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Emerging trends in periodontal pocket diagnosis: current to future perspective

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Abstract

Periodontal disease is a chronic inflammatory disease of multifactorial etiology characterized by progressive attachment loss, bone loss and eventually tooth loss. Traditionally Periodontal tissues are clinically assessed using caliberated periodontal probe to assess the extent and severity of periodontal disease. However, manual periodontal probing does not provide adequate information on three dimensional nature of periodontal pockets. Newer noninvasive imaging strategies using Cone Beam Computed Tomography, Optical Coherence Tomography, Endoscopic Capillaroscopy, Photoacoustic imaging, Magnetic Resonance Imaging have been attempted to accurately evaluate Periodontal pockets. This review aims to summarize the existing technology, as well as new imaging strategies that could be utilized for accurate evaluation of periodontal pocket dimensions

Keywords: Periodontal probe, periodontal pocket depth, probing techniques

Introduction

Periodontal disease is a chronic inflammatory disease of multifactorial etiology characterized by progressive attachment loss, bone loss and eventually tooth loss. Destruction of periodontal tissue occur as a consequence of host – immune inflammatory response to plaque bacteria.(1) A variety of risk factors have been identified such as, smoking, diabetes, drug etc. Chronic periodontitis is also recognized as a risk factor for a number of systemic diseases like cardiovascular, diabetes mellitus and rheumatoid arthritis. Periodontal disease and associated tooth loss affects the wellbeing and quality of life. Literature reports that in United States half of adults above 30 years and 64% of adults above 65 years have periodontitis.(2) Hence early diagnosis of Periodontal disease is essential.

Traditionally Periodontal tissues are clinically assessed using caliberated periodontal probe to assess the extent and severity of periodontal disease. Diagnosis of Periodontal disease mainly depends upon clinical measurements and radiographic imaging. Greenstein and Lamster (1995) has reported, both clinical and radiographic measures as the gold standard in determining an individual's healthy Periodontium. However, manual periodontal probing does not provide adequate information on three dimensional nature of periodontal pockets. Newer noninvasive imaging strategies using CBCT, Optical Coherence Tomography, Endoscopic Capillaroscopy, Photoacoustic imaging, Magnetic Resonance Imaging have been attempted to accurately evaluate Periodontal pockets. (3) Accuracy and reproducibility in measuring pocket depth would be a striking adjunct in current technologies which would facilitate analysis of extent and severity of periodontitis.

Generations of Probes

Various types of periodontal probes have been described which serves the purpose of measuring gingival sulcus. Philstrom (1992), described three generations of probe namely; the first generation probe/ conventional manual probes, the second generation probe/ constant force probes, the third generation probes/ constant force automated probes.

Later in 2000, Watts added two more generations to this namely; the fourth generation/ three dimensional probes, the fifth generation probes/ three dimensional probes with ultra sound attached. Advantages and disadvantages of different generations of probe are described in Table 1.

First generation probes / conventional probes

First generation probes are tapered rod like instruments with rounded blunt working end, calibrated in millimeter. Depending on the type of probe, the markings can vary from 1 to 15mm which results in easy detection of probing pocket depth. The working end is placed at 450 angulation to handle by an angled shank. The probe is inserted into the pocket between the gingiva and tooth root, and advanced to the base of the pocket until resistance is met by the first intact collagen fibers. (4) Williams' periodontal probe, invented by Charles H.M. Williams (1963) is considered as a benchmark for all first generation periodontal probes. University of Michigan "O" probe, World Health Organization probe, University of North Carolina probe and Goldman- Fox probe are some of the first generation probes. (Fig:1)

Fig.1: First-generation periodontal probes (left to right): Williams' Graduated, CPITN, UNC-15, Goldman-Fox, Nabers.

Limitations of conventional probing technique

Uncontrolled probing force may allow probe tip to pass beyond the base of the pocket

Visualization errors may occur

To transfer readings assistance is required

Under-estimation of the periodontal pocket

Inability to obtain 3-D information

Second generation probes / constant force probes

Constant pressure probes are pressure sensitive probes which enable better standardization of probing pressure. (Fig:2) Scientific literature demonstrated that probing pressure should be standardized and not exceeds 0.75N. (5) These probes can be used for both general dental practices, as well as periodontal practices. They do not require computerization in dental office

Armitage et al (1977), introduced the first pressure sensitive probe. In 1978, van der Velden and de Vies devised a pressure-sensitive probe with a cylinder and piston connected to an air-pressure system. Subsequently, it was modified with a displacement transducer for electronic pocket-depth reading (6) Slots et al (1993) compared the reproducibility of probing depth of pressure sensitive probes and conventional probes and concluded that pressure-sensitive probe provide higher reproducible probing depth measurements compared to conventional manual periodontal probe.(7)

