

White Paper on Endodontic Care

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Executive summary

This white paper summarizes the main issues currently affecting the provision of endodontic care. It provides a reference and tool for dentists, national dental associations and other oral health actors, outlining what endodontics is, why it is important and what can be done to improve endodontic outcomes and health.

The first section outlines the scope of endodontics, describing the aetiology of endodontic conditions and how changes to the pulp and periapical tissue determine current endodontic diagnoses (Sections 1.1 and 1.2). It then discusses why endodontic conditions are important and addresses the prevalence and burden of endodontic disease. Untreated endodontic conditions can have a significant impact on quality of life, particularly through craniofacial pain, the inability to chew, and disturbed sleep. The potential connections between endodontic disease and overall health, and their implications for the importance of endodontic care, are also considered (Section 1.3). Section 1 concludes with an overview of endodontic prevention and treatment. The measures that can be taken inside and outside the dental practice to prevent pulpal and periapical disease are discussed, followed by a summary of endodontic procedures to treat disease when it manifests, including their indications and objectives. While this summary describes the scope of endodontic treatment from regenerative and reparative procedures to surgical endodontics, the standard of endodontic care varies worldwide according to a variety of contextual factors, as discussed at the end of this section (Section 1.4).

Section 2 addresses the current challenges faced in providing endodontic care and maintaining health. Most quality criteria and treatment outcome measures have historically focused on technical goals and clinical symptoms after treatment. The development of more patient-centred outcomes, such as those focused on teeth retention, quality of life, and overall health, can ensure that endodontic care addresses and is measured against a broader spectrum of health outcomes as valued by the patient (Section 2.1). Beyond measurement, a range of contextual challenges exist to achieving and maintaining these outcomes. They include challenges related to health systems, regulation of oral health care, dental education, the availability of resources, and patient perceptions of endodontic procedures (Section 2.3).

The third section of this white paper builds on the challenges identified and discusses ways in which they could be tackled to improve and maintain endodontic health. While the appropriate strategies to work towards this goal vary considerably according to national context, some general principles and possible solutions are discussed (Section 3.1). The paper concludes with a call to action, inciting stakeholders to work towards the accessibility and provision of optimal endodontic care and improved endodontic health worldwide (Section 3.2).

Section 1 Definitions, Scope and Relevance of Endodontics and Endodontic Health

1.1 What is endodontics?

According to the glossary of the American Association of Endodontists¹, endodontic therapy relates to “the aetiology, diagnosis, prevention and treatment of diseases and injuries of the pulp and associated periradicular conditions”. According to Ørstavik and Pitt Ford², the biological aim of endodontic therapy is to “either prevent or cure apical periodontitis”. The most frequent cause of pulpal and periapical disease is deep dental decay (caries)³; however, dento-alveolar trauma and certain periodontal conditions and their respective sequelae may also lead to endodontic disease. The scope of endodontic treatment includes regenerative procedures and dental traumatology to prevent microbial entry and subsequent host defence effects. Importantly, it is vital pulp therapy, an occasionally overlooked area of endodontic treatment, that is likely to address patient needs on a global scale. This should include screening for pulpal status as a routine diagnostic step.

Endodontic societies and textbooks suggest certain quality criteria and competencies^{4,5}. Historically, these criteria have focused on technical goals, such as the appropriate working lengths, effectiveness of irrigation, and root canal filling quality; in most cases, these criteria apply to a best-case scenario where both patients and providers have access to unlimited resources. In contrast, basic root canal treatment (BRT) has been described as effective and comparable to standard endodontic treatment^{6,7}.

Primary clinical goals of eliminating pain and infection notwithstanding, the long-term goal of endodontic treatment is the preservation of a natural dentition, including oral function and oral health. Consequently, endodontic health may be defined as the absence of any clinical and sub-clinical symptoms, while retaining all dental functions required for oral health⁸.

1.2 Aetiology and disease: why do we perform endodontic treatment

The first line of defence in endodontic therapy is prevention of dental decay. This recognizes that dental caries and its associated microbiota, if not removed before pulpal disease becomes irreversible^{3,9}, lead to changes in pulpal microcirculation. Consequently, the process may become unstoppable, as the local absence of blood supply allows further and deeper entry of pathogens into the root canal system. Predominantly gram (-) flora and their cell wall components, e.g. lipopolysaccharides or LPS, then drive periapical bone resorption, and apical periodontitis is ultimately established^{2,10}. This process may occur with or without clinical symptoms, both at the pulpal and the periapical disease stage, due to the on-going, but variable, level of interplay between irritants and host defence¹⁰.

Dental trauma may, in the case of deep crown fractures, give oral microorganisms direct access to the pulp space. In case of luxation-type injuries, the blood supply is compromised or lost at the level of entry into the pulp and, subsequently, the dental pulp becomes necrotic. When secondarily infected, this avascular pulp space is also associated with apical periodontitis.

