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Review article

LASER DOPPLER FLOWMETRY IN THE EVALUATION OF PERIODONTAL HEALTH AND DISEASE

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ABSTRACT

Laser Doppler Flowmetry (LDF) is a method of measuring blood flow in tissues. Periodontal tissues in health and disease, as well as peri-implant mucosa, have microcirculation which can be easily monitored by LDF. So LDF can be used as an additional diagnostic tool for evaluation of gingival health or inflammatory diseases. The changes in blood flow can provide additional data for detailed and personalized treatment approaches for patients with periodontitis, implant placement procedures and mucogingival surgeries. This review is focused on the working principles and application of LDF in periodontal practice, the advantages, disadvantages and its limitations.

Key words: laser, dopler, flowmetry, periodontal health, periodontitis

INTRODUCTION

Laser Doppler Flowmetry (LDF) is an inexpensive, noninvasive method of measuring the continuous circulation of blood flow in tissue. It has been extensively used in medical and dental research.

LDF utilizes the Doppler effect (or shift), proposed in 1842 by the Austrian physicist Christian Doppler. Doppler effect means the frequency (wave length) change that light, as well as all waves, undergo being reflected by moving objects such as red blood cells. A beam of low power laser light (2 mW He-Ne at 632.8 nm) is led by an optical fiber to a measuring head. From here it enters the tissue to which it is applied by a hemisphere with a 1 mm radius. Blood cells traversing this volume are struck by the light and reflect it, whereby the light undergoes a doppler shift. The surrounding tissue also reflects the light but in an unshifted manner. Thus the volume of illumination is a mixture of an unshifted and a doppler shifted component, the magnitude and frequency of the latter being related to the number of moving cells and their velocity. The measured microflow is proportional to an arbitrary scale (0 to 10) [1].

A laser Doppler instrument output gives flux, velocity and concentration of the moving blood cells [2]. Flux is a term, used to estimate the blood flow – a quantity, proportional to the average speed of the blood cells and their concentration. This is expressed in arbitrary perfusion units – that are linearly related to flux.

LDF is a reliable, user-friendly method for the detection of blood flow in oral mucosa, in the gingiva, in the alveolar bone, and in the pulp [3]. Recent studies showed that LDF is a reliable method before implant insertion [4].

LDF has proven to be an effective tool of choice to evaluate microcirculation in the oral cavity, preferentially of the gingiva and dental pulp, respectively [5]. LD techniques enable assessment of tooth vitality after various procedures including bleaching, tooth implants and prepared teeth, surgical intervention after trauma, as well as tracing microcirculation following treatment of gingival diseases, such as inflammation, and gingival blood flow resolution after surgical procedures [6, 7].

Gingival blood supply

The gingiva receives its blood supply mainly through supraperiosteal blood vessels which are terminal branches of big arteries. The various arteries are often considered to supply certain well defined regions of the dentition. In reality, however, there are numerous anastomoses present between the different arteries. Thus the entire system of blood vessels rather than individual groups of vessels should be regarded as the unit supplying the soft and hard tissues of the periodontal complex. Supraperiosteal blood vessels in their course towards the free gingiva divide into numerous small branches which form the subepithelial plexus, located immediately beneath the oral epithelium of the free and attached gingiva. This plexus further forms thin papillary loops to each of the connective tissue papillae projecting into the oral epithelium. The number of such capillary loops is constant over a very long time.

In the free gingiva, the supraperiosteal blood vessels anastomose with the blood vessels from the periodontal ligament and the bone. Beneath the junctional epithelium, another plexus of blood vessels is formed, named dento-gingival plexus. The vessels in this plexus have a thickness of approximately 40 µm, which means that they are mainly venules. They supply the epithelium with various nutrients as well as defense cells (leukocytes). In healthy gingiva, no capillary loops occur in the dento-gingival plexus.

There is a difference in the blood supply of marginal gingiva of the upper and lower jaws [8] as well as a difference between the blood flow at the anterior and posterior teeth [5, 9].

The vascular system of peri-implant mucosa originates only from the supraperiosteal blood vessel on the outer side of the alveolar ridge. This vessel gives branches to the supraalveolar mucosa and to the capillaries beneath the oral epithelium and the vascular plexus located immediately lateral to the barrier epithelium [10].

So, the gingiva at teeth and the peri-implant mucosa have some characteristics in common, but the blood supply apical of the barrier epithelium is different.