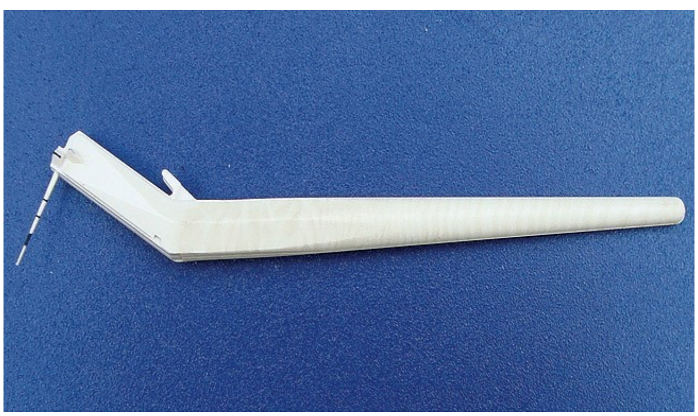

Fig. 2: The True Pressure Sensitive Probe, a second generation periodontal probe.

Third Generation Probe / Constant Force Automated Probes

Despite the benefits of second generation probes, there are certain errors, such as in reading the probe, recording data, and calculating attachment level. Inorder to reduce these errors third generation probes were introduced. These probes uses standardized pressure with digital readouts reducing examiner bias and allows greater probe precision and computerized data storage.

Jeffcoat et al (1986) introduced the third generation probe namely the Foster-Miller probe. Florida probe, Goodson and Kondon fiber- optic probe and the Toronto automated probe are some of the other automated periodontal probes.(Fig 3) Gupta etal (2010) conducted a study comparing the periodontal probing depth and attachment level using florida probe and conventional probe and concluded that efficacy of Florida probes in assessing probing pocket depth and clinical attachment levels is more consistent to that of conventional probe. (8)

Fig. 3: Florida probe, a third-generation periodontal probe

Fourth Generation Probes / Three Dimensional Probes

Fourth generation probing system records sequential probing position along gingival sulcus.(9) These probes are currently under development.

Fifth Generation Probes / Ultrasonographic Periodontal Probe

Fifth generation probes are designed as three dimensional with ultrasound attached to it.(Fig 4) These probes are made inorder to measure the pocket depth without penetrating the probe into the gingival sulcus. The probe uses ultrasound waves to detect, image, and map the upper boundary of the periodontal ligament and its variation over time as an indicator of the presence of periodontal disease (10) Mark et al (2006) compared ultrasonographic periodontal probe to manual and controlled-force probing and concluded that ultrasonographic periodontal probe have a higher efficacy in probing pocket depth assessment comparing to manual and controlled-force probing (11)

Fig. 4: US periodontal probe

Courtesy: Mehta etal Periodontal Probing Systems: A Review of Available Equipment; Dentistry India 2009 vol 3 Iss 3

Table 1: Advantages and disadvantages of different generations of probe

Generation of Probe	Advantages	Disadvantages
First generation probe	Gold standard method Inexpensive Simple and easily available Color coded probes are available for easier identification of readings	Probing force cannot be controlled resulting in penetration of probe beyond base of the probe Sometimes painful Probe tip may pass beyond the pocket depth resulting in over-estimation of the pocket Can sometimes result in under-estimation of the pocket Visualization error Assistant is needed to record data Inability to obtain 3-D information
Second generation probe	Standardization of probing forces Reduces operators error	No computer storage of data Assistant is needed to record data Inability to obtain 3-D information Lack of tactile sensation Probe tip may pass beyond the pocket depth resulting in over-estimation of the pocket Can sometimes result in under-estimation of the pocket
Third generation probe	Standardization of probing forces Computer storage of data Eliminates readout errors	Inability to obtain 3-D information Lack of tactile sensation Probe tip may pass beyond the pocket depth resulting in over-estimation of the pocket Can sometimes result in under-estimation of the

		pocket
Fourth generation probe	Can obtain 3-D information Non invasive	Currently under development
Fifth generation probe	Non invasive Computer storage of data	Expensive Operative should know to interpret echo wave forms

Newer imaging techniques of periodontal pocket

Limitations of these conventional probing techniques led to the introduction of newer imaging strategies. This include Cone beam computerized tomography, Optical coherence tomography, Endoscopic capillaroscopy, Photoacoustic imaging, Magnetic resonance imaging. Advantages and disadvantages of these newer techniques are described in Table 2