Pulpal changes are often detected indirectly via patients' responses to thermal or electric stimuli, while changes in periapical bone are visible only in radiographs. The diagnostic efficacy of conventional pulp testing is about 80% or higher¹¹; however, the inability to detect asymptomatic cases of pulpal disease and the lack of correlation between disease severity and test outcomes are significant shortcomings of current pulp tests.

Periapical changes may be detected via pain on percussion or palpation, while changes in bone

mineralization are historically visualized in periapical radiographs. More recently, cone beam tomography has been introduced into endodontic practice in some countries¹². While this technology can detect three-dimensional bone content, and therefore is more accurate in showing apical changes, it does not determine the degree of inflammation and infection and requires sequential imaging to assess healing trends.

Through determining pulpal and periapical conditions, typical endodontic diagnoses are developed in the clinical setting. The current and widely-adopted terminology was established at the AAE Consensus Conference in 2009^{13,14} and is used unaltered today¹. As indicated in *Table 1*, an endodontic diagnosis in the current system is a dual diagnosis, with a description of pulpal and apical conditions, respectively. Treatment modalities have been developed to address acute and chronic disease conditions.

TABLE 1 Current diagnostic terms describing pulpal and periapical diseases

Diagnosis	Sensitivity	Pain	Radiolucency	Sinus tract
Healthy pulp	yes	no	no	no
Reversible pulpitis	yes	yes/no	no	no
Irreversible pulpitis	yes	yes/no	no	no
Condensing osteitis	yes	no	radiopacity	no
Necrosis	no	no	no	no
Symptomatic apical periodontitis	no	yes	yes/no	no
Asymptomatic apical periodontitis	no	no	yes	no
Acute apical abscess	no	yes	yes/no	no
Chronic apical abscess	no	no	yes	yes/no

Adapted from 'Arens DE, Gluskin AH, Peters CI, Peters OA. *Practical lessons in endodontic treatment*. Chicago: Quintessence Publishing; 2009.'

It is important to note that these current diagnostic terms, while of superior utility in the current dental practice model, focus primarily on local conditions and do not include any oral health terminology. In this regard, current concepts address a patient's condition along the triad of disease, illness and sickness¹⁵ and should in the future address potential and actual connections between endodontic conditions and oral and overall health^{16,17}. They also have other shortcomings, such as lacking a clear definition of what biologically separates reversible from irreversible pulpitis.

1.3 Importance of endodontic health for general health and epidemiology

About 4 billion people were, in 2013, reportedly afflicted with oral diseases, with untreated caries accounting for 35% of the cases and more than 65% of the individuals¹⁸. The high prevalence and the recurrent nature of dental caries, as well as periodontal disease, result in direct annual costs of US\$102 billion in the United States alone¹⁹ and an estimated US\$300 billion worldwide²⁰. Moreover, there is growing inequality in oral health between and within countries²¹⁻²³.

Pulpal disease is frequent, with estimates of the proportion of people affected ranging from 16.4%²⁴ to more than 30%²⁵; however, irreversible pulpitis may not be painful, and therefore undetected, in up to 40% of cases²⁶. For people who receive regular dental care, emergency visits for endodontic treatment appear to be relatively low, with an incidence of 5–14%²⁷. On the other hand, the overall burden of often asymptomatic apical periodontitis is believed to affect 40–50% of individuals, increasing with age and the number of root canal-treated teeth²⁸. As dental caries is highly prevalent in developing countries with access to sugary food, the estimated need for dental treatment of pulpal pain is also high and often results in extractions. No current figures are available regarding worldwide needs for endodontic treatment due to trauma, but it has been estimated to affect up to 1 billion people²⁹.

The impact of unmet endodontic treatment needs on Quality of Life (QoL) is obvious and substantial, specifically when QoL is impacted by craniofacial pain and the inability to sleep. Liu and colleagues³⁰ estimate that patients requiring more extensive endodontic care are more likely to have poorer oral health-related QoL, with endodontic treatment leading to improved QoL^{30,31}. In those studies, QoL is measured by versions of the Oral Health Impact Profile (OHIP), which assesses self-reported dysfunction, discomfort, and disability.

Endodontic disease is distinctly different from “focal infection”^{32,33}. The focal infection theory held that bacteria concealed in portions of a treated root canal system could somehow escape and lodge in distal organs, causing, for example, arthritis and diseases of the kidney, heart, nervous, gastrointestinal, endocrine and other organ systems. It was believed, but never proven, that the extraction of root canal-treated teeth would heal systemic diseases. The focal infection theory, as the basis for wholesale tooth extraction, was widely discredited in the 1950s with the advent of controlled laboratory and clinical studies in endodontology. Moreover, it became clear that the removal of teeth or tonsils, which were also suggested as a potential source of harmful bacteria, did not eliminate diseases that had been thought to be caused by focal infection.

