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Laser Doppler flowmetry in endodontics: a review

A Project Submitted to

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By

Noor Alhuda Saad Khudaer

Montaha Fares Hashim

Supervised by

Asiss. Lecturer Ghufran I. Ibrahim
B.D.S., M.Sc.

Laser Applications

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بسم الله الرحمن الرحيم

وَأَن لَّيْسَ لِلْإِنسَانِ إِلَّا مَا سَعَى

وَأَنَّ سَعْيَهُ سَوْفَ يُرَى

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صدق الله العلي العظيم

Certification of the supervisor

I certify that this project **" Laser Doppler Flowmetry In Endodontics: A Review"** was prepared by the fifth-year student Montaha faries hashim and Noor alhuda saad under my supervision at the college of dentistry /Ahur university in partial fulfilment of the graduation requirement for the Bachelor Degree in Dentistry.

Dr . Ghufran Ismail Ibrahim
2025/3/

Dedication

I dedicate this work to my family, friends, mentors, and all those who have supported and believed in me throughout this journey. Your love, encouragement, and guidance have been my strength, especially during the toughest times. To my mentors, thank you for sharing your wisdom and pushing me to always strive for excellence. To my family, your unwavering support has been my foundation, and to my friends, thank you for the laughter and companionship that kept me going. This accomplishment would not have been possible without all of you.

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ABREVIATIONS AND SYMBOLS

Abbreviation	Term
LDF	Laser Doppler Flowmetry
RP	Reversible Pulpitis
IP	Irreversible Pulpitis
PC	Pulp Chamber
RC	Root Canals
PV	Pulp Vitality
TT	Thermal Tests
ET	Electrical Tests
LDF in Endo	Laser Doppler Flowmetry in Endodontics
Nd: YAG	Neodymium-doped Yttrium Aluminum Garnet

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Abstract

Assessing dental pulp vitality is a crucial aspect of endodontic diagnosis and treatment planning. Traditional methods such as thermal and electric pulp testing provide indirect assessments of pulp health, often yielding subjective results. Laser Doppler Flowmetry (LDF) has emerged as a non-invasive and objective technique for evaluating pulp vitality by measuring blood flow within the pulp tissue. This study explores the diagnostic methods used to assess pulp vitality, with a particular focus on the principles, applications, and advantages of LDF in endodontics.

The mechanism of LDF, its primary indications, and the factors influencing its accuracy are discussed in detail. By enhancing diagnostic precision, LDF contributes to improved clinical decision-making and better patient outcomes in endodontic practice.

Introduction

The progression of caries into deep dentine ultimately results in inflammation of the pulp, followed by pulp necro sis and, finally, apical periodontitis if adequate restorative treatment is not undertaken. Furthermore, chronic stimuli, injuries, and other conditions can lead to dentinal hypersensitivity, pulp necrosis, and root canal obliteration. Before commencing root canal treatment, information is collected regarding the history, clinical examination and special tests to allow a diagnosis **(Cohen, S. & Hargreaves, 2016.).**

There are several ways to obtain information about the condition of the pulp, including hot and cold thermal testing, electric pulp testing, and laser doppler flowmetry (LDF). Thermal and electric pulp testing remain the appropriate clinical tests to use. However, both thermal and electric pulp testing are crude and nonquantitative**. (Cohen, S. & Hargreaves 2016.).**

Each of the sensibility tests involves stimulating sensory nerve responses, at best, a proxy-marker of pulp health, so stimulation of the nerve fibers is not an ideal method to determine vitality status. As a result, teeth that have temporarily or permanently lost their sensory function (e.g. anaesthetized, traumatized, or teeth involved in orthognathic surgery) may be nonresponsive to these tests. However, they may have intact vasculatures. Moreover, some nerve fibers may be highly resistant to necrosis and so may remain reactive long after the surrounding tissues have degenerated. Therefore, thermal and electric tests may give false-positive responses if only the pulp vasculature is damaged. So, vascular supply and not innervation is the most accurate determinant of pulp vitality. **(Cohen, S. & Hargreaves 2016.).**

Tests for assessing vascular supply that rely on the passage of light through a tooth have been considered as possible methods for detecting pulp vitality.

