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ORIGINAL ARTICLE

Diagnosis consensus among endodontic specialists and general practitioners: An international survey and a proposed modification to the current diagnostic terminology

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Abstract

Introduction: This survey aimed to determine the consensus amongst endodontic specialists in North America and practitioners worldwide to diagnose the pulp and periapical conditions of selected case scenarios encountered in daily practice using the American Association of Endodontists (AAE) pulpal and periapical diagnostic terms. Secondly, an attempt was made to suggest modifications in terms accordingly.

Methodology: A survey designed by two endodontic educators was sent to endodontists in North America and clinicians worldwide through an electronic database. The survey included socio-demographic questions followed by the clinical and radiographic presentations of four clinical scenarios. The participants were then requested to provide the pulpal and the periapical diagnosis of 11 teeth presented in these cases (22 answers in total/participant) using the AAE diagnostic terminology. Cases were designed to include 12 pulpal/periapical conditions as control (non-controversial conditions) and ten so-called controversial conditions. A proportion threshold of 10% was required for any diagnostic term to be reported in this survey. The participants were divided into two groups based on the region of endodontic training and/or practice to 'Specialised North American' or 'International Practitioners,' and their results were statistically compared using chi-squared tests ($p < .05$).

Results: The survey included 421 participants. 74% were endodontists, and 46.1% were amongst the 'Specialised North American' group and 53.9% amongst the 'International Practitioners'. Eleven of 12 control conditions had an almost complete agreement amongst the participants regarding the diagnostic terms selected, ranging between 82% and 96%, with no other diagnostic term exceeding the 10% threshold. All the controversial conditions yielded more than one diagnostic term selected/condition that exceeded the 10% threshold for groups ('Specialised North American' and 'International practitioners'). There were no differences in the diagnostic terms selected between the two groups; however, the weight for each term varied between the groups in some cases.

Conclusion: There is a lack of consensus amongst clinicians, regardless of their training and region of practice, on the appropriate diagnostic terms to be used in particular clinical conditions. More diagnostic terms and modifications in the current terms may be required to establish a more reliable diagnostic terminology.

KEYWORDS
diagnostic terminology, diagnostic tests, periapical diagnosis, pulpal diagnosis, survey

INTRODUCTION

Having clearly defined pulp and periapical diagnostic terms correlating biological conditions to clinical and radiographic findings is essential for proper clinical assessment and communication between and amongst colleagues within the dental speciality (Gutmann et al., 2009). Moreover, providing pulpal and periapical diagnoses is decisive for treatment planning and prognosis. In 2008, the American Association of Endodontists (AAE) conducted a consensus conference with an aim to standardize the diagnostic terminology used in endodontics (Glickman et al., 2009). The meeting concluded with recommendations that included 13 diagnostic terms to describe the different pulpal (seven terms) and periapical (six terms) conditions (Glickman, 2009). The recommendations have been adopted since in North America, and soon afterwards, in multiple clinical and educational institutions worldwide.

The AAE diagnostic terminology has been implemented now for over a decade, and they appear to encompass the majority of the pulpal and the periapical conditions that clinicians may encounter in their practices. With the inherent limitation of the pulp sensibility tests (Mainkar & Kim, 2018; Petersson et al., 1999), and the introduction and widespread use of cone-beam computed tomography (AAE/AAOMR 2016; Fayad et al., 2015; Setzer et al., 2017), the diagnostic process has received more attention. Moreover, with the emergence of regenerative endodontic techniques and new guidelines for vital pulp therapy procedures by the European Society of Endodontology (Duncan et al., 2019) and the AAE (2021), it became evident that some pulpal and periapical conditions cannot be clearly described using the current AAE diagnostic terms. Therefore, the aim of this study was to determine the consensus amongst clinicians to diagnose the pulp and periapical conditions of selected clinical cases by conducting an international survey amongst endodontic specialists and general dentists. Secondly, an attempt was made to suggest modifications in terms accordingly.

MATERIALS AND METHODS

This study was approved by the institutional review board of the University (IRB no. 43101084). A descriptive, cross-sectional and international survey was conducted online in 2021 with two reminders sent 15 days apart. A multiple-choice self-administered questionnaire was sent by e-mail to all post-graduate programme directors in the United States and Canada with a request to forward the survey to their students and faculty. The questionnaire was also sent to all members identified as dentists on a web-based educational forum (Endolit). At the time of the investigation, it represented 5723 practitioners, of whom 54.3% were registered as endodontic specialists, 10.7% as endodontic residents, 31.3% as general dentists and 3.7% as dental students; the platform is broadly international and therefore recruitment extended worldwide.

