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A review of the questions and needs in endodontic diagnosis

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Abstract

The current diversity of opinions in endodontic diagnosis has been a source of interest and academic debate by clinicians and researchers. Currently, no single pulp testing technique can reliably diagnose all pulpal conditions neither it has been proven to be superior in all aspects.
Despite improvements of various aspects of this process, there are no historically dramatic changes, or consensus for pulpal status in health or disease in addition to a lack of relative systematic reviews.
In this review, the past, present and future most debated and critically questioned issues of endodontic diagnosis are discussed. The aim of this review is to provide insights in future diagnostic modalities and areas for further study in endodontic practice pertinent to diagnosis.

Keywords : Diagnosis, pulp testing, endodontics

Résumé

Revue des questions et besoins dans le diagnostic endodontique

La diversité actuelle des opinions en endodontie diagnostique a été une source d'intérêt et de débat académique chez les cliniciens et chercheurs. Actuellement, aucune technique de test de vitalité pulpaire ne peut diagnostiquer avec fiabilité tous les états pulpaires ni prouver sa supériorité.
Malgré les progrès des divers aspects de ce procédé, il n'y a pas de changement historiquement notable ou consensus sur l'état de la pulpe saine ou malade, avec de plus un manque d'études relatives systématiques.
Dans cette étude, le passé, le présent et le futur des questions les plus débattues sur le diagnostic endodontique sont discutées. Le but de cette étude est donner un aperçu des futures modalités et domaines diagnostiques pour de prochaines études de pratique endodontique utiles au diagnostic.

Mots-clés : Diagnostic, test pulpaire, endodontie

Introduction

Diagnosis, is "the art and science of detecting deviations from health and the cause and nature thereof' where the data obtained from questioning, examining and testing are combined by the dentist to identify deviations from the normal (1, 2).
Aim of endodontic diagnosis is to prevent irreversible pulpal injuries and apical periodontitis and thereby optimize the outcomes of preventive and interventional endodontic treatments (3).
All methods to determine the status of the pulp and root-supporting structures except for surgical exploration and histological examination (biopsy), rely on indirect diagnostic data interpreted from the patient response to a stimulus placed externally to the tissue (4, 5).
Due to this inability to directly test the pulp, testing results are based on assumptions of what is presumed to be the underlying disease process of a given clinical state with multiple clinicians arriving at vastly different interpretations of the same data (6).
Tests used with "yes" or "no" response which varies from patient to patient can generally identify patients free of disease but are less

effective in identifying patients who have pulp disease (7).
Extra testing measures advised to substantiate a more predictable result and attain a reproducible reading, although predictive in some cases, were not able to solve the problem of indirect response of the patient.
Literature on diagnosis of pulpal status is almost devoid in the area of permanent teeth with immature apices particularly following trauma (6, 8).

The aim of this comprehensive search of the literature from September 1954 to May 2010 was to critically discuss the different grey areas in actual diagnostic process to address challenges and needs and to plan a more evidence based thinking for researchers and academics to enhance clinical care particularly in treating developing teeth.

Materials and methods

A library electronic search of MEDLINE, PubMed, and Cochrane databases using specific MeSH terms from September 1954 to May 2010 was made. Exhaustive hand searching and citation mining for all relevant articles as well as classic and meaningful endodontic textbooks reporting endodontic diagnostic tests and their relevance to clinical situations in traumatized and developing teeth was also targeted.

Study selection

Following this literature search, the titles and abstracts of all articles identified from the electronic and hand searches were first screened to select articles that clearly meet the search criteria and selected articles were reviewed to develop consensus that the inclusion and exclusion criteria were respected.

The diagnostic dilemma

Clinical pulpal states of health and disease we use today were early described by MORSE et al. (9), but there is little or no correlation between clinical diagnostic findings and the histopathologic state of the pulp (10, 11).