Laser Doppler flowmetry is a true pulp vitality test because it can detect pulpal blood flow without relying on the patient's response and is thought to provide more accurate pulp status. This is a non-invasive, objective, painless, and semiquantitative measurement which has been proved to be a reliable method for pulpal blood flow measurement. **(Cohen, S. & Hargreaves 2016).**

Laser light is transmitted to the pulp by means of a fiber optic probe. Scattered light from moving red blood cells will be frequency-shifted whilst that from the static tissue remains unshifted. The reflected light, composed of Doppler-shifted and unshifted light, is returned by afferent fibers and a signal is produced **(Cohen, S. & Hargreaves 2016).**

The aim of study

The primary aim of this study is to evaluate and compare different diagnostic methods for assessing dental pulp vitality, with a specific focus on Laser Doppler Flowmetry (LDF). Also, it will address the mechanism, indications, influencing factors, limitations and practical considerations in the use of LDF.

CHAPTER 1

Literature Review

1.1 Anatomy of the Dental Pulp

The dental pulp is a soft, living tissue located at the core of the tooth surrounded by the dentin and encased in the pulp chamber and root canals. It plays a critical role in tooth development, sensory function, and maintaining tooth vitality. **(Nör, *et al* 2018).**

1.1.1. Structure of the Pulp

The pulp consists of four primary components: blood vessels, nerves, connective tissue, and cells

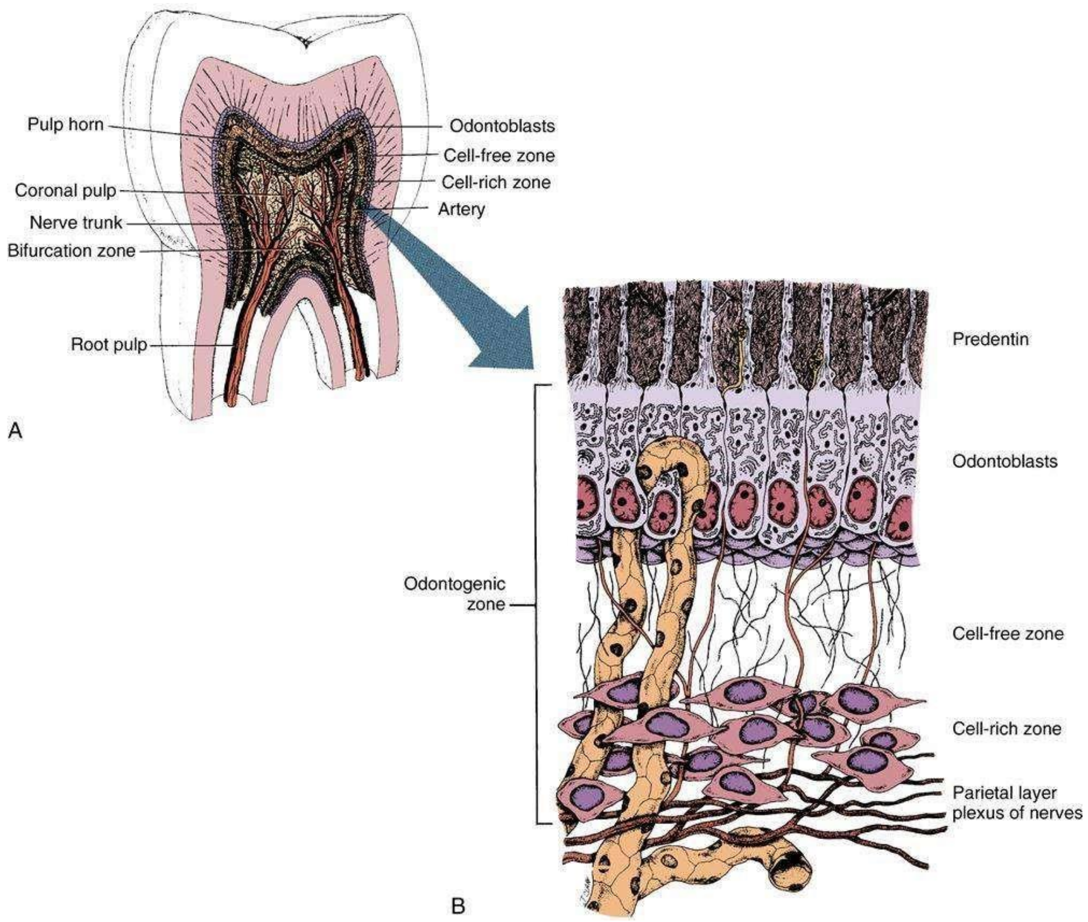


Figure 1. Structure of the Pulp. **(Nör, *et al* 2018)**

1. Blood Vessels: The pulp has an abundant blood supply that nourishes the tooth. These blood vessels enter the pulp through the apical foramen and branch out within the root canals. Blood vessels are crucial for the pulp's vitality and are involved in maintaining tissue health and responding to injury. **(Nör, *et al* 2018)**

2. Nerves: The pulp contains sensory nerves that transmit pain signals to the brain. These nerves are responsible for the sensation of pain in response to stimuli such as temperature changes, pressure, and chemical irritants.