The close-ended questionnaire included a total of 30 questions. Eight questions were regarding the participants' socio-demographic data: age, sex, clinical experience, years of experience, geographic region of practice (country and continent), previous education and whether the participants are involved in any teaching activities in a dental school (appendix). The other 22 questions were regarding the pulp and periapical diagnosis of 11 teeth presented in four different clinical scenarios. Each clinical scenario included a brief history, clinical examination and radiographic images (Figures 1, 2, 3, and 4). The participants were then prompted to choose only one answer for the pulpal diagnosis and one answer for the periapical diagnosis for each tooth, according to the AAE recommended diagnostic terminology (Glickman, 2009). The questionnaire was pilot tested with a subgroup of endodontists and endodontic residents in one school in North America and another one outside North America for language, time commitment and functionality.

Clinical scenarios were designed with 10 of the pulpal and periapical conditions written in a way that they would potentially be compatible with more than one diagnostic term. These conditions were termed 'controversial conditions' for the purposes of this study. The other 12

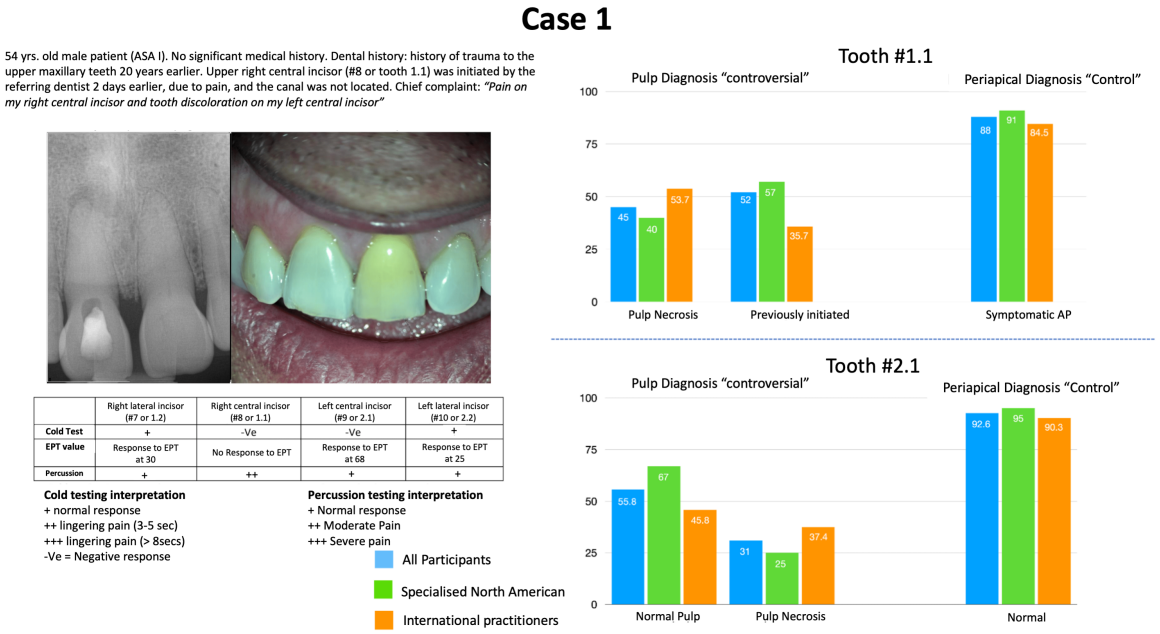

FIGURE 1 Case 1 as presented to the survey participants and the associated results.