On the other hand, possible connections between oral disease and overall health have been increasingly studied in the last two decades. In periodontics, there have been reports of associations between active periodontal inflammation and significant health problems, such as cardiovascular disease. Recent studies have shown the relationship between tooth loss, the associated lacking masticatory function, and the development of different types of cancer and mental disease³⁴⁻³⁷. Conversely, research shows that chewing may help improve cognitive function and be beneficial to Parkinson’s disease patients³⁷. It must be mentioned that association and a cause-and-effect relationship are systematically different, and the latter has not yet been demonstrated. Nevertheless, it has been suggested, similar to the term “periodontal medicine”, to establish “endodontic medicine”, accounting for the fact

that diseases of the pulp and periapical tissues are occurring in a larger context – within the human body. On this matter, there are known systemic diseases and conditions, such as diabetes or systemic immunosuppression, that harm endodontic outcomes and can result in specific endodontic entities, such as acute abscesses, that reduce overall health.

1.4 Endodontic treatment and prevention of disease/trauma

Prevention of pulpal and periapical disease addresses their most common causes, which are dental caries and trauma. Primary and secondary prevention of dental caries are required to stop progression to the pulp and onset of pulpal disease. Population-level approaches, such as community water fluoridation and sugar-reduction policies, as well as individual-level interventions in the clinic, are needed to advance primary dental caries prevention^{38,39}. Clinical measures include nutrition and hydration counselling, oral hygiene education, and professionally applied gels, varnishes and sealants. Even when dental caries manifests in a patient, secondary prevention measures can arrest and regress the process, preventing its progression to the pulp and the need for endodontic treatment. Many of the strategies for primary prevention are applicable to secondary prevention if dental caries is diagnosed early and lesion activity is adequately assessed^{3,40}.

Improving the safety of the environment is the most important aspect of oral trauma prevention. Policies to improve road safety, reduce violence in the home and school, and increase the use of adequate helmets, facemasks and mouth guards in certain sports are good examples of ways in which oral trauma can be prevented³⁹.

1.4.1 Scope of treatment: Regenerative/reparative procedures

Vital pulp therapy offers significant benefits if microorganisms’ access to the pulp is limited in amount, virulence, and time⁴¹. Conversely, when the

pulp is necrotic, regenerative procedures may be selected to treat periapical disease and manage root growth. The following table illustrates principal

avenues of endodontic treatment aimed to retain or repair a functional pulp.

TABLE 2 Retention or repair of a functional pulp

	Pulp capping	Pulpotomy apexogenesis	Guided pulpal repair
Indications	Deep carious lesions near viable pulp (indirect pulp capping) or pulp exposure through non-infected dentine (direct pulp capping)	Coronal pulp sections are irreversibly inflamed or infected, and preservation of pulp vitality is desired	Immature teeth with necrotic pulps in which additional growth in root wall thickness and length is desired
Objective	Protect vital pulp from additional injury and allow healing and repair	As a definitive procedure, maintain the vitality of the radicular pulp when the coronal pulp is exposed or diseased, or alleviate symptoms of pulpal disease as an interim procedure	Promote healing of apical periodontitis and retain a functional dentition, ideally restore structure, including dentin and root wall, as well as cells of the pulp-dentin complex
Main procedure	Removal of caries from the tooth and treatment of the remaining dentine or application of biocompatible material on the exposed pulp	Surgical removal of the coronal pulp and capping of the radicular pulp at the appropriate level	Canal debridement and disinfection, eliciting of apical bleeding with ingress of stem cells and mediators as well as formation of scaffold to promote continued hard tissue formation in the canal space

1.4.2 Scope of treatment: Non-surgical root canal treatment

If dental caries progresses to affect the pulp beyond the point of possible repair, non-surgical endodontic

therapy is required to retain the affected tooth. The extent of the therapy is dependent on the level of progression and vitality of the pulp. The table below illustrates the principal treatment spectrum in root canal treatment.

TABLE 3 Removal of diseased pulp

	Apexification	Root canal treatment	Root canal retreatment
Indications	Teeth with immature root development and a necrotic pulp, in which an apical hard tissue barrier is desired	Irreversible pulpitis or necrotic pulp, cracked or fractured teeth with significant pulpal involvement, or as elective treatment	Continued periradicular disease or symptoms due to failure of a previous root canal treatment
Objective	Management of cases with wide root canals and immature apical foramina that require root canal treatment	Eliminate pulpal and periradicular disease, and promote healing of the periradicular tissue	Eliminate pulpal and periradicular disease, and promote healing of the periradicular tissue
Main procedure	Canal debridement and long-term disinfection with medication, allowing for hard tissue deposition or placement of apical plug with biocompatible material	Mechanical debridement of the canal system, followed by shaping, irrigation, and filling	Removal of existing canal filling material, complete mechanical debridement of the canal system, followed by shaping, irrigation, and filling

1.4.3 Scope of treatment: Surgical endodontics

Some presentations of pulpal and periapical disease cannot be treated using non-surgical interventions and require surgery to alleviate pathosis and prevent

further damage. Dental trauma often requires endodontic treatment to resolve or prevent pulpal or periapical disease. The treatment given will depend on the type of injury. The following table illustrates examples of surgical endodontic treatment.