3. Connective Tissue: The pulp is made up of soft connective tissue, which provides structural support to the pulp. It contains collagen fibers, ground substance, and extracellular matrix. This tissue helps protect the pulp from injury and supports the repair process when damage occurs. **(Nör, *et al* 2018, Goldberg *et al* 2015)**

4. Cells: Various cells are found in the pulp, including fibroblasts, odontoblasts, and immune cells. Odontoblasts are responsible for dentin formation, while other cells help with tissue regeneration and immune responses during pulp inflammation**. (Nör, *et al* 2018, Goldberg *et al* 2015)**

1.1.2. Pulp Chamber and Root Canals

The pulp is housed within the pulp chamber (in the crown) and the root canals (in the roots). The pulp chamber is large in young teeth and diminishes as the tooth matures. The root canals vary in number depending on the tooth and are connected to the surrounding periodontal ligament via the apical foramen. **(Berman & Hargreaves 2019)**

The pulp chamber is a continuous structure that extends down to the root canals. In permanent teeth, the pulp size decreases with age, leading to a more narrowed chamber and canals, primarily due to the deposition of secondary dentin. **(Stashenko *et al*., 2020)**

1.2. Pulpitis: Definition and Pathophysiology

Pulpitis refers to the inflammation of the dental pulp, a response to various forms of dental trauma, including caries, dental procedures, or physical injury. It is typically categorized into two forms: reversible pulpitis and irreversible pulpitis**. (Berman & Hargreaves 2019)**

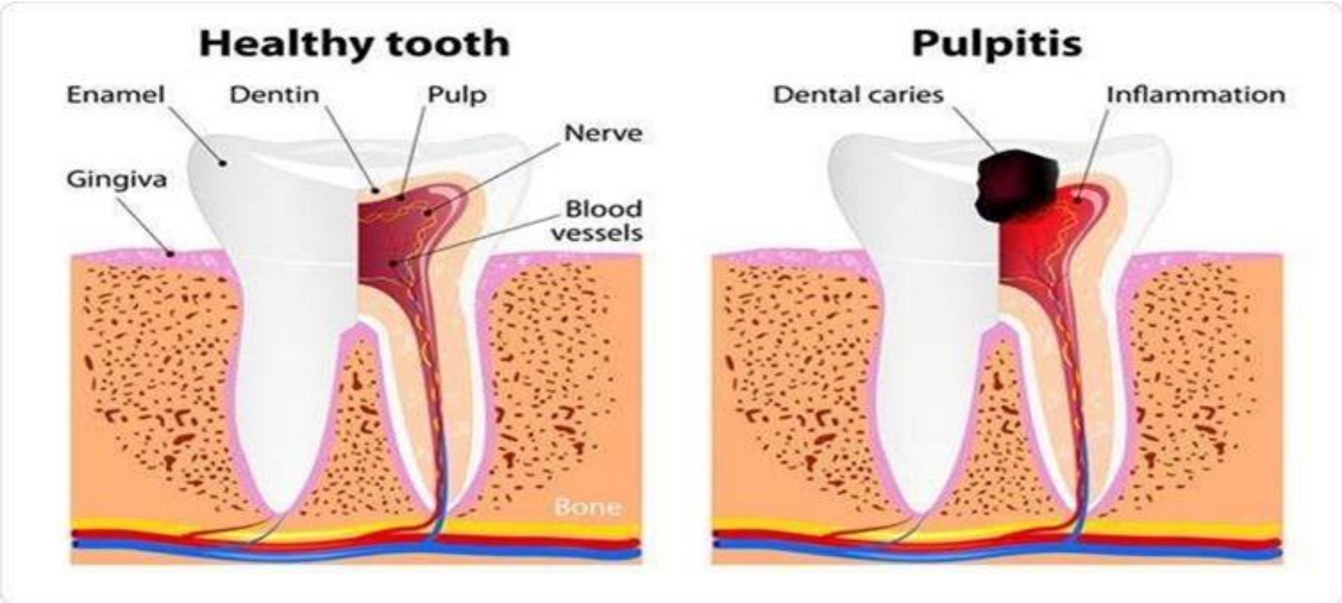


Figure 2: pulpitis. **(Berman & Hargreaves 2019)**

1.2.1. Causes of pulpitis

Pulpitis is caused by infection or injury to the tooth that compromises pulp tissue. The most common cause is dental caries, which can gradually lead to bacterial invasion of the pulp. Other causes include:

Trauma: Physical injuries like fractures or luxation can disrupt the blood supply to the pulp, leading to inflammation or necrosis. **(Berman & Hargreaves 2019)**

Restorative Procedures: Aggressive or deep cavity preparations, repeated fillings, or the use of certain materials can irritate the pulp, leading to inflammation. (Berman, et al 2019, Ricucci et al., 2010, Estrela et al., 2014) **Thermal or Chemical Irritation:** Hot and cold temperature extremes or the use of irritating chemicals during dental treatments can cause pulp irritation. **(Berman, *et al* 2019, Ricucci *et al*., 2010, Estrela *et al*., 2014)**

1.2.2. Types of Pulpitis

1. Reversible Pulpitis: This is a mild form of inflammation where the pulp can recover if the irritant (such as caries or trauma) is removed. Symptoms typically include sharp, short pain that subsides once the irritant is eliminated. Reversible pulpitis is usually a precursor to healing, with the pulp returning to a normal state if treated early. **(Cohen et al., 2020, Ricucci et al., 2010)**

2. Irreversible Pulpitis: In this more severe form, the pulp is extensively damaged and cannot recover. The inflammation is persistent, and the pulp often becomes necrotic. (7). Symptoms include prolonged, severe pain, which may occur spontaneously or be triggered by hot or cold stimuli. Irreversible pulpitis often requires root canal therapy or extraction to eliminate the infected pulp **(Cohen et & Hargreaves 2020)**

1.3. Clinical Features of Pulpitis

1.3.1. Symptoms of Reversible Pulpitis

- Sharp, transient pain: Typically triggered by thermal stimuli, such as hot or cold food or drinks.

- Pain subsides quickly once the stimulus is removed. **(Pitt et al., 2019)**

- No lingering discomfort: The pulp is still vital and able to recover when the irritant is removed **(Pitt et al., 2019, Hargreaves et al., 2015)**

1.3.2. Symptoms of Irreversible Pulpitis

- **Severe, lingering pain:** Pain may continue long after the stimulus has been removed, often described as a dull ache or throbbing.

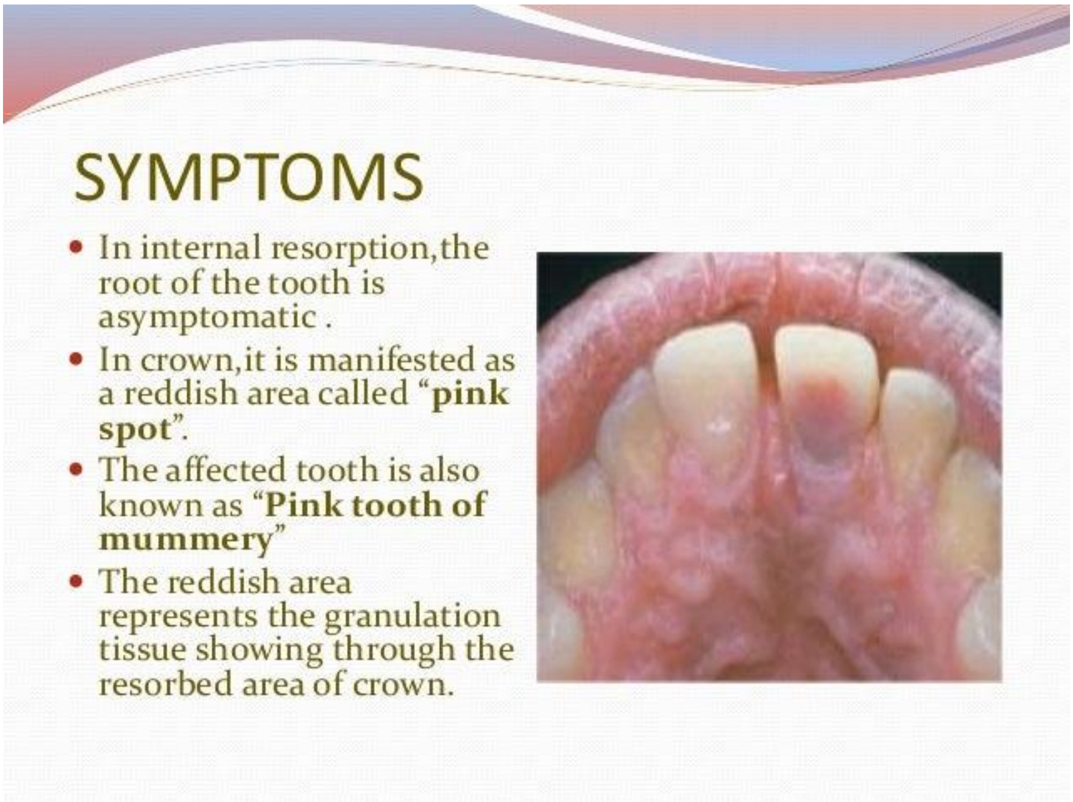


Figure 3. Symptoms of Irreversible Pulpitis. (**Singh, A. 2015)**

• **Spontaneous pain:** Pain can occur without an apparent external stimulus. **(Pitt et al., 2019)**

