clinical LO].

2.3 *Be competent at* identifying endodontic treatment complexity. Case assessment guidelines or tools such as the Endodontic Complexity Assessment Tool (Essam et al., 2021), Nordic Endodontic Assessment Form (Haug et al., 2023), EndoApp (Shah & Chong, 2018), the Dutch Endodontic Treatment Index (Ree et al., 2003) and the American Association of Endodontists Endodontic Case Difficulty Assessment Form and Guidelines (2010) may provide a helpful framework for structured patient evaluation, and the identification of clinical challenges. [Supporting Clinical LO].

2.4 *Have knowledge of* orofacial pain conditions, including both odontogenic and nonodontogenic pain conditions. [Supporting Clinical LO].

3 *Reach a diagnosis and identify possible differential diagnosis/—es, including their aetiology:*

3.1 *Be competent at* interpreting the outcomes of the entire investigation, including history, clinical examination, diagnostic tests and radiographic examination. [Supporting Clinical LO].

3.2 *Be competent at* recognizing the symptoms and signs of common pulpal and periradicular conditions. [Supporting Clinical LO].

3.3 *Have knowledge of* conditions that may mimic pulp and periradicular disease of endodontic origin, and how to exclude them. [Supporting Clinical LO].

4 *Establish a treatment plan and communicate this to the patient:*

4.1 *Be competent at* prioritizing endodontic interventions. [Supporting Clinical LO].

4.2 *Be competent at* communicating the principles and practice of preventing pulpal and periradicular disease. [Supporting Clinical LO].

4.3 *Be competent at* communicating with patients to describe management options, and their potential benefits, risks and likely outcomes. [Clinical LO].

4.4 *Be competent at* securing informed consent for treatment. [Supporting Clinical LO].

4.5 *Be competent at* identifying personal limitations of experience and expertise in the management of endodontic care, and acting appropriately in the interest of the patient. [Clinical LO].

4.6 *Have knowledge of* conditions and complexities that may warrant referral to a medical or dental specialist. [Supporting Clinical LO].

5 *Perform procedures to retain all or part of the dental pulp in health:*

5.1 *Be competent at* managing the clinical environment for infection control, including the disinfection of cabinetry and equipment surfaces, the sterilization of instruments, zoning and the use of appropriate barrier techniques. [Clinical LO].

5.2 *Be competent at* performing topical, local infiltration and regional dental local anaesthesia for the management of vital pulp procedures. [Clinical LO].

5.3 *Be competent at* tooth isolation, including the use of dental dam. [Clinical LO].

5.4 *Be competent at* managing dental caries for disease control and pulp survival. [Clinical LO].

5.5 *Be competent at* preserving vital pulp functions by the implementation of vital pulp therapies, including indirect pulp capping, direct pulp capping, partial pulpotomy and full pulpotomy. [Clinical LO].

5.6 *Be competent at* providing appropriate postoperative instructions on mouth care and the management of postoperative pain. [Supporting Clinical LO].

5.7 *Have knowledge of* the benefits and use of magnification and enhanced illumination in endodontic practice. [Supporting Clinical LO].

5.8 *Have knowledge of* the management of teeth with cracks. [Supporting Clinical LO].

5.9 *Have knowledge of* the principles and practices of managing pulp and periradicular disease in primary and immature permanent teeth, including pulp capping,

pulpotomy, continued root development (apexogenesis), root-end closure (apexification) and pulp revascularization/regenerative procedures. [Supporting Clinical LO].

*6 Perform good-quality root canal treatment:*

6.1 *Be competent at* managing the clinical environment for infection control, including the disinfection of cabinetry and equipment surfaces, the sterilization of instruments, zoning and the use of appropriate barrier techniques. [Clinical LO].

6.2 *Be competent at* performing topical, local infiltration and regional local anaesthesia for the management of pulp and periradicular pain. [Clinical LO].

6.3 *Be competent at* performing dental dam isolation for endodontic purposes. [Clinical LO].

6.4 *Be competent at* accessing the pulp chamber and identifying canal orifices for effective treatment without unnecessary dentine removal in uncomplicated anterior and posterior teeth. [Clinical LO].

6.5 *Be competent at* negotiating uncomplicated root canals and securing a working length by radiographic and electronic means. [Clinical LO].

6.6 *Be competent at* securing angulated but undistorted intraoral radiographs from which lengths can be calibrated or controlled during root canal treatment. [Clinical LO].

6.7 *Be competent at* shaping root canals without procedural error and with length control in uncomplicated anterior and posterior teeth. [Clinical LO].

6.8 *Be competent at* irrigating root canals for the elimination of microorganisms and organic and inorganic materials. [Clinical LO].

6.9 *Be competent at* medicating root canals for the control of microbial infection. [Clinical LO].

6.10 *Be competent at* filling the root canals of uncomplicated anterior and posterior teeth, densely and with length control. [Clinical LO].

6.11 *Be competent at* securely temporizing teeth during and after root canal treatment. [Clinical LO].