TABLE 4 Endodontic surgery and treatment of the traumatized dentition

	Incision and drainage/ trephination	Apical surgery	Resective therapy	Treatment of traumatized teeth
Indications	Accumulation of fluid in soft or hard tissues that cannot be accessed through the root canal	Periradicular disease that cannot be addressed through root canal therapy or endodontic retreatment, or overextension of a root filling	Periradicular disease or root defects that cannot be treated with root canal therapy or apical surgery, periodontal defects, or crown and vertical root fractures	Traumatic events, such as crown/root fractures, luxations and avulsions and alveolar fractures
Objective	Reduce fluctuant swelling of soft tissue, promote repair of affected tissue, and prevent damage to teeth and other structures	Treat pathosis in the radicular pulp and periradicular tissue and prevent further progression	Alleviate periradicular disease or canal and/or coronal defects; alleviate signs and symptoms of crown and/or root fracture	Successfully reposition a tooth that has been displaced from its socket, achieving re-attachment of periodontal ligament fibres to retain function; promote root development in immature teeth
Main procedure	Opening of the soft or hard tissue to remove accumulated fluid, using a drain if necessary	Removal of diseased periapical tissue, resection and retrograde filling of root sections that cannot be treated through root canal therapy, or intentional replantation of teeth that cannot be treated with conventional endodontic surgery	Surgical removal of one or more roots, or one or more roots and a portion of the crown, of a multi-rooted tooth	Pulpal management, repositioning and splinting as appropriate; use of conditioning media and medications and to include follow-up

1.4.4 Potential contraindications for endodontic treatment

Lack of patient compliance, insufficient periodontal support, impossibility of a functional long-term restoration, and a severely compromised patient medical history are potential contraindications for endodontic treatment. However, the large majority of the national or regional guidelines do not contain any restrictions for endodontic therapy^{5,42}. Prosthetic or implant/prosthetic rehabilitation options exist for “hopeless teeth” but the utility of that approach has also been questioned^{43,44}.

1.4.5 Standard of treatment: a response to global quality needs

The standard of endodontic treatment depends on a multitude of criteria, such as being sensitive to the operator, the patient, technique, technology, and the working environment. Endodontic societies and health ministries of different countries have drawn-up treatment guidelines, many of them being technique- and technology-oriented and sometimes not revised in a timely manner. The treatment benefits of the latest technology and techniques, which often require high investment costs and

are found in high-end practice settings, may not be essential when considering the outcomes of basic root canal treatment (BRT), a technique based on simple instrumentation, tactile working length determination, and the independence of an electrical power supply, which can be easily performed in the most remote settings.

As discussed below, fee-for-service schemes are not a reliable way of remunerating the treatment options with the best outcomes for patient health. Favouring

better compensated, but less effective, procedures also goes against the standard of professional ethics⁴⁵. The only essential standard criteria to be applied worldwide should be the best achievable quality of care and the guarantee of patient safety⁴⁶. The keys to ensuring these minimum standards are adequate undergraduate education and lifelong learning. Any definition of treatment standards should go hand in hand with a standard of prevention⁴⁷.

Section 2 The Challenges of Endodontics and Maintaining Health

2.1 What are the overarching outcomes of endodontic care?

In early disease stages, the main treatment goal is to retain a vital and functional pulp. This can be achieved with high likelihood, depending on diagnosis and operative strategies⁴⁸⁻⁵⁰.

As discussed before, root canal therapy has been defined as treating or preventing apical periodontitis. Consequently, outcomes of root canal treatments have historically been described primarily in relation to apical conditions (as judged from radiographs) and clinical symptoms after treatment. Using this paradigm and criteria of varying stringency, the prognosis of root canal treatment was found to vary greatly among all included studies in a systematic review by Friedman, with 46–91% of cases healed⁵¹.

More recently, the variable “retention” has gained attention in relation to root canal treatment. Indeed, Kvist⁵² has argued that the need to save teeth is a significant challenge going forward due to an increase in populations being affected by dental caries. The variable “retention” is an example of patient-centred outcomes⁵³⁻⁵⁵ that are now being used to describe the efficacy of endodontic therapy.

In essence, endodontic therapy, when seen from a patient’s perspective, has the following goals:

- i. to cure or prevent pain,
- ii. to retain the function of the affected tooth over the long-term, and
- iii. to prevent negative consequences to overall health.

Root canal treatment is often initiated when dental caries has led to pulpal disease and pain⁵⁶, and the treatment is typically very effective in eliminating pain in a short timeframe⁵⁷. Moreover, the likelihood

of significant exacerbations over the long term is comparatively low, being around 5%⁵⁸.