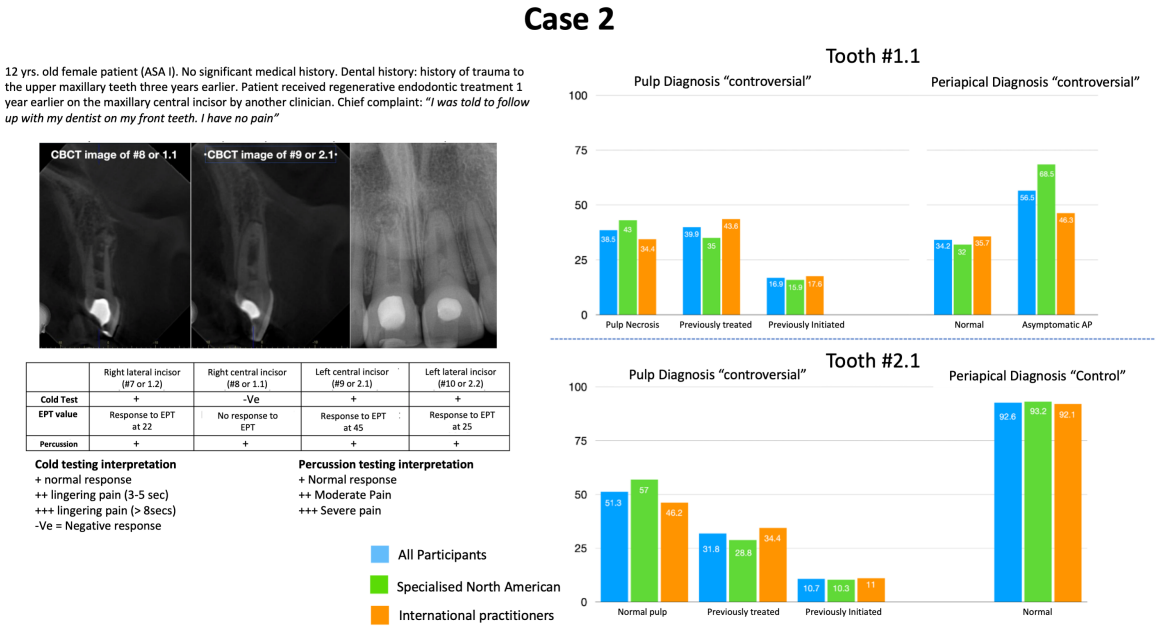

FIGURE 2 Case 2 as presented to the survey participants and the associated results.

conditions were controls, in which participants familiar with the AAE terminology were expected to choose the same answer based on the presented clinical and radiographic findings. Since the diagnostic terminologies used in this survey were proposed by the AAE, and possibly practitioners and students outside the United States or Canada may be unfamiliar with these terms, endodontic residents and endodontists who are/were trained and/or practising in the United States or Canada were grouped as 'Specialised North American', whilst all the remaining participants, regardless of their region, education or experience were grouped together as 'International practitioners'. Due to the presence of multiple teeth to be diagnosed in this survey together with the differences in clinical experience, education and regions of the participants, a threshold of 10% was required for any diagnostic term to be reported (i.e., diagnostic terms with <10% selection/condition [pulpal or periapical] were considered erroneous and were not reported in this study). Chi-squared tests were used to compare between the results of 'Specialised North American' and the 'International practitioners' groups. p value was set at .05.