• Pain intensity increases over time, with some patients experiencing unrelenting discomfort, especially at night **(Pitt et al., 2019, Hargreaves et al., 2015)**

1.3.3. Pain Characteristics

• In reversible pulpitis, pain is typically sharp, localized, and transient.

• In irreversible pulpitis, pain is usually more intense, prolonged, and may involve both spontaneous pain and sensitivity to temperature changes. **(Pitt et al., 2019)**

1.4 Diagnosis of Pulpitis

Pulpitis is diagnosed based on patient history, clinical examination, and various diagnostic tests. A detailed patient history helps identify the causes of pulp inflammation, such as trauma, caries, or previous restorative treatments.

Clinical examination includes:

1. Thermal Testing: Applying hot or cold stimuli to the tooth can help evaluate the pulp's response. A positive response to cold in reversible pulpitis typically subsides after the stimulus is removed. A prolonged response, especially to heat, may indicate irreversible pulpitis **(Jafarzadeh & Rosenberg, 2009)**

1. Electric Pulp Testing: This method assesses the pulp's ability to conduct electrical stimuli, aiding in the evaluation of pulp vitality. **(Jafarzadeh & Rosenberg, 2009)**

2. Percussion and Palpation Tests: These are used to check for sensitivity in the surrounding periodontal tissues, which can help distinguish between pulpitis and periodontal disease**. (Jafarzadeh & Rosenberg, 2009)**

3. 4- Flowmetry in dentistry refers to the measurement of blood flow, specifically within the dental pulp. Its primary purpose is to evaluate pulp vitality, determining whether the pulp has an adequate blood supply. This information helps guide clinical decisions, such as preserving the pulp or performing endodontic (root canal) treatment. **(Jafarzadeh & Rosenberg ,2009)**

1.5 Common Techniques of Flowmetry in Dentistry

Laser Doppler Flowmetry (LDF): Uses a laser beam to measure blood flow by analyzing light scattering caused by the movement of red blood cells. **(Cohen et al., 2020)**

Pulse Oximetry: Measures oxygen saturation in the blood, although it is less commonly used than LDF in dentistry. **(Cohen et al., 2020)**

1.5.1. Applications

- Determining whether the dental pulp is vital or non-vital after trauma or deep caries.

- Assessing pulp responses to treatments, such as restorations or orthodontic procedures.

Differentiating between pathological conditions, such as apical lesions related to vital or non-vital pulp**. (Cohen & Hargreaves 2020)**

Flowmetry is advantageous because it is non-invasive, painless, and provides objective results compared to traditional methods like thermal or electric pulp testing. **(Cohen & Hargreaves 2020)**

1.5.2. Benefits of LDF in Endodontics

- Accurate Pulp Vitality Assessment: LDF directly measures pulpal blood flow, providing a reliable indicator of pulp health

- Early Detection of Pulpal Changes: By monitoring blood flow, LDF can identify early signs of pulpal inflammation or necrosis, facilitating timely interventions. **(Pitt et al., 2019, Ricucci et al., 2010)**