Different classification systems have been advocated for pulp diseases based on histologic findings or mixing clinical and histologic terms (12, 13). LINDA et al. 2009 (14), identified 14 different classification systems for pulp diseases over the years most of them are based on histologic findings.
The result was a misleading diagnosis for the same clinical condition creating confusion when a rational treatment plan needs to be established. To describe various disease states of the pulp, new clinical classification scheme were added with claims of superiority to enhance the accuracy and clinical relevance of diagnostic terminology (15-18).
Diagnosis is needed to perform clinical endodontic treatment, and histopathologic diagnosis is impractical in daily endodontic practice with questionable value of clinical detection of a histologic change as a diagnostic term in some cases (19-22). This perception of treatment which is not actually different with the different diagnostic terms raised the question as to whether diagnosis should be a separate activity from treatment (5).
Of all the histopathological pulpal states, the term pulp necrosis used to classify death of the pulp, which is, for the most part, a histological finding is successful in terms of the extent of possible canal infection and the use of the term pulp necrosis is most reliably predicted from a clinical testing point (11, 18).

While distinction between partial and full necrosis becomes important when dealing with immature teeth that have an open apex (13, 23), in exposed pulps of children, test results

and clinical symptoms do not coincide with pulpal histology complicating diagnosis in these teeth (24). The correlation between a clinical diagnosis and the histological status of the pulp as reported by GARFUNKEL et al. was about 50%. All 25 previously traumatized anterior teeth that reacted negatively to conventional pulp testing contained vital pulps when examined histologically (25).

Biological considerations

Understanding the biology of the dental pulp and demarcation of pulpal inflammation and healing (26), is fundamental to the understanding of patient response to different testing modalities (27) and would result in more biologically and ethically oriented treatment options (28).

Diagnostic tools to determine the extent of pulpal inflammation are imprecise and studies that have attempted to determine diagnostic accuracy of reversible versus irreversible pulpitis are few (28). Clinical tests available can only test the ability of the pulp to respond to a stimulus (21) which does not represent our best clinical judgment for the actual state of the pulp where the coronal pulp might be infected but the apical pulp remains vital with a varying degree of inflammation (29).

Another area of debate is the presence of cellulitis or acute exacerbation that present a more complex etiological and therapeutic situation (30). Identification, quantification and link of bacterial and biologic markers and genetic assays with pulpal inflammation and symptomatic teeth will help in controlling endodontic infection and its complications and will affect the ultimate outcome of endodontic treatment (31, 32).

Based on the individuality of each lesion and the progression of pulp diseases through various stages, a comprehensive clinical diagnostic approach and steps in examination must be recognized. Since etiologies, treatment strategies, and prognoses vary considerably, the term ''differential diagnosis'' was also suggested as more realistic in its application in endodontics, especially when tooth pain is the chief complaint (33, 34).

The pain system in the pulp

The inconsistent definitions of pulpal disease have led many researchers to classify pulpal status into two main general categories: vital or nonvital or response versus no response (35).

The dental information gathering process and the history of periradicular pain for teeth with necrotic pulps, is an acceptable initial pain-assessment tool for endodontic emergency patients that might increase the accuracy of pain localization and aid in determining a pulpal diagnosis, but it would not yield predictive value for many patients (36-38).

Subjective symptoms are only partially related to the status of the pulp and are occasionally misleading (39). This relatively straightforward diagnostic outcome becomes more difficult to interpret particularly in posterior teeth (40) when the area would ''ache all over'' with increasing discomfort (41).

Although pain is strongly synonymous to endodontics, most endodontic pathoses are asymptomatic and pain cannot be used to differentiate endodontic problems from non endodontic pathoses (42, 43).

Distinguishing true pain originating from an irreversible pulpitis that may indicate the need for root canal treatment versus hypersensitivity that may indicate the need for palliative management is important (44,45) .