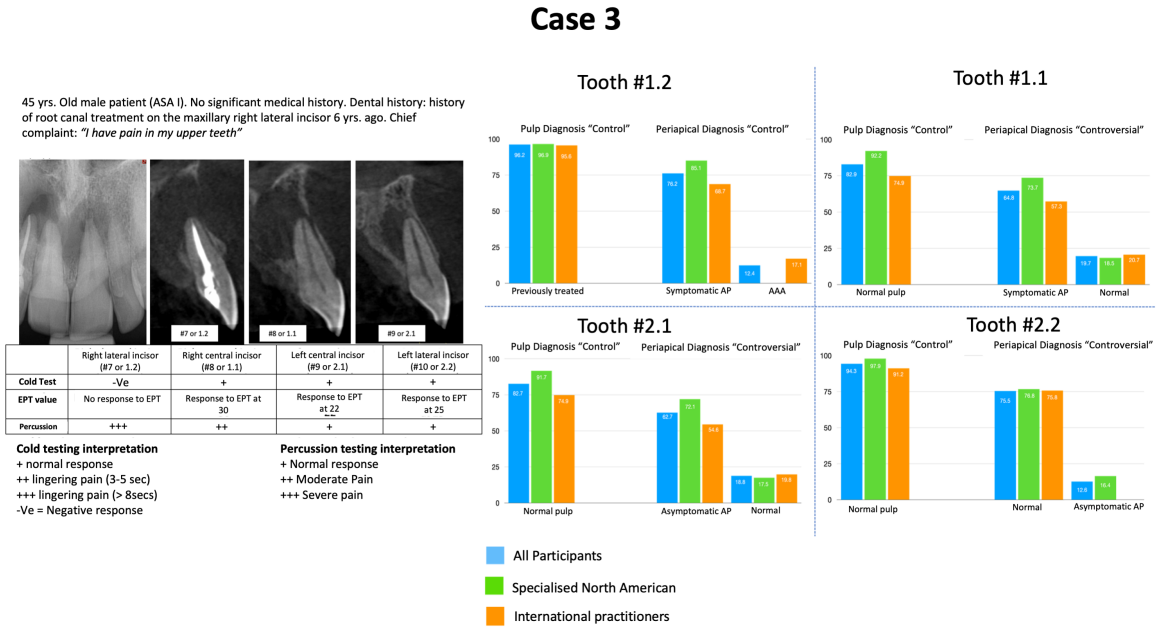

FIGURE 3 Case 3 as presented to the survey participants and the associated results.

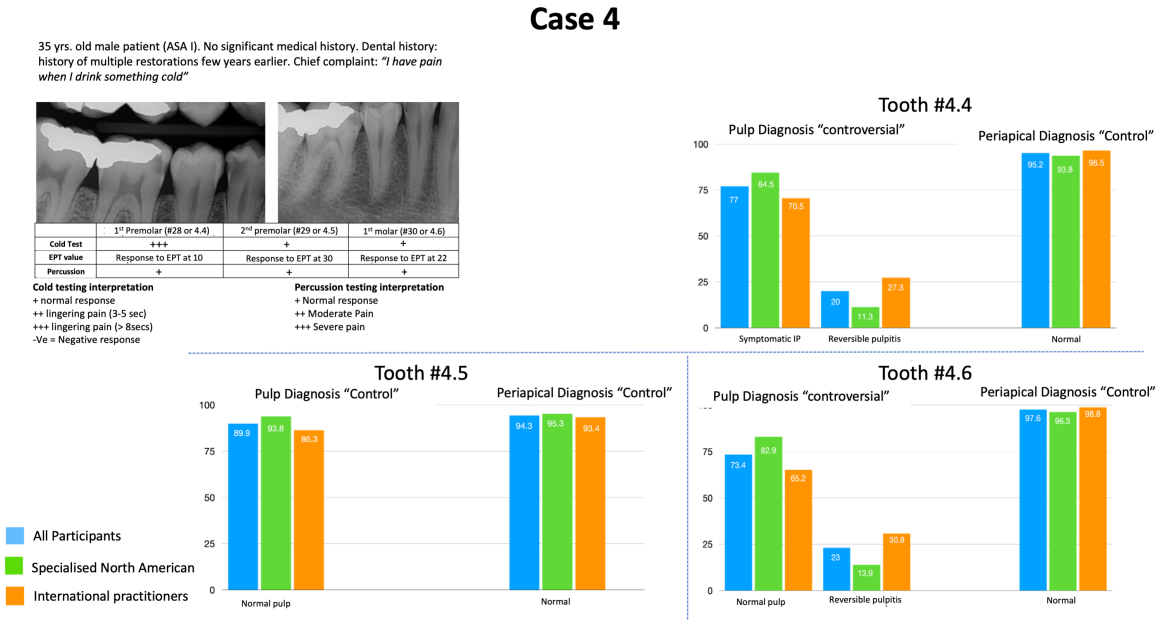

FIGURE 4 Case 4 as presented to the survey participants and the associated results.

RESULTS

A total of 421 individuals participated in this online survey (response rate = 7.4%), with the majority identifying themselves as endodontists (74.3%), and 55% of them reported teaching endodontics in a dental school. About 80% of the participants had more than 4 years of clinical experience, and 46.1% belonged to the 'Specialised North American' group, whilst 53.9% belonged to the 'International Practitioners'. The socio-demographic data of the participants are presented in Table 1.

The results for the control and controversial conditions amongst 'All Participants', the 'Specialised North American' and the 'International practitioners' are displayed in Figures 1, 2, 3 and 4. Unanimous agreement amongst all the participants was observed in 11/12 control pulpal and periapical conditions selected, ranging between 82% and 96%, with no second diagnostic term exceeding the 10% threshold. Only in one control condition (periapical diagnosis of tooth 12 in case 3), a second diagnostic term exceeded the 10% threshold for the 'International Practitioners' group but not the 'Specialised North American' group.

