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# EARLY BIRD CATCHES THE WORM! - CHAIRSIDE DIAGNOSTICS IN PERIODONTICS

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## ABSTRACT

Periodontal diseases are chronic oral inflammatory conditions caused by microbial dysbiosis and the host immune response, affecting the periodontium. The staging and grading of periodontal diseases are based on recording medical and dental histories, thorough oral examination, and multiple clinical and radiographic analyses of the periodontium. Early and accurate diagnosis of these diseases is indispensable to prevent the disabilities such as tooth loss, compromised oral functions and secondary systemic complications. Numerous studies and innovations have been evolved to ease clinicians with chairside diagnostics. This article reviews the available toolkit for diagnosing periodontal diseases and to overcome the challenges of rapid periodontal disease diagnosis.

**KEYWORDS:** Periodontitis, diagnosis, probes, biomarkers.

## INTRODUCTION

Periodontal diseases are chronic oral inflammatory conditions caused by microbial dysbiosis and the host immune response, primarily affecting the tooth-supporting tissues. If left untreated, periodontal diseases can ultimately progress to tooth loss, compromised oral function, and are also known to contribute to systemic inflammation. Therefore, early and accurate chairside diagnosis of these diseases is of critical importance.

Due to the heterogeneous clinical presentation of periodontal diseases, multiple diagnostic analyses are conducted at the chairside for staging and grading. Moreover, risk factors such

as smoking, diabetes, obesity, stress, and genetic susceptibility that may influence the condition, are systematically examined for a comprehensive diagnosis.[1]

Conventional diagnostics can only assess disease history but not disease activity. This is because periodontal disease is characterized by periods of activity and remission. To compensate for this limitation, biomarkers from saliva and gingival crevicular fluid have been developed for periodontal diagnosis.[2] The incorporation of these biomarkers is expected to provide current disease activity and risk factors associated with the disease, allowing rapid diagnosis.

## CHAIRSIDE PROBING TOOLS

### Plaque and Calculus

Periodontal disease is driven by dysbiotic, subgingival biofilms in susceptible hosts. These subgingival species secrete various compounds that can cause dental caries and periodontal disease. Calculus is a biofilm-retentive factor. Thus, teeth with calculus show a significantly higher risk of attachment loss than teeth without calculus. The traditional tactile assessment of the subgingival root surface without visual accessibility lacks accuracy, specificity, and reproducibility. To overcome these shortcomings, several different technologies have been incorporated into the probes to identify calculus.[3]

1. **Detec Tar** identifies subgingival calculus by evaluating the characteristic optical signals on root surfaces and detecting spectro-optical differences between calculus and the tooth surface. When the subgingival calculus is irradiated with a specific wavelength light, it results in the production of a characteristic spectral signature caused by absorption, reflection, and diffraction. These spectral signals are sensed by an optical fiber and converted into an electrical signal for computer analysis. The shape and dimension of the DetecTar probe tip are similar (0.45 mm diameter) to those of conventional periodontal probes. The system is also available as a portable cordless handpiece with a curved periodontal probe with millimeter scales to measure CAL and PD.
2. **Perioscopy**, a miniature periodontal endoscope, is inserted into the periodontal pocket for subgingival visualization of the root surface and residual calculus with tens of magnifications (48×).
3. **Diagnodent** is a pen-like probe that sends a safe, painless laser beam into the tooth to detect the autofluorescent signal from calculus lesions. It can measure a wide range of

fluorescence intensities that are digitally displayed as a series of relative calculus detection values.

4. **Perio Scan** provides a diagnosis mode to detect calculus deposits and a treatment mode for the conventional ultrasonic debridement with different power levels. When the ultrasonic tip detects calculus on the tooth surface, blue light and an acoustic signal simultaneously are displayed on both the handpiece and the display to facilitate diagnosis.
5. **Key Laser 3+** is an automated device that contains a 655-nm InGaAs diode laser for calculus detection and a 2940-nm Er:YAG laser for calculus removal. The Er:YAG laser is activated or inactivated depending on the detected calculus level based on the feedback-controlled system.