6.12 *Be competent at* providing appropriate postoperative instructions on mouth care and the management of postoperative pain and swelling. [Supporting Clinical LO].

6.13 *Have knowledge of* the benefits and use of magnification and enhanced illumination in endodontic practice. [Supporting Clinical LO].

6.14 *Have knowledge of* the removal of restorations such as crowns and core build-ups for endodontic access. [Supporting Clinical LO].

6.15 *Have knowledge of* different techniques for access cavity preparation. [Supporting Clinical LO].

6.16 *Have knowledge of* techniques to manage natural impediments to access, such as secondary and tertiary dentine, and pulp stones. [Supporting Clinical LO].

6.17 *Have knowledge of* different techniques for shaping root canals. [Supporting Clinical LO].

6.18 *Have knowledge of* common procedural errors during the instrumentation of root canals, including ledges, fractured instruments and root perforations; their prevention and management. [Supporting Clinical LO].

6.19 *Have knowledge of* different techniques for filling root canals. [Supporting Clinical LO].

6.20 *Have knowledge of* the management of endodontic emergencies, including symptomatic reversible pulpitis, symptomatic irreversible pulpitis, symptomatic apical periodontitis, acute apical abscess (including mid-treatment 'flare-ups'), extrusion accidents and cracked/fractured teeth. [Supporting Clinical LO].

6.21 *Have knowledge of* materials and methods for the removal of root canal filling materials. [Supporting Clinical LO].

6.22 *Have knowledge of* supplementary agents and methods for the management of intra-operative pulpal and periradicular pain. [Supporting Clinical LO].

6.23 *Have knowledge of* methods of enhancing irrigant action, including the use of ultrasound. [Supporting Clinical LO].

6.24 *Be familiar with* techniques for the removal of foreign bodies such as fractured instruments and posts from root canals. [Supporting Clinical LO].

*7 Restore endodontically treated teeth:*

7.1 *Be competent at* restoring endodontically treated teeth to function and aesthetics using intracoronary and extracoronary restorations, including provisional restorations, permanent direct restorations, posts, core build-ups, onlays and crowns. [Clinical LO].

7.2 *Have knowledge of* adjunctive treatments for the restoration of endodontically treated teeth, including surgical crown lengthening and orthodontic forced eruption. [Supporting Clinical LO].

7.3 *Have knowledge of* bleaching procedures to restore the aesthetics of discoloured endodontically treated teeth. [Supporting Clinical LO].

*8 Monitor and evaluate the outcome of endodontic treatment:*

8.1 *Be competent at* prescribing monitoring plans for endodontic patients. [Supporting Clinical LO].

8.2 *Be competent at* identifying patient-reported symptoms that may indicate the presence of post-treatment endodontic disease. [Supporting Clinical LO].

8.3 *Be competent at* conducting a dental history to elucidate symptoms and clinical signs of post-treatment endodontic disease. [Supporting Clinical LO].

8.4 *Be competent at* prescribing, conducting and interpreting the results of investigations for post-treatment disease, including responses to pulp sensitivity testing, tenderness to percussion or palpation, presence of a soft-tissue swelling, presence of a sinus tract or locally deep periodontal probing defect, increased tooth mobility, radiographic signs of static or expanding periapical lesions, radiographic signs of root fracture or resorption. [Clinical LO].

9 *Communicate verbally and in writing with dental and medical colleagues:*

9.1 *Be competent at* keeping clear, concise and contemporaneous clinical records. [Clinical LO].

9.2 *Be competent at* effectively presenting the details of a previously examined patient to a colleague for case discussion. [Supporting Clinical LO].

9.3 *Be competent at* making a formal referral letter to a medical or dental colleague. [Supporting Clinical LO].

9.4 *Have knowledge of* dental and medical specialists who may be able to provide advice during the assessment and treatment of endodontic patients. [Supporting Clinical LO].

10 *The management of dentoalveolar trauma:*

10.1 *Have knowledge of* the prevention of dental trauma, especially during sporting pursuits. [Supporting Clinical LO].

10.2 *Have knowledge of* the principles and practice of managing dentoalveolar trauma, including crown fractures, crown-root fractures, root fractures, luxation injuries and avulsions. [Supporting Clinical LO].

10.3 *Have knowledge of* the principles of emergency trauma management, splinting protocols and recommended follow-up regimes. [Supporting Clinical LO].

10.4 *Have knowledge of* a range of possible complications after dentoalveolar trauma, including obliteration and the several types of resorptions, their implications and potential treatment options. [Supporting Clinical LO].

## 2b: Post-treatment endodontic disease and surgical endodontic treatment

The undergraduate should *be competent at*:

1 Conducting a detailed general and dental history for a patient with post-treatment endodontic disease.

2 Conducting a comprehensive clinical examination of a patient with post-treatment endodontic disease.

3 Reaching a diagnosis and identifying possible differential diagnosis/—es, including their aetiology, and presenting treatment options for the management of post-treatment endodontic disease.