TABLE 1 Socio-demographic information of the survey participants

Socio-demographic information	%
Sex	
Male	66.3
Female	33.7
Age (in years)	
18–24	1.7
25–34	26.6
35–44	31.4
>45	40.4
Practice as	
Endodontist	74.3
General dentist	12.8
Post-graduate student	10.5
Dental student	2.6
Continent where you practice	
North America	47.2
Asia	27.6
Europe	17.4
South America	3.9
Africa	2.2
Australia	1.7
Years of practice (years)	
>16	44.7
12–15	8.6
8–11	13.3
4–7	15.7
0–3	17.7

On the contrary, the results of all the ten 'controversial conditions' resulted in disagreement in all cases. In specifics, either two (cases 1, 3 and 4) or even three (case 2) different diagnostic terms selected/condition were used in both groups, each of which exceeded the 10% threshold.

Respondents in the 'Specialised North American' and 'International Practitioners' groups did not differ in the terms they selected; there was, however, a significant difference between the two groups in the weight selection for the pulp condition of three teeth [case 1 (teeth 11 and 21) and case 4 (tooth 46)], which was statistically significant ($p < .05$).

DISCUSSION

The results of this survey highlight the lack of consensus amongst clinicians in choosing the most descriptive terminology for the pulp and periapical diagnosis in some clinical scenarios. This may stem from the lack of appropriate terms to define these clinical conditions, ambiguity in the definitions of some diagnostic terms and the introduction of new definitive clinical procedures that were not commonly practised when the consensus paper was released (Glickman, 2009). Whilst the response rate was rather low, as previously reported for online surveys, the number of participants was sufficiently large with an even distribution between 'Specialised North American' group and the 'International Practitioners' group allowing a valid comparison between the two cohorts of clinicians. The survey was carefully designed to test the validity of the diagnostic terms proposed in the AAE consensus paper as well as the reliability of the clinicians taking the questionnaire. Our results showed consistency of a single answer between 82% and 96% in almost all control conditions. There were also no differences in the selected diagnostic terms amongst the 'controversial conditions' between the groups in any of the teeth. These results generally confirm that the participants were not randomly selecting answers and were familiar with the AAE diagnostic terminology. Only in one control condition, a second term exceed the 10% threshold amongst the 'International Practitioners' group. This may stem from the deficiency in the case description of 'Case 3' in which the presence or absence of a clinical swelling was not clearly stated in the narrative of the case. This can be considered a limitation in the survey design.

The pulp and periapical diagnosis of a tooth determines to a great extent the course of endodontic treatment and the required level of intervention. Using the wrong diagnostic term can potentially have clinical consequences and/or legal implications. For example, in 'Case 1' presented in this survey, 31% of the participants diagnosed the pulp condition for tooth 21 as 'pulp necrosis', likely due to the lack of response to cold testing and the delayed response to electric pulp testing. Accordingly, clinicians choosing this pulp diagnosis, or their referring dentists, may consider or expect endodontic intervention since the tooth is non-vital/necrotic/diseased. On the contrary, about 56% of the participants diagnosed tooth 21 as 'normal pulp'. This is likely due to the lack of a clear cause for a disease (caries or fracture), the tooth response to electric pulp testing and the radiographic evidence of a receded pulp space without any periapical radiolucency. Accordingly, these clinicians are likely to choose 'no treatment' for this tooth. Both conclusions can be clinically justified based on the pulp testing results. However, the pulp is either normal or necrotic. It cannot be both. Similar clinical presentation can also be present following trauma cases or patients receiving head and neck radiation, where the neural responses can be altered for several months, but the blood supply is still present (Bastos et al., 2014;

Gupta et al., 2018). Moreover, it is well documented that teeth may not go through any painful period when the pulp condition is deteriorating ('silent pulpitis'), which further complicates apply labels for pulpal conditions (Michaelson & Holland, 2002).

Whilst other tests such as laser Doppler and pulse oximetry are more reliable in determining the pulp vitality (Ahn et al., 2018a, 2018b; Mainkar & Kim, 2018), these tests are technique sensitive, expensive and not widely used by clinicians in their daily practice (Ghouth et al., 2019; Mainkar & Kim, 2018). Also, in the narrative description of 'Case 1', access preparation was attempted on tooth 11 by the referring dentist, but the canals were never located, and pulpotomy or pulpectomy were not performed. Based on the AAE diagnostic terminology, 'Previously initiated' *is a clinical diagnostic category indicating that the tooth has been previously treated by partial endodontic therapy (*e.g.*, pulpotomy, pulpectomy)* (Glickman, 2009). The term currently does not encompass access preparation as part of the definition, which can explain the dichotomy in the pulpal diagnosis for tooth 11, amongst the participants between 'pulp necrosis' (52%) and 'Previously initiated' (45%).