Microcirculation is the terminal vascular network where the exchange of substances between the blood and the tissues occurs. Usually, the term refers to a functional unit comprising vessels with a diameter of fewer than 100 ìm, including arterioles, capillaries, and venules. Appropriate vascularization of tissues and an intact microcirculatory bed are prerequisites for adequate tissue perfusion and thus normal functioning.

Page and Schroeder divided the progression of periodontal inflammation into 4 phases – initial, early, established and advanced stages (or lesions). First histopathologic changes marking gingival inflammation are seen in the gingival vasculature. The significant dilatation of the arterioles, capillaries and venules is a predominant sign of the initial lesion, together with increased hydrostatic pressure. Along with the initial dilatation of the vessels in the dentogingival plexus, their number increases due to opening up of previously inactive capillary beds in the phase of the early lesion. Dilated vessels, vascular proliferation and slow blood flow, is characteristic for clinically established gingivitis and periodontitis [11].

LDF could be a useful tool in identifying the early microcirculatory changes in free and attached gingiva. It has been shown that LDF readings are positively correlated with the degree of gingival inflammation. Gingival blood flow is significantly increased in chronic gingivitis patients [12].

LDF proves there are gingival microcirculatory changes in inflamed gingival sites. Kerdvongbundit et al. used LDF to examine the facial soft tissues of 6 maxillary anterior teeth in 12 clinically healthy patients and in 12 patients with signs of chronic gingivitis. The records were significantly different in inflamed sites, compared to those, obtained from healthy free and interdental gingivae and alveolar mucosae. Conservative treatment - scaling and root planning, together with adequate oral hygiene measures, lead to a reduction of blood flow 3 months after. The flows of diseased sites were restored to the same level as the healthy gingiva [13].

It can be an objective tool also to control blood perfusion during the phases of tissue recovery after flap surgery and to track healing progress [14, 15]. One of the first clinical studies regarding flap vascularity changes is performed by Donos et al. in 2005, with flap surgery in patients with advanced generalized periodontitis. The blood flow decreased immediately the following anesthesia and remained in lower values compared to baseline immediately following surgery. After this, an increase was recorded, which remained 1 weekpost op, but 2 weeks after, the blood flow in alveolar mucosa and the palatal sites were very similar to baseline. However, increased blood flow changes were observed at the buccal interdental sites, which remained high up to 2 months following surgery. This pilot study suggested that LDF might present clinical applicability in recording changes in gingival blood flow following periodontal surgery. [16]

LDF can be used in a number of plastic surgery techniques to evaluate the revascularization of grafts and flaps after root coverage procedures and choose a surgical approach which is associated with faster recovery [17].

LDF is a useful tool for assessment of microcirculation not only in the soft tissues but also the alveolar bone. Today, an implant placement and restoration is therapy with high long-term success, if the preliminary planning is carefully performed. Bone density is evaluated by cone beam computed tomography. But bone vascularity is another important factor for osseointegration. After implant site preparation and insertion of the implant, very good microcirculation in the area is necessary for the successful healing process. Human and animal studies showed that LDF is an adequate method for bone vascularity assessment [18] and might determine future implant stability [4].

The advantages of LDF in periodontal practice include non-invasiveness and the ability to measure the microcirculatory flux of the tissue and fast changes of perfusion during provocation [19]. The technique can measure perfusion quantitatively (although relative) in real time.

The disadvantages are the influence of the tissues' optical properties on the perfusion signal, motion artifact noise, lack of quantitative units for perfusion, lack of knowledge of the depth of the measurement and the biological zero signal (perfusion measured at no flow condition).

The limitations of LDF in periodontology are due to the following reasons:

- Morphological characteristics of gingiva – the gingival biotype can influence LDF variability.
- Age of the patient – in older patients, the epithelial thickness is decreased.
- Mechanical stimulation of gingiva– toothbrushing significantly increases gingival blood flow [20].
- Plaque accumulation and subgingival margins of restorations [21].
- Limited diagnostic value in patients with fixed crowns and bridges.
- Smokers – although there was a theory that smoking may not impair gingival blood flow [22], it is proven that smokers are with constant changes in the blood supply of periodontal tissues [23], which vary significantly.

CONCLUSION

LDF can be a useful tool in providing accurate treatment for periodontitis patients, for optimal planning and results after implant therapy and mucogingival procedures. Being a non-invasive method, it is well tolerated by patients. When properly analyzed, the data can offer accurate additional information for personalized treatment modalities in our patients.

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