The undergraduate should *have knowledge of*:

4 Recognizing conditions that may best be managed by surgical endodontic treatment.

5 Assessing the benefits, risks and likely outcome of endodontic surgery.

6 Postoperative monitoring of surgical endodontic patients.

*Supporting clinical learning outcomes:*

In order to meet these capabilities, the curriculum should provide learning opportunities for students to be able to:

1 *Conduct a detailed general and dental history for a patient with post-treatment endodontic disease:*

1.1 *Be competent at* deriving a clear, concise medical and dental history.

1.2 *Be competent at* clarifying points of uncertainty without prejudicing the response.

1.3 *Be competent at* keeping legible, accurate and concise clinical notes.

2 *Conduct a comprehensive clinical examination of a patient with post-treatment endodontic disease:*

2.1 *Be competent at* conducting a detailed examination of extra-oral and intra-oral tissues and structures.

2.2 *Be competent at* prescribing and conducting a range of diagnostic tests of relevance to the diagnosis of post-treatment endodontic disease, including pulp sensitivity testing; periodontal probing; assessment of tooth mobility; soft-tissue palpation for tenderness and fluctuance; tenderness to tooth percussion; investigation for cracks by differential cusp wedging, transillumination and staining; occlusal examination; sinus tract exploration; selective anaesthesia; examination of jaw muscles; intra-oral radiography, including the use of paralleling devices and extra-oral radiography.

2.3 *Be competent at* identifying signs of post-treatment endodontic disease.

2.4 *Have knowledge of* orofacial pain conditions.

3 *Reach a diagnosis and identify possible differential diagnosis/—es, including their aetiology, and present treatment options for the management of post-treatment endodontic disease:*

3.1 *Be competent at* interpreting the outcomes of the entire investigation, including history, clinical examination, diagnostic tests and radiographic examination in the diagnosis of post-treatment endodontic disease.

3.2 *Be competent at* presenting treatment options to patients with post-treatment endodontic disease.

3.3 *Have knowledge of conditions that may mimic pulp and periradicular disease of endodontic origin in endodontically treated teeth and the principles of how to identify them.*

3.4 *Have knowledge of benefits and potential risks of 3D imaging in assessment and treatment planning for post-treatment endodontic disease.*

3.5 *Have knowledge of management options for patients with post-treatment endodontic disease, including continued monitoring, root canal treatment, nonsurgical retreatment, surgical endodontic treatment and extraction with or without prosthetic (including implant-supported) restoration.*

3.6 *Have knowledge of outcome data for a range of conditions including vital pulp therapies, root canal treatment, nonsurgical endodontic retreatment, surgical endodontic treatment, implant-supported prostheses and conventional and resin-bonded bridge work.*

3.7 *Be familiar with implant surgical procedures and their limitations.*

4 *Recognize conditions that may best be managed by surgical endodontic treatment:*

4.1 *Have knowledge of the indications for surgical endodontic procedures including periradicular surgery, external cervical resorption repair, intentional replantation, autotransplantation, perforation repair, crown lengthening, regenerative procedures, tooth hemi-section, root resection and decoronation.*

4.2 *Have knowledge of the principles of microsurgical endodontics, including perisurgical care, infection control, magnification and illumination, pain and anxiety control, flap design and elevation, osteotomy, periradicular curettage, haemostasis, root-end resection (apicectomy), minimally invasive root-end preparation and filling, the properties of various root-end filling and perforation repair materials, suturing, and postoperative wound care.*

4.3 *Have knowledge of the general care of surgical patients.*

4.4 *Have knowledge of systemic conditions that may complicate oral surgical procedures.*

4.5 *Have knowledge of the indication for and procedure of incision and drainage.*

4.6 *Be familiar with a range of surgical endodontic procedures, ideally by observation or direct assistance, including exploratory endodontic surgery (e.g. for the diagnosis of root fractures or perforations), planned extraction and replantation, hemi-section, root amputation, surgical perforation repair, apicectomy and root-end filling.*

4.7 *Be familiar with adjunctive surgical procedures, including guided bone regeneration.*

5 *Assess the benefits, risks and likely outcome of endodontic surgery:*

5.1 *Have knowledge of common risks associated with surgical (including endodontic surgical) procedures and how they are managed.*

5.2 *Have knowledge of outcome data for surgical endodontic procedures.*

6 *Postoperative monitoring of surgical endodontic patients:*

6.1 *Have knowledge of the postoperative care and monitoring of surgical (including endodontic surgical) patients.*

6.2 *Have knowledge of the management of post-surgical complications including pain, swelling, haemorrhage and infection.*

6.3 *Have knowledge of when referral to a specialist may be indicated.*

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All authors contributed considerably to this work.

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The authors have no conflict of interest to declare.

## DATA AVAILABILITY STATEMENT

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## ETHICS STATEMENT

This work is in full accordance with ethical principles.

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