The advantage of both PerioScan and Key Laser 3+ systems is that the diagnostic and treatment modes can be used continuously on the same tooth surface without changing tools, but the specificity of the calculus detection still needs to be improved, as irregularities on the root surface are erroneously recognized as calculus.

**Pocket Depth and Clinical Attachment Loss**

Since chronic periodontal inflammation can lead to a loss of the supporting periodontium, measuring the loss of this attachment has been a key criterion for classification of the disease stage and grade and a strong predictor for future tissue destruction and disease progression.

Generally, a periodontal probe is used to measure both clinical attachment loss (CAL) and pocket depth (PD). Five generations of periodontal probes have been designed and developed. Manual probes remain the gold standard in dental clinics for measuring CAL and PD. To provide additional evidence in periodontal disease diagnosis, various sensors (e.g., mobility sensor, calculus sensor, temperature sensor, sulfide sensor) have been integrated into the probing tools.

**Bleeding on probing**

The presence of bleeding on probing (BOP) can be a poor predictor of periodontal disease activity, but the absence of BOP is an excellent indicator of periodontal stability.[4] In the 2017 World Workshop, the BOP score was recognized as a basic parameter that set thresholds for the diagnosis of gingivitis and assures the state of gingival health (BOP score < 10%) or gingivitis (localized: 10%≤BOP score≤30%, generalized: BOP score > 30%). So far, electronic probe which automatically measures BOP score has not yet been commercialized.

**Ito et al (2021)** reported that hemoglobin presence in GCF suggests slight tissue damage, even in healthy sites defined as an absence of BOP.[5] Therefore, the emergence of new probes capable of detecting the bleeding or hemoglobin within the periodontal pocket in a quantitative way may help improve the utility of the analysis and increase the diagnostic sensitivity of periodontal diseases.

**Tooth Mobility**

It is an important physical feature of periodontal diseases. For an accurate and reproducible evaluation of the degree of tooth mobility, numerous techniques have been studied and tested.[6]

1. **Periotest (Schulte, Lukas, 1990)** is an electronic wireless device for assessing periodontal disease parameters including mobility of teeth and osseointegration of dental implant. It measures contact duration per impact between the rod and the tooth while an electrically controlled rod percusses the tooth and then recoils. If there is any periodontal structural deviation in bone and/or soft tissue that is caused by any periodontal disease, it will be reflected in the contact duration.[7]

2. **Muhlemann's Periodontometry (1954)**

The macro-periodontometer consists of an impression tray secured with a **dial indicator** and the point of the indicator being at right angles to the labial/ buccal surface being measured. The dynamometer deflects the teeth palatally or labially with a known force which is measured in hundredths of millimetres. Although the reproducibility of measurements is high, the usefulness of the instrument is limited, due to its design which primarily can be used only in the upper incisor, cuspid, and first premolar regions.

The micro-periodontometer has rubber dam clamp held to tooth on the contralateral side of arch holding the small-dial indicator. The precise use of the instrument is tough to learn, the technique is tedious, and values obtained are less reproducible compared to macroperiodontometer.

3. **Goldberg's Periodontometry (1961)**

The mobility of upper and lower teeth could be quantified at once. It consists of a **carrier device** which is fixed in the oral cavity with cold cure acrylic or impression plaster by engaging the masticatory surfaces of both jaws. The carrier device is used with measuring devices or along with Mühlemann's periodontometry dial indicator. The carrier is guided

around the mouth by a semicircular platform hooked to the acrylic occlusal keys and the device was only capable of **horizontal anterior teeth measurement.**

4. **Dental Holographic Interferometry (1975)** is a non-contact and non-destructive method which uses a Q-switched double-pulsed ruby laser. An electronic sub miniature force sensor is used for pulse triggering that is initiated by the masticatory force of the patient. An oscilloscope registers force increase and pulse positions synchronously on the screen. The applied force exerted by the patient's masticatory muscles could then be elucidated according to its point of application, amplitude, duration and direction. A double exposed, synchronized hologram measures the corresponding surface deformation. Mobility of teeth and deformation of related structures could be recorded with a sensitivity of 0.5 μm within a total measuring range of approximately 30 μm.