The considerable number of techniques described for pain measurement including verbal and numeric rating scales (46, 47), visual and color analog scales (48), finger span expression (49), calibrated questionnaires (50), cortical evoked potentials (51), and formatting the process using systematic format such as S.O.A.P., which is an acronym for Subjective findings, Objective tests, Assessment (or Appraisal), and Plan of treatment to increase efficiency and consisten-

cy indicate the significant deficit of pulpal pain assessment (52).
Statistical analysis by GRUSHKA and SESSLE (53), using the McGill Pain Questionnaire to differentiate valid predictors of whether pulp inflammation is reversible or irreversible did not allow an acceptable level of determination accuracy. None of the other metrics such as the history of presenting symptoms (54) or a history of being spontaneous (10) could result in sensitivity, specificity, or positive/negative predictive value of the symptoms.
Subcategories of classification of pulpitis and systematic evaluation of pain that represent the biologic rationale for endodontic diagnostic tests are required to enable practitioners differential diagnosis of which pulps can be managed conservatively and which ones require more radical treatment including extraction of the tooth (14, 55).
As a result of the vague descriptors relative to the pain experienced by the patient, recent forms of more precise pain measurement including electroencephalography and standardizing the measurement of mechanical allodynia were introduced, yet, their value in endodontic diagnosis and treatment are to be determined (56-59).

Diagnostic concerns in traumatized and developing teeth

Many attempts have been made over the years to classify dental injuries. The currently accepted system applicable to injuries to the teeth and supporting structures that can be applied to both primary and permanent dentitions is based on the World Health Organization's Application of International Classification of Diseases to Dentistry and Stomatology, and its modification by ANDREASEN (60).
Even though definite diagnosis is established only after inspection and probing of the pulp chamber and the root canal, examination of a patient with dental injuries often includes chief complaint, history of traumatic injury to the facial area, pertinent medical history, and clinical examination (61).
The value of electric pulp tester (EPT), currently the most used test to assess the neurovascular supply to the pulp of a traumatized tooth drops considerably following trauma in which conditions the innervation of the pulp might be jeopardized, at least temporarily (62) and may lead to false negative or false positive responses as roots mature (6, 63).

The less variability in findings for specificity and sensitivity of electric pulp tests renders them more consistent at identifying teeth without disease (vital pulp) (6, 29).
After a luxation injury in traumatized young teeth with wide-open apices in either developing or even mature teeth, lack of response to EPT should not automatically be accepted as proof of pulp necrosis (5, 64). On the other hand, the response at the time of first injury should also be interpreted with caution as sensory nerves may not yet have developed fully and the response might also be affected by overreaction of the child to the stimulus (34).
There is no agreement as to whether thermal tests, when used in the absence of other tests, can reliably determine the presence of a diseased pulp or to identify teeth without disease (29). These qualitative tests can only determine health versus disease caused by a particular primary afferent nerve response and, by necessity, the patient's symptoms (65). In teeth with open apices after traumatic injury, these tests may be unreliable, no response might be elicited even after circulation has been restored and heat tests in permanent teeth with developing apices are rarely performed (8).
Ice and ethyl chloride are of limited value and have consistently been reported to be inferior to carbon dioxide snow shown reliable by many studies concerned with vitality determinations in luxated, avulsed, or root fractured

teeth (54, 62, 63, 66) (8, 67), and dichlorodifluoromethane (DDM) (68).

The oldest pulp vitality tests, palpation and percussion, may be reliable in identifying inflammation in the periodontal ligament space and can also provide information about the relationship between the tooth and adjacent bone indicating lateral or intrusive displacement (69), but cannot differentiate pulpal from periodontal diseases (70).

A positive response to the biting stress test is highly suggestive of periodontal inflammation or incomplete crown-root fracture (59). Mobility and periodontal pocket depth are more standardized than percussion, palpation, and biting stress tests. Even though type of luxation can be related to the degree of mobility, information regarding changes in the root-supporting structures is limited (60).

Transient coronal discoloration has been reported in 4% of teeth after luxation injuries as a result of transient apical breakdown after displacement injuries (26, 71). Transient periapical radiolucency, together with coronal discoloration, negative electric pulp test, and cold response up to 4 months, was shown to subsequently regain the original color and normal pulpal responses when healing is complete. To avoid mistakes, there should be no rush in treatment undertaken on the basis of negative responses (26, 71).

