Making sense of sensibility: part 1

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Key points

- Provides a background overview of pulp testing and a summary of the 'jigsaw' of information a clinician may put together when making an endodontic diagnosis.
- Outlines terminology relevant to pulp testing and their definitions.
- Provides a summary of the diagnostic uses of pulp testing and the diagnostic accuracy of common pulp tests used in clinical practice.

Abstract

Thermal and electric pulp sensibility tests are commonly used by the majority of clinicians when diagnosing endodontic disease. These tests indirectly determine the state of pulpal health by assessing the response of the Aδ nerve fibres within the pulp-dentine complex. A positive response to sensibility testing indicates that the nerve fibres are functioning but does not give any quantitative information on nerve function, pulpal blood flow or histological status of the dental pulp. These tests have inherent limitations, including a reliance on a patient's subjective response to the test and the dentist's interpretation of the patient's response. This two-part series aims to help clinicians to reach an accurate endodontic diagnosis by providing an overview of how to undertake common pulpal sensibility tests correctly, how to interpret their results and understand their limitations. This section provides an overview of pulp testing, definitions of terminology relevant to pulp testing, the diagnostic uses of pulp testing and a summary of the diagnostic accuracy of different pulp tests.

Background

The importance of an accurate diagnosis in dentistry cannot be overstated. Made in a timely manner, it significantly impacts on patient care as it allows treatment to be provided which is tailored to a correct understanding of the patient's health problem.[1] Recording an accurate diagnosis also has important implications for research, resource allocation and dental public health policymaking. In addition, medico-legally, it is important for a clinician to record a clear diagnosis before undertaking treatment and to detail the process used to reach this diagnosis.[2]

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Endodontic diagnosis can be likened to solving a jigsaw puzzle: multiple pieces of information need to be put together to see the full picture. Accurately establishing an endodontic diagnosis is a process of synthesising information which includes the patient's history, clinical and radiographic findings, a periodontal evaluation and results from special tests (pulpal and periapical).[3] The information a clinician should evaluate when making an endodontic diagnosis can be broken down into four subsets and these are summarised in Figure 1. The better these pieces of information correlate with each other, the more reliable the pulpal diagnosis. In some cases, clinical and radiographic findings and pulp testing results are inconclusive or contradictory and therefore a definitive pulpal and periapical diagnosis cannot be made. In such cases, it may be wise to reassess the patient at a later date or to refer for a specialist endodontic opinion.[3]

In the early stages of endodontic disease, the microcirculation within the healthy dental pulp initiates an inflammatory response as part of a complex defence mechanism, attempting to sustain pulpal health.[4] For this reason, it is generally accepted that changes in the blood supply within the dental pulp (pulp vitality) are one of the earliest indicators of pulpal disease.[5] Pulp testing is therefore a useful means of diagnosing or excluding disease of endodontic origin. The ideal pulp test should provide a simple, objective, standardised, reproducible, non-painful, non-injurious, accurate and inexpensive way of assessing the condition of the pulp tissue.[6] Vitality testing of the pulp's blood supply using laser Doppler flowmetry (LDF) or pulse oximetry (PO) can assess pulpal blood flow directly, without relying on a patient's subjective response to a stimulus and are considered to be the 'gold standards' in pulp testing.[7,8,9] Both of these types of vitality test require strict adherence to optimum application techniques and due to technical challenges, including patient head movement,[10] non-pulpal 'noise',[11] signal detection limits[12] and the need for custom-made probes,[13] their use is complicated. Additionally, the necessary equipment is expensive and not widely available. Using LDF or PO is impractical for the majority of dentists in general practice.

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Thermal and electric pulp sensibility tests are most commonly used by the majority of clinicians when diagnosing endodontic disease.[14] These tests indirectly determine the state of pulpal health by assessing the response of the Aδ nerve fibres within the pulp-dentine complex.[15] A positive response to sensibility testing indicates that the nerve fibres are functioning but does not give any quantitative information on nerve function, pulpal blood flow or histological status of the dental pulp.[6] These tests have inherent limitations, including a reliance on a patient's subjective response to the test and the dentist's interpretation of the patient's response.[16] In order to reach an accurate endodontic diagnosis, it is important for clinicians to understand how to correctly undertake pulpal sensibility tests, how to interpret their results and to understand their limitations. The aim of this two-part series is to provide an overview of pulp sensibility testing, including: clinical techniques; diagnostic accuracy in different clinical scenarios; and how to interpret the results to aid clinical decision making.