When root canal treatment is followed by appropriate restorative treatment, long-term teeth retention rates of 80–90% after 10 or more years of function have been reported for root canal-treated teeth⁵⁹⁻⁶². However, it is important to consider that vital teeth have a better long-term retention rate than root canal-treated ones⁵⁹, suggesting the potential for vital pulp therapy to enhance overall endodontic outcomes⁹.

On the other hand, apical periodontitis remains a prevalent health issue⁶³, with the current definition of *endodontic medicine* considering potential effects of systemic diseases on the outcome of root canal treatment¹⁶. However, much is still to be learned about the relationship between persistent apical inflammation and overall health⁵².

While there is no evidence that persistent apical periodontitis directly causes, for example, coronary heart disease, it may be argued that a strategy preventing microorganisms from establishing themselves deep in the root canal system would be advantageous⁶⁴. This approach would call for a renewed focus on pulpal diagnosis and early intervention to retain pulp vitality⁴⁸.

Patient-centred outcomes, most notably measurements of oral health⁸ and related quality of life, are served by the endodontic treatment spectrum, from vital pulp therapy to apical surgery.

Endodontic therapy that is driven by patient-centred outcomes focuses on the absence of symptoms, retained oral function, and limited impact on overall health. This kind endodontic therapy is an example of a multifaceted approach to oral health.

2.2 What are the specific challenges to achieving and maintaining optimal endodontic outcomes?

Despite the global importance of endodontic health, there are many barriers to achieving and maintaining optimal endodontic outcomes. These barriers exist at multiple levels, ranging from national policy to the dental practice, and concern diverse sectors, including health system organization and financing, dental education, and the dental industry. Challenges vary considerably by country, and potential strategies and solutions for addressing them, as discussed below, must be appropriate within the national context. National dental associations (NDAs), governments, and other actors have independence and primacy in determining the strategies and policies to pursue improved care and oral health in their countries.

To identify and better understand the challenges related to achieving optimal endodontic care, FDI conducted a survey and Political, Economic, Social, Technological, Environmental and Legal (PESTEL) survey exercise among its member NDAs and national endodontic societies. The exercise is used to identify the major challenges and potential solutions to a given problem across several domains and rank their relative importance. In total, 63 NDAs and endodontic societies completed the exercise from all five FDI regions. The sub-sections below outline the major challenges identified through the exercise and in the published literature.

2.2.1 Political commitment and financing challenges

A lack of political commitment to oral health and an absence of policies to strengthen oral disease prevention and care provision can act as barriers to optimal endodontic care. While the importance of oral health on the political agenda varied among the countries responding to the NDA survey, many indicated that the lack of national oral health policies, or low importance being placed on oral health in national health policies, presents

a challenge. The reasons for political neglect are complex but well-recognized challenges include a failure to coordinate multisectoral action to implement population-level prevention approaches, disconnect between oral health and general health, including in the measurement of the oral disease burden, and a lack of political leadership and civil society activism^{39,65,66}. In addition, neglect of oral health within health systems and public health strategies is typically coupled with low financing, resulting in inadequate reimbursement and remuneration of endodontic procedures as discussed below.

2.2.2 Reimbursement and remuneration

In many countries, particularly in low-resource settings, the dental procedures covered by health authorities or insurers are limited, resulting in foregone treatment and inequitable access^{67,68}. Evidence from several high-income countries similarly suggests that out-of-pocket payments and public health insurance programmes with restricted eligibility and limited benefit packages act as barriers to dental treatment, particularly for low-income populations⁶⁹⁻⁷³. Of the NDAs who responded to the FDI survey, nearly half reported lack of reimbursement of endodontic procedures as a challenge to providing optimal endodontic care. In many instances, endodontic treatment is subject to partial or no reimbursement and is available only to those who have access to insurance or who can afford out-of-pocket payments. Depending on the system, financial aid for endodontic treatment may only be available for very low-income groups or children. Several countries, including both high- and low-income countries, reported that patients opt to have teeth extracted rather than undergo endodontic treatment due to high costs.

Surveys of dentists in several countries have also revealed insufficient remuneration to be a commonly cited reason for non-compliance with endodontic treatment standards⁷⁴⁻⁷⁶. Dentists may opt to extract teeth rather than perform endodontic restoration if remuneration for endodontic treatment is perceived to be too low^{40,77}. Root canal treatments by National Health Service dentists in the UK fell by over 45%, with extractions increasing in parallel, following

remuneration changes in 2006^{78,79}. Remuneration systems also have implications for the prevention of pulpal disease, with only a few systems adequately incentivizing preventive practice⁴⁰. Twenty percent of NDAs in the FDI survey reported that low remuneration levels, particularly in view of the time taken to complete endodontic procedures, were a barrier to optimal care.