Do radiographs tell the truth ?

A routine radiograph does not reveal the third dimension, which is important in teeth with an open apex. In addition, correlation between radiographic and histologic diagnosis is poor.

Showing better specifity than sensitivity, conventional radiographs are better able to identify the teeth without periapical disease than to identify the teeth that have periapical disease (72, 73), leading to unrealiable inter and intraexaminer agreement on interpretation of structural changes in the periradicular tissues (64, 74).

Following traumatic injuries, two or three periapical x-rays taken from different angles were suggested to increase the accuracy of the radiographic interpretation of the changes in the dentoalveolar complex (64, 75, 76).

A relatively high probability of a false-negative result with both periapical and panoramic imaging techniques was reported preventing reliable differentiation of periapical cysts and granulomas made with conventional periapical radiographs (77).

Another difficulty is encountered when radiographic observation is used as predictable criterion for revascularization and continued root development. The difficulty lies in obtaining the same film position, and the possibility to distinguish arrested root formation and complete development (78).

On the horizon

Radiographic improvements have reduced radiation exposure and improved convenience visualization of changes in a measurable way.

Digital and digital subtraction radiography appears to enhance and improve the ability to detect and measure the size of periradicular lesions and may improve diagnostic accuracy particularly in the evaluation of healing (79, 80).

The potential of Ultrasound imaging introduced in endodontics by COTTI et al (81) agreed with the histopathological diagnosis in all 15 cases examined. The wide spectrum applications of cone beam volumetric tomography (CBCT) in endodontics apart from evaluating endodontic treatment outcomes include diagnosis, detection of canal morphology, non endodontic pathosis, root fracture, internal resorption, invasive cervical resorption, anatomic presurgical assessment (82,83).

As (CBCT) machines become more common in dental offices, CBCT may be the answer to more early and accurate diagnosis of peri-apical

pathosis and may resolve the issue of inter- and intraobserver interpretation of radiographic images (5). Despite the slight variation in sensitivity due to tooth location, very high specificity was found in all tooth types for both imaging techniques (77).

While for teeth with fully formed roots, clinical diagnostic determinations for endodontic therapy depend on whether the pulp spaces are infected, in vital pulp therapy to preserve the pulp of teeth with incompletely formed roots, primary question is whether the treated pulp remains healthy (84, 85).

Developing teeth have the potential of regeneration and revascularization of the injured pulp after trauma and having information about the pulp status of traumatized teeth can be of great value. Measurement of tooth surface temperatures was widely used as a step ahead to determine pulp vitality. A review of the literature reported that this technology is not sensitive enough to identify periapical lesions deep within the bone that would indicate a necrotic pulp or irreversible pulpitis (86).The usefulness of the technique in endodontics needs improvement of science and technology (87).

Several experimental methods have been used to assess pulpal blood flow. These include invasive methods such as radioisotope clearance (88), H2 gas desaturation (89), and non invasive techniques such as Laser Doppler Flow metry (LDF) (90), pulse oximetry, photoplethysmography, and dual wave length spectrophotometry (91).

Transmitted light photoplethysmography (TLP), is a non-invasive technique successfully used to monitor pulpal blood flow in animal and human studies causing less signal contamination from the periodontal blood flow than is the case for LDF (92).

LDF, initially designed in the early 1970s to measure blood flow in the retina and pulse oximetry are two gold standards of vitality tests, having higher sensitivity and specificity than cold, heat, and electric tests (93, 94).

The only few investigations of pulpal vitality using this approach indicated that the consistency of time between peaks in pulses would give an indication of vitality in a tooth pulp by establishing pulsatile reading of similar frequency to the heart rate and might prove a more feasible method to be used in dentistry (95, 96).

The use of LDF in dental trauma has proven to be more valuable than in assessing vitality in healthy pulps especially those with history of trauma or luxation injuries where LDF can detect revascularization after a few weeks, and well in advance of other more traditional clinical tests (97, 98).