Table 1 Definitions of pulp vitality, sensibility and sensitivity

Term	Definition
Pulp vitality	The presence of blood supply to the tissues of the dental pulp[21]
Pulp vitality testing	Direct assessment of the pulpal blood supply without relying on patient response.[7,8,9] This can be undertaken using laser Doppler flowmetry or pulse oximetry
Pulp sensibility	The ability of the Aδ nerve fibres within the pulp-dentine complex to respond to a stimulus[15]
Pulp sensibility testing	Assessment of the pulp's sensory response which can be used as a surrogate indicator of pulpal blood flow.[21] Electric or thermal testing are examples of pulp sensibility tests. If the nerve fibres within the pulp do not respond to electric or thermal stimuli, a clinician can usually assume that the pulp does not have a viable blood supply and has therefore undergone necrosis. Should the nerve fibres respond to an electric or thermal stimulus, clinicians generally assume that the pulp has a viable blood supply and may infer that it is either healthy or inflamed, depending on the nature of the response, the history and the other clinical findings (see Figure 1). It is important to note that there are clinical scenarios where there may be false responses and these are discussed in more detail later in the paper
Pulp sensitivity	This is the condition of the pulp being very responsive to a stimulus due to pulpitis[17]
Pulp sensitivity testing	Thermal and electric pulp tests can be used as sensitivity tests when attempting to diagnose a tooth with pulpitis since such teeth can be more responsive than normal.[17] In this scenario, they are described as sensitivity tests as they are assessing which tooth responds more severely than the others. The severity and duration of response can help distinguish between reversible and irreversible pulpitis[21]

Table 2 Diagnostic uses of pulp tests in clinical practice

Diagnostic use	Rationale
Diagnosis of pain	The diagnosis of orofacial pain can be challenging and the pain can be difficult to localise.[22] Pulp testing can assist in the location and diagnosis of pain in the trigeminal area.[23] A normal response to pulp testing may help eliminate a diagnosis of pulpal pathology in orofacial pain of unknown aetiology. Conversely, a negative response or exaggerated response to pulp testing may indicate pulpal or periapical pathology and confirm the presence of disease of endodontic origin
Prior to restorative or orthodontic treatment	Pulp testing can be used to confirm pulpal health or to diagnose endodontic disease prior to operative restorative or orthodontic procedures[6]
Investigation of radiological lesions/ confirmation of normal radiological anatomy	Radiological lesions including periodontal lesions, cysts, fibrous lesions, congenital abnormalities and even neoplastic conditions may present as periapical radiolucencies, similar to those associated with apical periodontitis.[24] Pulp testing can help to confirm if these lesions are of endodontic origin. Similarly, the mental foramen and incisive canal are two normal anatomical structures which may be mistaken for periapical radiolucencies. Pulp testing of adjacent teeth can be used to exclude pulpal pathology and endodontic disease
Post-trauma assessment and monitoring	Sensibility testing is an integral part of pulp assessment following trauma. International Association of Dental Traumatology guidelines recommend that sensibility testing should routinely be used in the assessment of traumatised teeth at baseline and at key review appointments.[25] Careful interpretation of sensibility test results following trauma is necesssary as the validity of results can be questionable. For example, in traumatised teeth where pulpal nerve fibres have been damaged, there may be no response to thermal or electrical stimuli, but pulpal blood supply may remain viable.[26] The interpretation of sensibility testing results following dental trauma will be discussed in more detail in a later section
Assessment of anaesthesia prior to endodontic treatment	Soft tissue anaesthesia has been reported to correlate poorly with pulpal anaesthesia.[27] Thermal or electric sensibility testing can be used as a more reliable assessment of pulpal anaesthesia prior to undertaking endodontic treatment[28]
Monitoring of teeth following vital pulp therapy	Teeth treated with vital pulp therapy such as indirect pulp capping, direct pulp capping or pulpotomy can be monitored for success or failure of the procedure using a combination of pulp testing, clinical and radiological examination and accurate history taking[29]

Terminology

Often the terms pulp vitality, sensibility and sensitivity are used synonymously by clinicians. It is important to understand the difference between these terms and to use appropriate terminology when communicating with colleagues. Definitions of pulp vitality, sensibility and sensitivity are summarised in Table 1.