2.2.3 Challenges related to the patient and society

Patient perceptions of endodontic treatment can result in avoidance of treatment and difficulties in carrying out procedures. Fear of visiting the dentist may cause patients to delay dental visits until their problems are severe^{80,81}. Several studies have suggested that root canal treatment provokes particularly strong dental anxiety due to the expectation of pain during and after the procedure⁸²⁻⁸⁴. Over 20% of NDAs identified negative patient perceptions, especially related to the perceived complexity and painfulness of endodontic procedures, as an important problem.

Patient awareness and knowledge of oral health and endodontics were also frequently cited by surveyed NDAs as barriers to optimal care. Over 40% of NDAs reported that some patients in their country forego endodontic treatment because they do not consider oral health or the preservation of their natural dentition to be important health concerns. Similarly, NDAs reported a lack of patient awareness about the goals and outcomes of endodontic procedures; in certain countries, patients believed extractions and implants to be the only solutions for painful teeth.

Low-income countries frequently cited patient awareness and knowledge as a factor in the extraction of treatable teeth, and many countries also cited differences between wealthy and poor, or urban and rural, populations in this respect.

As with all areas of dentistry, demographic and societal change present further challenges to providing endodontic care. An increase in population ageing worldwide requires new models of oral care, which should focus on the physical needs of the elderly as well as their personal values.

They should also address the increasing demand for care, varying levels of access to care, and existing self-care skills^{18,85,86}.

2.2.4 Availability of materials and technology

In some countries, dental equipment may be unavailable or unmaintained due to a lack of means, technical expertise, or infrastructure^{6,87}. A lack of adequate training in using new technologies and a lack of decision-making power by dentists regarding the technologies and materials purchased in some health systems can also act as barriers^{75,88}. One-third of the NDAs reported availability of equipment as a challenge in the FDI survey. Several countries in Africa, Asia, and Latin America reported low availability of endodontic equipment in their dental practices, particularly in rural areas. The cost of equipment, such as surgical microscopes, was also cited by several countries, regardless of income level, as a challenge to providing optimal care in all clinics.

2.2.5 Dental education and endodontic specialization

The quality of undergraduate education, including the time dedicated to endodontics, teaching and assessment methods, and availability of staff with specialization or a specific interest in endodontics, varies across countries and regions and has a clear impact on the subsequent quality of care provided by graduates^{87,89-92}. The evolution of undergraduate curricula also means that dentists who graduated years ago may be less likely to adhere to current standards of care^{77,93,94}. Access to continuing education, including time to pursue courses and the availability of courses with high-quality content and methods, is important for dentists to maintain up-to-date knowledge of endodontic procedures and technologies^{88,95,96}. Similarly, undergraduate and continuing education for preventive practice is still lacking in many areas, with curricula focused on restorative dentistry⁴⁰. In the FDI survey, limited procedures being taught at the undergraduate level and limited to no availability of specialist courses were identified as challenges by many NDAs in low- and middle-income countries. In high-income countries, the most commonly cited challenge

was the lack of availability of suitable patients for students to treat.

A lack of access to appropriate dental care in some health systems or geographic areas can result in lower- quality care. General dentists may treat cases beyond their competency if no specialist is available for referral, or long waiting times for specialist care can result in increased extraction as tooth condition deteriorates^{73,97-99}. In some low-income countries, poor access to any kind of dental care, which is often limited and clustered in urban areas, seriously compromises endodontic health¹⁰⁰.

2.2.6 Regulation and legal challenges

The regulation of endodontic care and malpractice systems vary significantly across countries. Systems

that allow malpractice litigation against dentists, such as the US system, may encourage referral of more complex cases to specialists. On the other hand, systems that prioritize open investigation of malpractice claims over financial compensation may promote learning from errors and continued improvement of care standards^{73,101,102}. The FDI survey revealed diverse systems for monitoring adherence to standards of treatment and dealing with malpractice claims, including integration into law, regulation by dental associations or other non-governmental bodies, and non-existence of formal regulations or malpractice procedures. Some countries reported that malpractice procedures might encourage referral, but this was not widespread. Insurance to protect practitioners from the cost of malpractice payments is also common in several countries.

Section 3 Improving Endodontic Care and Outcomes

3.1 Potential solutions for achieving and maintaining optimal endodontic outcomes

From a biomedical and population health perspective, a focus on prevention, in this case prevention of pulpal disease and prevention of bacterial presence deep in the root canal system, has been suggested as a strategy¹⁰³⁻¹⁰⁵. Vital pulp therapy is currently discouraged, as explored throughout this paper; however, changes to health systems and education can address this.