Showing signs of adverse outcomes in luxated teeth, LDF may provide opportunity to identify "at-risk" teeth early after the trauma, and initiate treatment with confidence prior to the tooth being lost from pulpal necrosis and infection (99, 100).

The technology of pulse oximetry has allowed significant advances in the medical field.

Approximately 25 models of the pulp oximeter are available to provide pulse rate and oxygen saturation readings calculated in a micro-processor (101). The distinct advantage offered by this pulp testing method in trauma cases will allow unique opportunity for an immediate objective diagnosis of vascular integrity and diagnosis of the pulpal vitality (102).

The accuracy rate of detecting negative test result to indicate a vital pulp by the use of a custom-made pulse oximeter probe specifically made for dental application compared with thermal and electric pulp tests, was found by GOPIKRISHNA and coll. to be 74% with the electrical tests, 81% with the cold test, and 100% with pulse oximetry(62).

The accuracy of this diagnostic method, the completely noninvasive nature and superior patient acceptance support the need for additional studies in the use of the pulse oximeter to interpret the pathological processes of the

pulp (102-104).
Advances in measuring pulpal blood flow still in their infancy and the high-resolution, 3-dimensional imaging may allow better correlation between pulpal histopathologic states and clinical phenomena (14, 105, 106). Used within their limitations, all findings of these technologies are promising in assessing pulpal vitality in healthy and traumatized teeth (98).
Future developments could possibly be a part of using easier, less costly and more refined oral diagnostic procedures that may have a better chance of success. The use of specific biochemical markers in the gingival crevicular fluid such as electrophoresis technique proposed in the early 1970s to differentiate between periapical cysts and granulomas, may yield future useful diagnostic tools (107, 108, 109).

Conclusions and recommendations

Despite that current (old) diagnostic tests still hold a place of respect results from the literature suggest that endodontic practitioners are supportive and optimistic about the future use of more sophisticated and noble endodontic procedures (110). There is a gap in the evidence and a gap in the knowledge to support and validate what we are doing in the actual diagnostic practice, yet, exploration of new testing devices, approaches and materials in the new era of endodontic practice appear to have improved in theory and application giving a better picture as to what the dental pulp might appear as histologically (111-113).
Because of the relatively few evidence-based, randomized, controlled clinical trials in this topic area, in addition to the lack of treatment-oriented diagnosis scheme, a more reliable body of scientific evidence is the more pressing need today to find out an ideal metric, or combination of metrics, that would result in greater specificity and sensitivity and higher levels of evidence to select the appropriate treatment modalities (19).

In addition to being inexpensive, any diagnostic method to arise in the near future should be able to discriminate more accurate pulpal conditions tested than today, based on the best available evidence to produce predictive value for pulpal pathology in a clinical setting. On the basis of available evidence, it appears that better and more accurate quantification modalities of periradicular pain may lie in devices that allow direct measurements of pain thresholds as well (19). A new clinical-related classification which will improve communication among clinicians and researchers and unify practitioners is essential. This new classification should be simple to learn and teach, and should include the most common types to develop universally accepted criteria. The arbitrary use of terms, without taking into account the historic basis for the endodontic diagnostic scheme, may very well lead to overtreatment.
The importance of diagnostic skills in the practice of endodontics has been underscored by a recent 2008 AAE-sponsored symposium on endodontic diagnosis (66). Diagnostic process is not pure science, and the necessary examining equipment may not be the diagnostic tool or instrument but the diagnostician who will perform the test and arrive at a reliable conclusion. Practitioners should be equipped with the basic requirements and skills including the art of listening, knowledge, training, interest, curiosity, patience and above all common sense. As educators and instructors, it's our responsibility and duty to declare that many aspects of the true "puzzlement" could be attributed to the scope of university training, as diagnostic skills might be beyond the comfort level of the students.

Having an influence on subsequent endodontic decision making and treatment, referral should be considered, particularly if diagnosis reaches a dead end or the chief complaint is not of endodontic origin.

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