Regenerative endodontic treatment (revascularization/revitalization) is a relatively new definitive procedure in the endodontic field, which became more widely accepted after the release of the AAE consensus paper (Glickman et al., 2009). This can explain why the most discrepancies in pulpal diagnosis were observed in 'Case 2', where the patient had a history of regenerative treatment. The majority of the participants based their diagnosis on the pulp sensibility responses [none-responsive (tooth 11) or responsive (tooth 21)] to diagnose the pulp as 'pulp necrosis' (38.5%) or 'normal pulp' (50%). The remaining participants described the pulp condition as either 'previously treated' (31%–39%) or 'previously Initiated' (10.7%–16.9%). Technically, the current definitions of all these terms make them somehow eligible to describe the pulp condition of teeth subjected to regenerative treatment. Selecting 'normal pulp' for a tooth that 'is symptom-free and normally responsive to pulp testing' or 'pulp necrosis' for a tooth that 'is not responding to pulp testing' appears to align with the current AAE definitions. 'Previously treated' is also an appropriate term to select, since the tooth have received a definitive endodontic treatment despite the absence of a root filling material on the radiograph. Choosing 'Previously initiated' can also be justified since the tooth has received a pulpectomy and has no radiographic evidence of a root canal filling material in the root canal space. There are merits for selecting any of these terms based on the current AAE definitions; however, none of the terms seems to accurately capture the pulp status following a regenerative treatment.

Apical periodontitis is a sequela of a pulp disease that arises from an inflammation or infection of the root canal space (Kakehashi et al., 1965). Accordingly, clinicians may diagnose a tooth with apical periodontitis (symptomatic or asymptomatic) in the presence of a periapical lesion associated with a necrotic or a previously treated tooth. Is it possible, however, to diagnose a tooth with apical periodontitis (symptomatic or asymptomatic) in the presence of a normal healthy pulp? This was noted in 'Case 3' where the pulp conditions of teeth 11 and 21 was reported as normal pulp by 82%–94% of all the participants due to the normal responses to pulp testing. However, the periapical diagnosis for these teeth varied between symptomatic and asymptomatic apical periodontitis depending on the clinical presentation. Whilst the development of a periapical disease from a healthy pulp is not possible, selecting 'normal apical tissue' in the presence of periapical radiolucency surrounding the apex is also an inaccurate description of the clinical presentation. This particular case illustrates the limitation of the current diagnostic terms to demonstrate that periapical disease is a sequela of pulp disease.

According to the AAE terminology, reversible pulpitis is A clinical diagnosis based on subjective and objective findings indicating that the inflammation should resolve and the pulp return to 'normal' (Glickman, 2009). The subjective sign of reversible inflammation would be sensitivity to cold. The objective finding, however, would be clinical and radiographic signs of caries as shown in histological studies (Ricucci et al., 2014). In Case 4 of this survey, there were discrepancies in the pulpal diagnosis of tooth 46, which presented with radiographic signs of caries without clinical symptoms. Due to the normal responses to pulp sensibility tests, 73% of the participants chose 'normal pulp' to describe the pulpal condition of tooth 46. On the contrary, 23% diagnosed the tooth with 'reversible pulpitis', likely due to the radiographic evidence of caries. Tooth 44 also showed a discrepancy in the pulpal diagnosis amongst the participants between reversible (27.3%) and irreversible pulpitis (70.5%) based solely on the lingering pain duration. Such discrepancy may stem from the lack of consensus amongst clinicians on the lingering pain duration following thermal testing that would deem a pulp to be irreversibly damaged. It has been shown by Ricucci et al. (2014) that 16% of cases diagnosed with symptomatic irreversible pulpitis where histologically in the reversible stage. Likewise, Dummer et al. (1980) demonstrated that clear associations of clinical signs or symptoms with histologically demonstrated pulpal disease were rare. Such findings clearly suggest that further research is required to determine the expected duration for pain to linger following cold testing to better differentiate between reversible and symptomatic irreversible pulpitis.