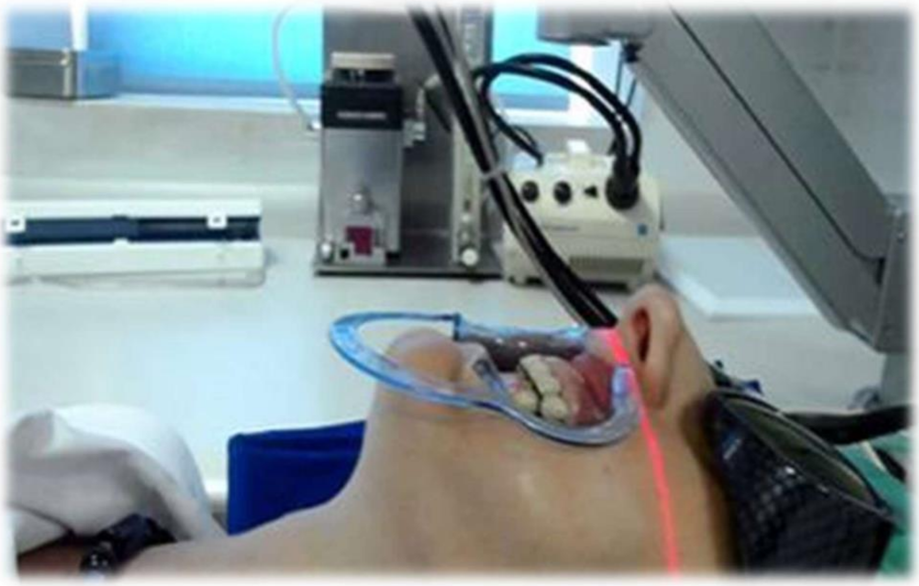
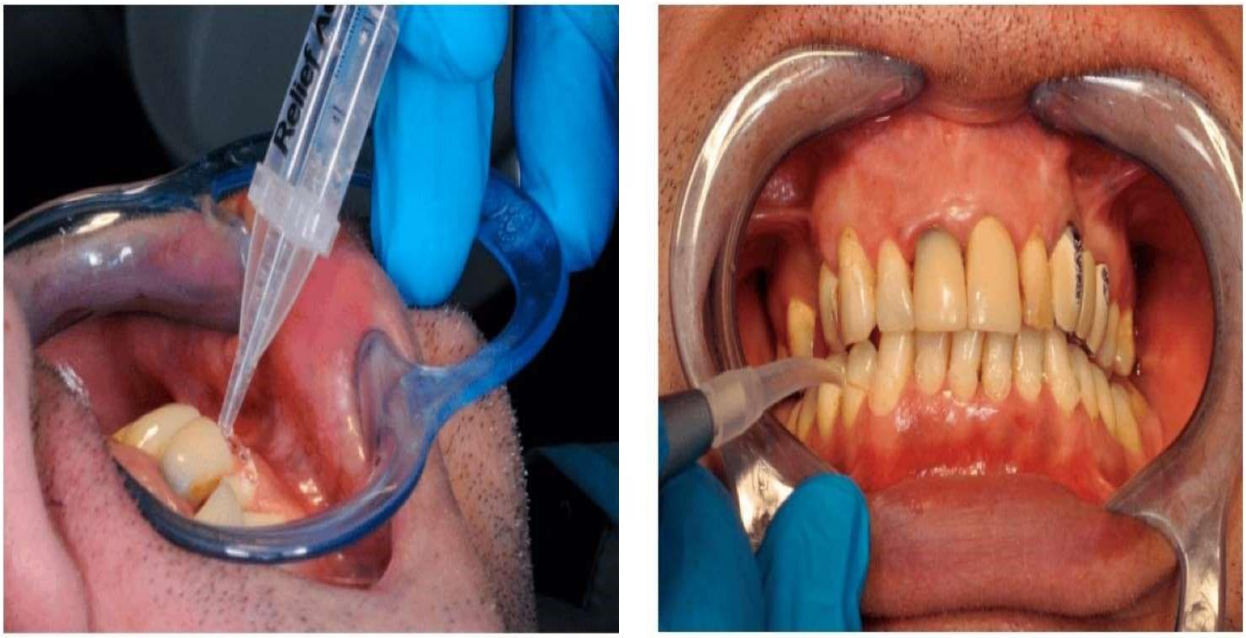


Figure 4. Laser Doppler line scanning procedure. **(Pitt *et al*., 2019)**

- Non-Invasive and Painless: Unlike traditional sensitivity tests, LDF does not cause discomfort, enhancing patient acceptance. **(Pitt *et al*., 2019, Ricucci *et al*., 2010)**

- Objective Measurements: LDF provides quantifiable data on pulpal blood flow, reducing subjective interpretation associated with conventional tests.
- Monitoring Healing Processes: LDF can track revascularization in traumatized teeth, offering insights into healing and treatment efficacy. **(Pitt et al., 2019, Ricucci *et al.*, 2010)**



(a) (b)

Figure 5. Treatment application: (a) desensitizing gel in the cervical vestibular area; (b) Nd: YAG laser radiation, directly through the gel, on a tooth in the fourth quadrant. **(Fouad & Abbott, 2003)**

(a) (b)

Figure 6. Laser-Doppler flowmetry (LDF) recording process: (a) periodontal liquid dam as gingival barrier applied around every tooth; (b) position of the impression with the LDF probe. **(Fouad & Abbott, 2003)**

The following can expect After undergoing Laser Doppler Flowmetry (LDF) for dental pulp vitality assessment:

Immediate Resumption of Activities: Since LDF is non-invasive and painless, the patient can return to the daily routine immediately after the procedure without any restrictions.