Cone beam computerized tomography

In Cone Beam Computed Tomography (CBCT), rotation of x-ray beam is done around the patients head in order to obtain the radiographic images. By this technique the coronal, transaxial, and sagittal planes can be imaged. (Fig 5) A digital 3-D image can be produced by collecting these images from all three planes without any magnification.(12) CBCT is widely used in the field of dentistry, mainly in detection of maxillofacial defects, dental implant placement, endodontic treatment and also for detection of periodontal defects. Vandenberghe et al (2008), they compared the diagnostic values of digital intraoral radiography and cone beam CT (CBCT) in the determination of periodontal defects and concluded that CBCT resulted in more accurate assessment of periodontal disease (13) Another study by Faria et al (2012) concluded that CBCT was the only method that allowed analysis of the buccal and lingual/palatal surfaces and an improved visualization of the morphology of the defect.(14) A recent systematic review (2018), concluded that CBCT is a supporting tool in regenerative periodontal surgery and furcation therapy. (15) Detection of periodontal pocket can be done using CBCT by inserting certain radio-opaque filler particles into the periodontal pocket. Velea et al (2014) placed radio-opaque biomaterials into the periodontal pocket of periodontitis patient. They used gold and silver nanoparticles, ZnO, ZrO_2, and $BaSO_4$ as contrast substances and concluded that ZrO_2 and $BaSO_4$ had sufficient radio-opacity to visualize periodontal pockets in CBCT images. The limitation of this technique is that it was difficult to cover the entire depth of periodontal pocket with these materials.(16)

Fig 5: CBCT machine

Optical Coherence Tomography

Optical coherence tomography (OCT) was introduced by Huang et al as a biomedical imaging modality in 1991.(16) OCT has an advantage of obtaining high resolution images with more accurate penetration depth. The first study using OCT in dentistry was reported in 1998.(Fig 6) Mota et al (2015) analyzed the structure of periodontal tissues in a pig model using 2 OCT systems operating in the Fourier domain at 930 and 1325 nm wavelengths. It was possible to identify free gingiva and attached gingiva. Moreover, gingival thickness and gingival sulcus depth were also non- invasively measured. The authors suggested that OCT systems operating at 1325 nm wavelength are of higher performance than systems operating at 930 nm, due to deeper tissue penetration.(17)

Kim et al (2017) conducted a study on accuracy of OCT in periodontal pocket detection and concluded that it can be used effectively in measuring periodontal pocket.(18) Fernandes et al (2016) suggested that OCT can be effectively used to assess the periodontal structures and measure gingival sulcus and they concluded that OCT is a reliable tool for periodontal tissue evaluation and for reproducible sulcus depth measurements in healthy sites. The limitation of the study was increased procedure time.(19)

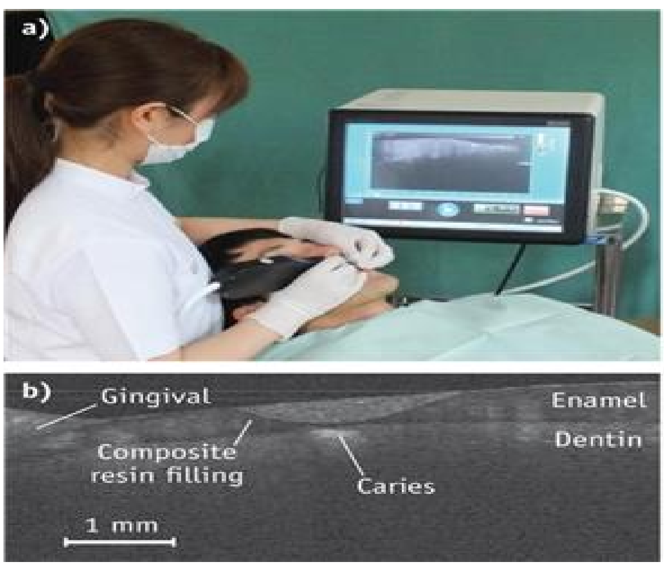

Fig 6: Optical Coherence Tomography Machine

Courtesy: National Center for Geriatrics and Gerontology

Endoscopic Capillaroscopy

Endoscopic Capillaroscopy uses fiber-optic fluorescence imaging systems which include portable handheld microscopes, flexible endoscopes well suited for imaging within hollow tissue cavities and microendoscopes that allow minimally invasive high-resolution imaging deep within tissue. Fiberscopes a type of flexible endoscopes uses fiber optics to inspect remote inaccessible internal structures. Fiber optics are flexible, transparent, can transmit light to a longer distance with less electromagnetic interference. (20)

Townsend et al (2010) demonstrated the feasibility of using fiber- optic probes to visualize directly the periodontal pocket wall through its microcirculation and measured the change in number and diameter of blood vessels associated with periodontal disease. From the study it was concluded that the combination of capillaroscopy and optical fiber technology could obtain high- resolution imaging of the periodontal pocket microcirculation. (21) A study using fiber- optic probe with the video microscopic system in tissues lining the gingival sulcus in periodontally healthy individuals allowed a consistent and repeatable assessment of the gingival microvasculature.(22) However it is not clear whether this imaging modality can be used in measuring periodontal pocket depth.