3.1.1 Health Care Systems and Financing

- Ideally, health care financing should strive to provide universal oral health care coverage, including endodontic care, to the population concerned. Different models of universal coverage exist, including systems based on taxation or multiple third-party payers. The important commonalities are financial risk protection and the provision of quality essential services¹⁰⁶. Systems offering universal coverage also require adequate funding to ensure they can respond to the care needs of the population, fairly reimburse dentists for quality treatment, and allow patients to access treatment in a timely manner^{107,108}. Moreover, fee-for-service models may wrongly incentivize clinicians to select treatments that are pricier but not more effective, for example root canal treatment over pulpotomy for adolescents.
- Health system planning should consider the availability of practitioners who are able to carry out endodontic treatment. Population needs vary between countries, but planners should consider evidence regarding patient access to appropriate practitioners, the availability of specialist care for referral from general dentists when required, and anticipated demographic

and epidemiological changes. The availability of qualified practitioners could be improved by emphasizing less learning-intensive, i.e. less complicated, procedures, such as some forms of vital pulp therapy.

- New ways of collaborating within the dental team and new types of oral health professionals may offer solutions to inadequate access to care. For example, the UK Department of Health's Dentists with Special Interest programme allowed general dentists to gain additional skills in specific areas without undertaking a full specialization, including the provision of more complicated endodontic procedures in the primary care setting. Dentists aware of, or involved in, the programme expressed positive opinions of its ability to improve patient care¹⁰⁹⁻¹¹¹. Similar programmes exist that reallocate tasks within the dental team or empower non-dentist oral health professionals to provide preventive care^{22,40,112}. Some believe that fewer, not more, specialists would be better able to provide health services to the population, especially if case managers were to have an expanded role²².

3.1.2 Clinical Practice of Endodontics

- Vital pulp therapy in its various forms⁴¹ is expected to become an attractive alternative to root canal treatment, even in cases diagnosed with what is now called “irreversible” pulpitis. The long-term cumulative success rate of vital pulp therapy in treating such cases is compellingly good⁴⁸, in particular in younger patient groups⁴⁹. Without a doubt, improvement in vital pulp therapy outcomes will be driven by further development of diagnostic and clinical technology⁵⁰.
- Basic root canal treatment (BRT) uses tactile working length determination to allow root canal

treatment to be undertaken in the absence of x-ray equipment or electric power supply. The technique has shown promising results for incisors and premolars in a real-world setting, and therefore offers a viable alternative to extraction in under-resourced settings where traditional root canal treatment is not possible^{6,113}.

- Certain specialist-level treatment, such as microscopic apical surgery, tomography derived 3D treatment planning, and dentoalveolar surgery should be accessible if the case requires it.

3.1.3 Dental Education

- Dental education needs to provide adequate training in endodontic procedures for both general dentists and endodontic specialists. In undergraduate dental curricula, this includes an appropriate number of hours dedicated to endodontics, effective training methods, and access to specialist endodontists or educators with a special interest in endodontics.
- Hands-on training and mock-clinical settings have been effective in improving procedure quality and in adopting new technologies at both the undergraduate and continuing education level^{91,95}. Together with revised curricula, improved funding and job flexibility to increase the number of clinically-focused endodontic educators in universities may also help improve the capabilities of newly qualified dentists^{89,90,92}.
- With regards to prevention in the dental practice, a shift in dental curricula is required to promote preventive dentistry over restorative dentistry⁴⁰. This should cover primary prevention, such as the provision of, or referral to, tobacco cessation services, nutrition counselling, reduction of alcohol intake, promotion of fluoride products, and application of dental sealants⁸⁶. As stated before, the very same approach may be extended to endodontic therapy, where retaining a vital pulp for as long as feasible appears to offer benefits to the patient.

- Efforts to improve access to continuing education by reducing time pressures on dentists and making courses more affordable may also be important to ensure that dentists stay up to date with procedural developments and new technologies¹¹⁴.

3.1.4 Adapting Endodontic Care Outcomes

- The adoption of patient-centred outcomes in treatment guidelines and reimbursement models can help ensure that endodontic care responds adequately to patient needs and contributes more fully and sustainably to patient health. Patient-centred outcomes can also play an important role in guiding the development of new treatment and diagnostic procedures and technologies. As described earlier in this white paper, patient-centred endodontic treatment implicates prevention and early intervention to improve tooth retention and reduce symptoms. It should also consider potential connections between endodontic and systemic health.
- FDI is currently working to develop an oral health measurement tool, providing a standard set of measures that incorporates patient perspectives into the assessment of oral health outcomes⁸. This set can be adapted and used by a variety of stakeholders, including health care authorities and payers, to better integrate patient-centred outcomes into endodontic care models.

3.1.5 Treatment Standards and Competencies

- Guidelines on endodontic treatment procedures and care are important resources for formal education and for ongoing guidance for practicing dentists. A number of national and international endodontic associations publish guidelines, which describe treatment standards and provide general dentists with guidance for case difficulty assessment and referral^{4,5,42}.
- Several tools for case difficulty assessment and referral decision-making exist to assist the general practitioner; these need to address the full spectrum of endodontic therapy. Methods

to facilitate implementation in the dental clinic, including a short screening questionnaire to assess the need for further evaluation, and integration into a mobile app, have been applied to such tools^{115,116}. This would allow practitioners to treat cases that are more realistically within their ability, reducing obstacles to providing adequate care⁷⁵.