Diagnostic uses of pulp testing

There are multiple uses of pulp testing in clinical practice which can provide important diagnostic information and aid in treatment planning. The uses of pulp tests in clinical practice and the rationale for their use is summarised in Table 2.

Diagnostic accuracy of pulp tests

Determining the true state of pulpal health is only possible by examining histological samples of pulp tissue to assess the extent of inflammation or the presence of necrosis.[15] This is not feasible clinically; therefore, surrogate markers of pulpal health, such as the assessment of pulpal blood flow (vitality testing) and nerve fibre response (sensibility testing) are used.[17] It has been demonstrated that there is good correlation between the results of sensibility tests and the histological status of the pulp.[18] However, this relationship is not always consistent due to occasional false responses. False responses can be misleading in some clinical situations so it is important that pulp sensibility testing is considered

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alongside the other 'jigsaw pieces' of patient history and other important clinical and radiological information (Fig. 1) when making an endodontic diagnosis.[19] Understanding the limitations and the diagnostic accuracy of the various sensibility tests can help a clinician to interpret the results correctly and reach an accurate diagnosis.

Sensitivity and specificity

Sensitivity and specificity are statistical terms that can be used to describe the diagnostic accuracy of various pulp testing methods.[14,15] The sensitivity of a test measures the proportion of patients tested who truly have the disease and the test result also correctly finds that they have the disease.[20] The specificity of a test measures the proportion of patients who do not truly have the disease and the test result also correctly finds that they do not have the disease.[20] In relation to pulp sensibility testing, the sensitivity of a test would describe the proportion of teeth tested which are non-vital (that is, have no pulpal blood flow), where the sensibility test finding is no nerve fibre response. In relation to pulp sensibility testing, the specificity of a test would describe the proportion of teeth tested which are vital (that is, have pulpal blood flow) and the sensibility test result has a positive nerve fibre response. A summary of the pooled sensitivity and specificity from a systematic review of five different pulp testing methods[14] can be seen in Table 3.

The systematic review by Mainkar and Kim,[14] summarised in Table 3, showed that LDF and PO had the highest sensitivity and specificity of all pulp testing methods, further supporting the view that these tests are the current 'gold standard' in pulp testing.[7,8,9] As previously discussed, these tests require expensive equipment and are impractical for use by many general dentists. On the other hand, cold pulp testing which is widely used was found to have a moderate diagnostic accuracy when evaluating both vital and non-vital teeth. A pooled sensitivity of 0.86 means that in 86% of cases a cold pulp test would correctly identify a non-vital (no pulpal blood flow) tooth with a negative nerve fibre response. Therefore, in approximately 14% of cases there may be a false result with a patient-reported 'positive' response but where the pulp is in fact necrotic. A pooled specificity of 0.84 means that in 84% of cases a cold pulp test would correctly identify a vital tooth (with pulpal blood flow) with a positive nerve fibre response. The corollary is that in approximately 16% of cases there may be a 'false negative' result, indicating that the tooth is non-vital when in fact it is vital.

Electrical pulp testing showed the lowest pooled sensitivity among all pulp testing methods, with the results indicating that in approximately 28% of cases there may be a 'false positive' result where there is a patient-reported 'positive' response, but the pulp is in fact necrotic.[14] It can be inferred from this that cold pulp testing is better than electric pulp testing at correctly identifying a tooth as non-vital (no nerve fibre response) when the tooth is indeed non-vital. Conversely, the results show that electrical pulp testing had a pooled specificity value of 0.92 which was comparable to LDF (0.95) and and PO (0.95).[14] This means that electrical pulp testing can be considered more reliable when identifying vital teeth than non-vital teeth. Due to the low sensitivity of electrical pulp testing, a prudent approach would be to check every positive response result with cold pulp testing to determine if the results are in agreement. Should the results from these tests not corroborate each other, then the clinician should repeat the tests and consider the results in the context of the other jigsaw pieces discussed in Figure 1.