Fig 7: Endoscopic Capillaroscopy Machine

Courtesy: Townsend etal Periodontal capillary imaging in vivo by endoscopic cappilaroscopy J.Med.Bio.Eng Vol 30 No 2 2010

Photoacoustic Imaging

Photoacoustic imaging is a hybrid imaging modality that combines visible and near infrared excitation with acoustic detection (23) In photoacoustic imaging a near infrared laser excites a light-absorbing target. The target then undergoes spatially confined heating followed by thermoelastic expansion. This generates wideband acoustic waves which is detected with ultrasound transducers for image generation(24)

C.Y. Lin et al (2017) was the first to study on the use of photoacoustic imaging for measuring periodontal probing depth. Comparison of pocket depth measurements obtained by photoacoustic imaging to measured by William's periodontal probing method was done in an artificially created periodontal pocket in pig jaw models. It was concluded that photoacoustic imaging could be a non-invasive diagnostic tool for periodontal pocket imaging and depth measurements (25) However, evidence for absorption and scattering of optical energy and ultrasound waves by bone has been shown to be the limitations of this imaging modality, particularly for imaging infrabony pockets and interproximal pockets. Moore et al (2018) conducted the first human study using photoacoustic imaging for monitoring periodontal health and concluded that photoacoustic imaging could be a non- invasive diagnostic tool for periodontal pocket imaging (24)

Table 2: Advantages and disadvantages of Imaging Techniques of Periodontal Pocket

Imaging Techniques Of Periodontal Pocket	Advantages	Disadvantages
CBCT - Based Periodontal pocket imaging using radio- opaque contrast agents	High resolution Fast scanning Easily available Low radiation exposure	Metallic image artifacts are produced Ionizing radiations
Optical Coherence Tomography	High resolution Nonionizing radiation Higher tissue contrast	Increased procedure time Deep tissue imaging limited by light waves scattering
Endoscopic capillaroscopy	High resolution Deeper tissue penetration Nonionizing radiation Higher tissue contrast	Not clear weather this technique can be used for periodontal pocket probing
Photoacoustic imaging	High resolution Deeper tissue penetration Nonionizing radiation Higher tissue contrast Fast scanning compared to MRI	Thick bone can distort signals Approximately 5cm tissue penetration
Magnetic Resonance Imaging	Nonionizing radiation Higher tissue contrast compared to CBCT	Increased procedure time Hard dental tissues cannot be scanned using conventional MRI Feasibility of MRI to image periodontal pockets is yet to be studied

Magnetic Resonance Imaging

Dental Magnetic Resonance Imaging (DMRI) is a new promising soft tissue diagnostic tool, without ionizing radiation. In dental application MRI can be used in imaging soft as well as hard dental tissues. MRI scanners apply a magnetic field that spins the hydrogen nuclei in water molecules in the body. The excited hydrogen atoms give off Radio Frequency(RF) signal, which is received and measured by a receiving coil that converts the RF signals into an electrical current signal (1) Conventional MRI can image intraoral soft tissue including, gingiva, pulp, root canals and periodontal ligament area. However, hard dental tissue imaging is not feasible using conventional MRI as the amount of water in the microstructure of enamel and dentine is low and T2 relaxation times of water in the tubules are very short, (of the order of a millisecond) (26). Hard dental tissues still can be imaged by special MRI techniques such as single point imaging (SPI), SPRITE and stray field MR imaging (STRAFI). (27,28,29)

Sustercic et al (2012) did the visualization of human tooth pulp anatomy by MRI reported that Magnetic resonance (MR) microscopy could provide very accurate 3D visualization of dental pulp anatomy. Giebel et al(2015) evaluated use of MRI for the assessment of apical periodontitis and concluded that MRI can be applied for the identification of periapical lesions.(30) Apart from these, studies have yet to show the feasibility of the new generations of MRI to image periodontal pockets.

Fig 8: Magnetic Resonance Imaging

Conclusion

Even though newer imaging modalities are emerging in the field of periodontics for periodontal disease detection, a newer technique which can be completely considered as a gold standard method for periodontal pocket detection is lacking. These technologies are needed for accurate and digital measurements for comprehensive treatment planning and to assess outcomes of therapy.

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