No Post-Procedure Discomfort: Patients typically experience no pain or discomfort following LDF, as the technique does not involve any surgical intervention or stimulation that could cause irritation. **(Jafarzadeh *et al.*, 2009)**

- No Special Aftercare Required: There are no specific post-procedure care instructions to follow after LDF. You can maintain your regular oral hygiene practices without any modifications**.**

Discussion of Results: Your dentist will review the findings from the LDF assessment with you. Based on the results, they will discuss any necessary treatment plans or follow-up appointments if required. **(Jafarzadeh *et al.*, 2009)**

1.6 Mechanism of LDF:

1. Laser Light Emission: A low-power laser beam is directed onto the tissue through a fiber optic probe.

2. Interaction with Tissue: The laser light penetrates the tissue and encounters both stationary structures and moving red blood cells.

3. Doppler Shift: Light scattered by moving red blood cells undergoes a frequency shift (Doppler shift), while light scattered by stationary components remains unshifted.

4. Detection and Analysis: The backscattered light, containing both shifted and unshifted frequencies, is collected and analyzed. The proportion of frequency shifted light correlates with the velocity and concentration of red blood cells, providing a measure of blood flow. **(Jafarzadeh *et al.*, 2010, Estrela *et al.*, 2014, Hargreaves *et al.*, 2015)**

This method allows for real-time monitoring of microvascular blood perfusion in various tissues, including dental pulp, aiding in assessments of tissue vitality and health.

In dental applications, LDF has been utilized to assess pulp vitality by measuring blood flow within the tooth's pulp chamber. The technique involves transmitting laser light to the pulp via a fiber optic probe; scattered light from moving red blood cells is frequency-shifted, while that from static tissue remains unshifted. **(Hargreaves *et al.*, 2015, Ghouth *et al.*, 2019)**

It's important to note that while LDF provides valuable information about blood flow, factors such as movement artifacts and the presence of surrounding tissues can influence the accuracy of measurements. Therefore, proper technique and calibration are essential for obtaining reliable data. **(Jafarzadeh *et al*., 2010)**