Heat testing was found to be the least accurate pulp testing method, with the lowest values in all diagnostic accuracy categories except sensitivity. Furthermore, the authors found a wide variation in diagnostic values among the studies for heat thermal testing in comparison to the other sensibility and vitality tests.[14] Heat pulp testing is therefore not recommended as a primary pulp testing method but can be useful to reproduce a patient's chief complaint of heat hypersensitivity or to provoke a painful response for the diagnosis of a vital but diseased pulp.

Fig. 1 A summary of the information a clinician may consider when making an endodontic diagnosis

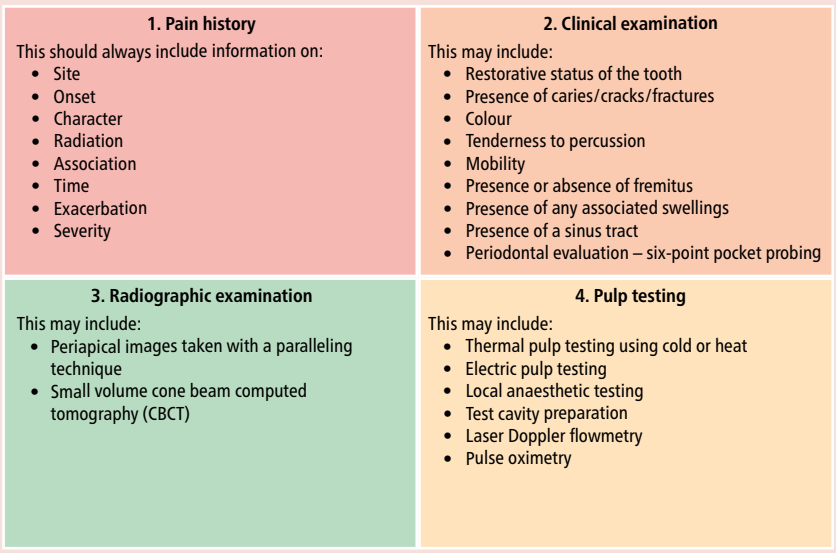

Table 3 Summary of pooled sensitivity and specificity of five different pulp testing methods[14]

Pulp testing method	Pooled sensitivity	Pooled specificity
Cold pulp test (95% confidence interval)	0.867 (0.810–0.909)	0.843 (0.773–0.895)
Electrical pulp test (95% confidence interval)	0.720 (0.647–0.783)	0.928 (0.877–0.959)
Heat pulp test (95% confidence interval)	0.778 (0.647–0.869)	0.665 (0.485–0.807)
Laser Doppler flowmetry (95% confidence Interval)	0.975 (0.926–0.992)	0.950 (0.907–0.974)
Pulse oximetry (95% confidence interval)	0.973 (0.796–0.997)	0.954 (0.909–0.978)

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Conclusion

There are multiple uses of pulp testing in clinical practice which can provide important diagnostic information and aid in treatment planning. The consequences of an inaccurate diagnosis include ongoing pain and infection for the patient or a biologically-unnecessary and financially-costly root canal treatment. Even with its acknowledged limitations, pulp sensibility testing remains a beneficial aid in endodontic diagnosis. Given the moderate diagnostic accuracy of cold testing and the low sensitivity of electrical pulp testing, it is advisable that cold testing should be used in conjunction with electrical pulp testing so that the results from one test will corroborate the findings of the other.[6] The second part of this series will focus on clinical techniques in pulp sensibility testing and factors to consider when interpreting pulp sensibility testing results.

Ethics declaration

The authors declare no conflicts of interest.

Author contributions

The original concept for the paper was devised by Kasim Butt and was developed, jointly, in discussion between the two authors. Both authors wrote substantial parts of the paper, with Ian Harris revising successive drafts. Both authors contributed equally to the final approval of the version to be published.

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