In addition, some other limitations of the study must be acknowledged, such as restriction of access to users of the Endolit database and direct invitations; whilst the platform has a large number of members, sampling this was

introduces a bias towards internet and social-media users. Also, non-English speakers are less likely to contribute.

PROPOSED MODIFICATIONS OF THE DIAGNOSTIC TERMINOLOGY

Based on the results of this survey, we are proposing the introduction of four new diagnostic terms (three pulpal and one periapical/periradicular), to improve the description of the various pulpal and periapical conditions encountered in today's practice (Table 2). We suggest dedicating two diagnostic terms to describe the pulpal status following regenerative endodontic treatments based on the pulp sensibility findings:

1. 'Responsive regenerated pulp' and
2. 'Non-responsive regenerated pulp'.

These terms would allow differentiation between teeth subjected to regenerative treatments that may or may not respond to pulp testing, teeth that maintain their original healthy 'normal pulp' and teeth with 'pulp necrosis' conditions that require endodontic intervention. It would also separate these cases from 'previously treated' conditions that are characterized by having a root canal filling material or 'previously initiated' cases that require further endodontic intervention. This differentiation is essential, particularly for insurance companies that may reject a treatment plan that includes retreatment codes on a case with a failed regenerative procedure since a root canal filling is not visible on the radiograph. Whilst the term 'Pulp regeneration' is not an accurate term to describe the nature of the tissues growing in the root canal space (Khademi et al., 2014; Lei et al., 2015; Wang et al., 2010), it is a common term used amongst clinicians to describe regenerative endodontic procedures.

TABLE 2 New proposed terms to the diagnostic terminology

Pulpal conditions	
Non-responsive regenerated pulp	A clinical diagnostic category in which the pulp space has been previously treated by a regenerative procedure and is currently not responding to pulp testing
Responsive regenerated pulp	A clinical diagnostic category in which the pulp space has been previously treated by a regenerative procedure and is normally responding to pulp testing
Inconclusive pulp condition	A clinical diagnostic category in which the pulp is symptom-free and is not responding normally to pulp testing without the presence of any subjective (pain) or objective (caries or fractures) cause for pulp disease and with no signs of periapical disease. The condition suggests further monitoring without intervention (e.g. calcified canals, trauma cases, hx. of head and neck radiation, hx. of vital pulp therapy)
Periapical/Periradicular conditions	
Inconclusive Periradicular condition	A clinical diagnostic category in which the apical or the periradicular area presents with clinical or radiographic signs of inflammation that resembles endodontic disease in a symptom-free pulp that is normally responsive to pulp testing (e.g. Lesions of non-odontogenic origin, or expanding lesions from adjacent teeth)

The third pulp diagnostic term we suggest would be 'Inconclusive pulp condition'. Given the limitation of pulp sensibility tests to accurately assess the pulp status in certain clinical scenarios, including but not limited to calcified canals, trauma cases, and patients undergoing head and neck radiation (Bastos et al., 2014; Dzeletovic et al., 2020; Gupta et al., 2018), an 'Inconclusive pulp condition' would present a solid clinical and legal justification to monitor and follow-up the tooth for an extended period of time without the need for clinical intervention, when there are no clinical or radiographic signs of periapical disease. A similar term can also be used to describe the periapical condition 'Inconclusive periapical condition' for teeth presented with vital pulps and a radiolucency surrounding the periradicular area that does not appear to be a sequela of pulp disease. This term can be used in cases with expanding periapical lesions encroaching on adjacent teeth, as seen in 'Case 3', or in cases associated with lesions of non-odontogenic origin.

Minor modifications in the definitions of the currently existing diagnostic terms appear to be also necessary to minimize ambiguity and provide clarity regarding the subjective and objective findings during pulp testing (Table 3). The definition of 'previously initiated' should not be limited to locating the root canal space but should be broadened to include attempts to locate the root canal space, such as access preparation. The definition should also state that further treatment is required since pulpotomy is currently accepted as a definitive treatment by the ESE (2019) and the AAE (2021). Accordingly, cases subjected to vital pulp therapy (pulp capping or pulpotomy) as a definitive treatment can be diagnosed as:

1. 'Normal pulp' if the tooth is normally responding to pulp testing following treatment;

TABLE 3 Suggested modifications in the definition of currently used diagnostic terminology