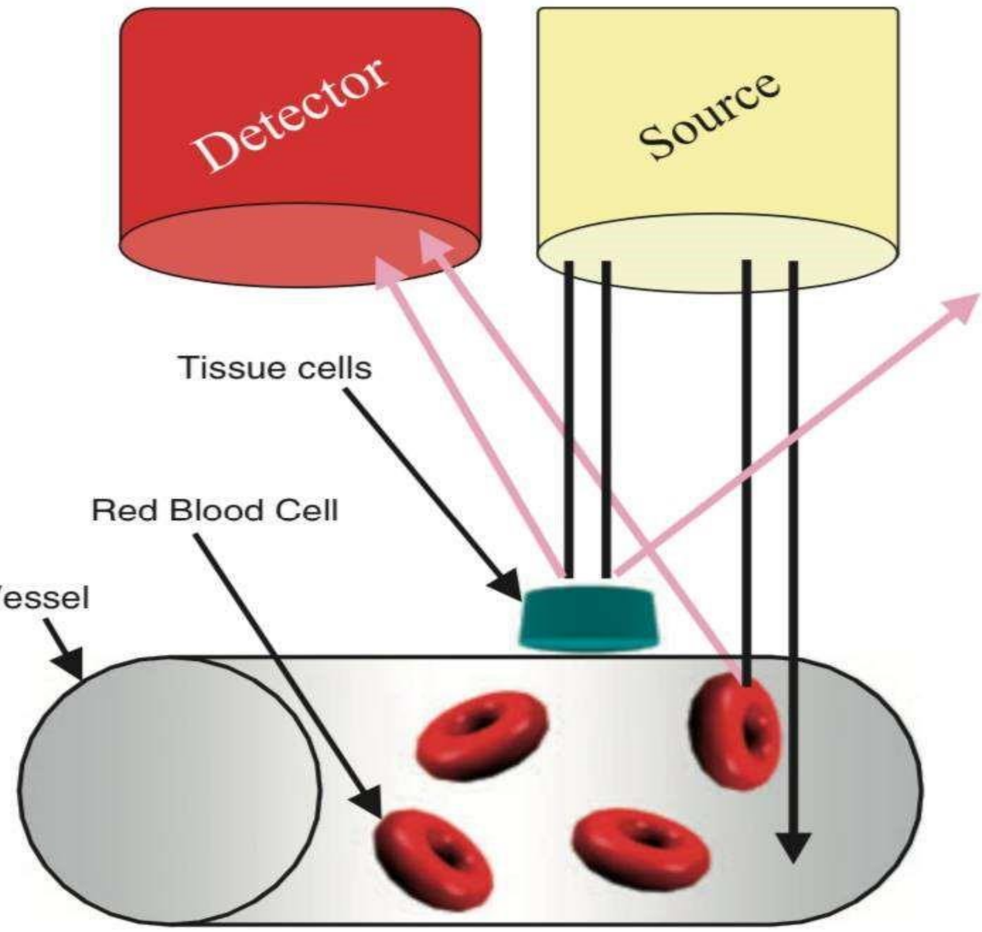


Figure 7. Doppler principle . **(Jafarzadeh *et al*., 2010)**

1.7 The primary indications for using LDF include

1. Assessment of Pulp Vitality: LDF provides an objective measurement of pulpal blood flow, aiding in determining whether the dental pulp is vital or nonvital.

2. Evaluation of Traumatized Teeth: In cases of dental trauma, such as luxation or avulsion injuries, LDF can monitor revascularization and healing of the pulp tissue.

3. Diagnosis of Pulpal Pathology: LDF assists in differentiating between reversible and irreversible pulpitis by evaluating changes in blood flow within the pulp. (Jafarzadeh et al., 2009)

4. Monitoring Pulpal Responses to Treatment: LDF can be used to assess the effects of various dental procedures, such as orthodontic treatments or restorative procedures, on pulpal blood flow.

5. Differential Diagnosis of Periapical Lesions: LDF helps distinguish between periapical lesions associated with vital pulps and those with necrotic pulps by assessing pulpal blood flow. (Jafarzadeh et al., 2009)

6. Evaluation of Pulpal Status in Immature Teeth: In young patients with developing teeth, LDF can assess pulp vitality without the discomfort associated with traditional sensitivity tests. (Jafarzadeh et al., 2009)

7. It's important to note that while LDF offers several advantages, such as being non-invasive and painless, it requires proper technique and calibration to ensure accurate readings. Additionally, factors like blood flow in surrounding tissues can influence measurements, so appropriate isolation of the tooth during assessment is essential**.** **(Jafarzadeh *et al.*, 2009)**

1.8 The factors effect on the result

1. Probe Pressure: Applying excessive pressure with the LDF probe can compress underlying tissues, leading to reduced blood flow and altered readings. Conversely, insufficient pressure may result in weak signals. Maintaining appropriate probe pressure is essential for accurate measurements.

2. Environmental Conditions: External factors such as ambient temperature, humidity, and lighting can affect LDF readings. For instance, temperature fluctuations can influence blood vessel dilation and constriction, thereby altering blood flow. Consistent environmental conditions are crucial for reliable measurements**.**

3. Motion Artifacts: Patient movement during the procedure can introduce artifacts into the LDF signal, leading to inaccurate readings. Ensuring patient stability and minimizing movement are important to obtain precise measurementsc **(Fouad & Abbott, 2003)**

4. Instrument Calibration: Proper calibration of the LDF device is vital for accurate measurements. Calibration ensures that the instrument's readings correspond correctly to actual blood flow values. Regular calibration checks are recommended to maintain measurement accuracy.

5. Tissue Characteristics: The optical properties of the tissue being measured, such as pigmentation and thickness, can influence LDF readings. Variations in tissue composition may affect light scattering and absorption, thereby impacting the accuracy of blood flow measurements. **(Fouad & Abbott, 2003)**

6. Laser Wavelength: The choice of laser wavelength can affect the depth of tissue penetration and the sensitivity of the LDF measurement.

Selecting an appropriate wavelength is important to optimize measurement accuracy for specific tissues.

7. Signal Processing Parameters: The settings used for signal processing, such as bandwidth and filtering, can influence the quality of the LDF signal.
Inappropriate settings may lead to noise interference or loss of relevant data. Adjusting these parameters appropriately is essential for accurate measurements.

Understanding and controlling these factors are essential for obtaining accurate and reliable LDF measurements, thereby enhancing the diagnostic utility of the technique in clinical practice. **(Fouad & Abbott, 2003)**

CHAPTER 2

Conclusions

Conclusions

According to the previous studies which assessed the efficacy of the laser doppler flowmetry technique in diagnosing pulp vitality after dental trauma showed that laser Doppler flowmetry is a useful tool for diagnosing traumatic pulp necrosis. However, laser Doppler flowmetry has some drawbacks Therefore, laser Doppler flowmetry can be used as a supplementary diagnostic tool but not to replace radiological or clinical examinations.

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Thank you!