- Accordingly, a chairside guide published as an accompaniment to this white paper will provide general dentists with guidance on providing endodontic care, including the implementation of relevant solutions as identified in this paper.

3.1.6 Awareness Raising and Advocacy

- Communications to dispel myths related to endodontic treatment are needed. It is a myth among patients that endodontic treatment is a painful and complicated procedure; it is a myth among dentists that patient acceptance is, or should be, a barrier to rubber dam use. Public awareness campaigns are specifically needed in the era of widely accessible and unmoderated information on digital media.
- NDAs and other non-governmental organizations (NGOs), including FDI, have an important role to play in advocating for the changes proposed in this paper and obtaining more attention and funding for policies to improve oral health. Better evidence of the oral disease burden and of programmes and policies that improve oral disease prevention, quality care, and oral health promotion can help reinforce these advocacy messages.

3.2 Call to Action

Key issues identified in endodontic care should be addressed on multiple levels, such as remuneration systems, outcome assessment, and educational strategy. First, **health authorities and third-party payers, in strong and constant collaboration with the representatives of the oral health**

profession, should constantly evaluate fee-for-service systems to incentivize treatments that are most likely to improve population health. This is closely linked with outcome assessment and educational conditions.

In endodontics, prioritizing periapical health as the outcome does not appear to address the needs of an ageing population for functional long-term teeth retention. **Researchers and professional bodies should adapt outcome assessment models that consider patient-centred variables and oral health outcome measures for use in endodontics and push for their adoption in care and preventive measures. This includes a focus on vital pulp therapy.** Such models could then be tied to remuneration and would likely result in a more diverse treatment spectrum to routinely include various regenerative procedures.

Education of dental specialists comes with a significant cost and limits access to care. **Health authorities and educators should prioritize care models with a focus on preventing pulpal disease - this may include dental auxiliaries to manage patients.** Conversely, wider access to education is needed to improve the quality of endodontic care delivery.

Finally, political neglect of oral health and failures to adequately implement population-level health promotion measures, including age-adapted patient/public literacy campaigns and awareness-raising for oral and general health, impact endodontic health and broader oral health. **Governments should accord adequate attention and funding to oral health, including the coordination of multisectoral, population-level approaches to prevent dental caries and other oral diseases.**

Ongoing advocacy by NDAs and other relevant organizations is required to increase the attention and funding given to oral health; advocacy efforts can be supported by research emphasizing the oral disease burden and effective interventions to improve oral health.

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- Asociación Mexicana de Endodoncia, Colegio de Especialistas en Endodoncia, A.C.
- Asociación Nicaragüense de Endodoncia
- Association Dentaire Française
- Association Marocaine de Prévention Bucco-Dentaire
- Association Rwandaise des Chirurgiens-Dentistes et Stomatologues
- Associazione Italiana Odontoiatri
- Bahamas Dental Association
- Bangladesh Dental Society
- Botswana Dental Association
- British Endodontic Society
- Cambodian Dental Association
- Circulo de Odontologos del Paraguay/Sociedad Paraguaya de Endodoncia
- Colegio de Cirujanos Dentistas de Costa Rica
- Colegio de Cirujanos Dentistas de Honduras
- Colegio Estomatológico de Guatemala
- Consejo General de Dentistas de España
- Cyprus Dental Association
- Czech Dental Chamber
- Dental Association of Bosnia & Herzegovina
- Dental Association of Malta
- Dental Association of Seychelles
- Dental Section of the Hungarian Medical Chamber
- Egyptian Dental Association
- Egyptian Dental Syndicate
- Federación Odontologica Colombiana
- Finnish Dental Association
- Ghana Dental Association
- Guam Dental Society
- Hong Kong Dental Association
- Hungarian Dental Association/Hungarian Association of Endodontists
- Indonesian Dental Association/Indonesian Endodontic Society
- Iran-German Implant Association
- Irish Dental Association
- Israel Dental Association/Israeli Endodontic Society
- Lebanese Dental Association
- Macau Dental Association
- Malaysian Dental Association
- Mauritius Dental Association
- Myanmar Dental Association
- Nepal Dental Association
- New Zealand Dental Association
- Ordre Nationale des Chirurgiens-Dentistes de la République Démocratique du Congo
- Pakistan Dental Association/Aga Khan University
- Polskie Towarzystwo Stomatologiczne
- The Royal Dutch Dental Association
- Singapore Dental Association
- Slovenian Dental Association
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- Société de Médecine Dentaire (Belgium)
- Sri Lanka Dental Association
- Stomatological (Dental) Association of the Kyrgyz Republic
- Swedish Dental Association
- Swiss Dental Association SSO
- Syndicat Tunisien des Médecins Dentistes de Libre Pratique
- Tanzania Dental Association
- The Dental Association of Thailand
- The South African Dental Association
- Vanuatu Dental Association

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