Pulpal conditions	
Normal pulp	A clinical diagnostic category in which the pulp is symptom-free **(no clinical symptoms, caries or fractures)** and normally responsive to pulp testing
Reversible pulpitis	A clinical diagnosis based on subjective **(thermal sensitivity) and/or** objective **(e.g. caries or fracture, exposed tooth/root surface, deep restorations, cracked tooth)** findings indicating that the inflammation should resolve **once the insult is eliminated** and the pulp return to normal
Symptomatic irreversible pulpitis	A clinical diagnosis based on subjective **(lingering pain to thermal changes for extended period)** and objective findings **(e.g. caries or fracture, deep restorations and cracked tooth)** indicating that the vital inflamed pulp is incapable of healing. Additional descriptors: lingering thermal pain, spontaneous pain and referred pain
Asymptomatic irreversible Pulpitis	A clinical diagnosis based on subjective **(no clinical symptoms and responses to thermal testing are within normal limits)** and objective findings **(extensive decay/fracture that is encroaching on the pulp canal space)** indicating that the vital inflamed pulp is incapable of healing
Previously initiated therapy	A clinical diagnostic category indicating that the tooth has been previously treated by partial endodontic therapy and **further treatment is required** (e.g. **access preparation**, pulpotomy, pulpectomy)
Previously treated	A clinical diagnostic category indicating that the tooth has been endodontically treated and the canals are obturated with various filling materials other than intracanal medicaments
Periapical/periradicular conditions	
Symptomatic apical periodontitis	Inflammation, usually of the apical or **periradicular** periodontium, **that is of pulpal origin**, producing clinical symptoms including a painful response to biting and/or percussion or palpation. It might or might not be associated with an apical radiolucent area
Asymptomatic apical periodontitis	Inflammation and destruction of the apical or **periradicular** periodontium, **that is of pulpal origin**, appears as an apical radiolucent area, and does not produce clinical symptoms
Acute apical abscess	An inflammatory reaction **in the apical or periradicular** periodontium to pulpal infection and necrosis characterized by rapid onset, spontaneous pain, tenderness of the tooth to pressure, pus formation and swelling of associated tissues
Chronic apical abscess	An inflammatory reaction **in the apical or periradicular** to pulpal infection and necrosis characterized by gradual onset, little or no discomfort and the intermittent discharge of pus through an associated sinus tract
Condensing osteitis	Diffuse radiopaque lesion representing a localized bony reaction to a low-grade inflammatory stimulus, usually seen at **apex or surrounding the roots** of tooth

Note: Modifications in the definitions are bolded and underlined.

2. 'Inconclusive pulp condition' if the tooth is non-responsive to pulp testing following treatment and without clinical or radiographic evidence of periapical disease; or
3. 'Pulp necrosis' if the tooth is non-responsive to pulp testing following treatment and with clinical or radiographic evidence of periapical disease.

Considering apical conditions, we suggest that every definition should clearly state that the cause of the disease is of 'pulpal origin', and it can be present in the apical or the 'periradicular area'. This would allow lesions not associated with the apical area, such as furcation lesions or lateral lesions of pulpal origin, to be encompassed as part of the diagnostic term.

CONCLUSION

There is a lack of consensus amongst clinician on the appropriate terminology to use in certain, perhaps controversial, clinical scenarios, which requires further discussion. All proposed terms mentioned in this paper, as well as the modifications suggested, may serve as basis for further discussions amongst endodontists and endodontic associations to better standardize the diagnostic terms and improve communication amongst dental colleagues.

AUTHOR CONTRIBUTION

Adham A. Azim: Study design, sending survey, data analysis, writing. **Khalid Merdad:** Study design, data analysis, writing. **Ove Peters:** Writing.

CONFLICT OF INTEREST

The authors deny any conflict of interest.

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APPENDIX

QUESTIONNAIRE

1. Age
   25–34.
   35–44.
   45+.
2. Sex
   Male.
   Female.
3. You Practice as...
   Dental student.
   Post-graduate student/resident.
   General dentist.
   Endodontist.
   Other ..... (please indicate).
4. Experience (if you are a student or resident, please skip this question)

0–3 years.
4–7 years.
8–11 years.
12–15 years.
16+ years.

5. In which content do you practice?
North America.
South America.
Europe.
Africa.
Asia.
Australia.

6. In which country have you completed or currently completing your endodontic training?
.....

7. In which country do you practice?
.....

8. If you are an Endodontist, are you involved in teaching activity in Endodontics at any university?

Yes
No