5. **Laser Vibrometry (1998)**

This technique involves the application of an impulsive excitation on the tooth by means of an impact hammer and the measurement of the displacement by a laser Doppler vibrometer. This arrangement facilitates uncomplicated and versatile noncontact measurements with precision and sensitivity (<0.1 mm/s). With this technique, it will be feasible to measure a pathological mobility of the tooth even before the manual technique.

6. **Osstell IDx** is a non-contact method, that measures the implant stability (osseointegration) with non-invasive and non-destructive techniques. This product utilizes Resonance Frequency Analysis with resonance frequency ranging from 3000 to 8500 Hz for an implant stability quotient of 0–100. The device consists of a transducer, a computerized analysis module, and an excitation source. Although the Osstell IDx is optimized for osseointegration instead of natural tooth mobility test, the device enhances patient comfort and increases reproducibility. Therefore, it is expected that the tools of tooth mobility test are also developed based on this technique.

**Temperature**

In general, the gingival temperature is increased by elevated blood flow and cellular/metabolic reaction as a host-response to inflammation.

**PerioTemp** has been used for subgingival temperature measurement. Key benefits of using this probe include a rapid response time (<1sec), high accuracy (±0.1 ◦C), and high

reproducibility. Its physical shape and dimensions, similar to conventional periodontal probes, allow the measurement of CAL, PD, and BOP along with temperature. It also has a computerized thermometer that displays actual subgingival temperature and a risk level with two-color light indicators.[8]

**Halitosis**

It is well known that gram-negative bacteria are plaque-induced bacteria that generate sulfur-related substances as by-products from their metabolism. These substances are volatile sulfur compounds (VSC), including hydrogen sulfide (H2S), methyl mercaptan (CH3SH), and dimethyl sulfide (CH3SCH3).

1. **Halimeter** analyses the concentration of Hydrogen Sulphide and Methylmercaptan without discrimination between the two. It is a portable-chair side test, non-invasive, relatively inexpensive, has low likelihood of cross infections and rapid turnaround time of one to two minutes between measurements. However, it detects only sulphur compound and cannot distinguish between individual sulphides. It has no specificity and instrument shows slight loss of sensitivity with time, necessitating periodic recalibration.
2. **Portable gas chromatography** is a method of instrumental analysis of halitosis using gas chromatography coupled with flame photometric detection. It measures the concentration of three key sulphur compounds (hydrogen sulphide, dimethyl sulphide, methyl mercaptan). It is highly sensitive and is inexpensive. However, it needs calibration and the sensor and column need to be replaced every two years.[9]
3. **Oral Chroma** is a portable gas chromatographic device. It is small, useful in quantitative measurements, highly sensitive, and cost effective. Sulfur-containing compounds in the breath can generate electro-chemical reaction. This reaction relates directly with levels of volatile sulfur-containing compounds. With this method, even low concentration of gases can be measured separately.
4. **Breathtron** is semiconductor type sulfide monitor, which is composed of an air inlet, sensor detector, control panel, digital display and printer. The semiconductor sensor is based on a thick Zinc Oxide (ZnO) membrane that has a high specificity for VSCs. Measurements are performed by directly inserting the disposable mouthpiece into the patient's oral cavity. The patients are instructed to close their mouth tightly and breathe through their nose during the measurement. The Breathtron values are presented in units of parts per billion (ppb).

5. **The Diamond Probe/Perio 2000 System** is designed to detect sulfide levels in the gingival sulcus and periodontal pockets in real-time for gram-negative bacteria monitoring. In this system, a microscale sulfide sensor was incorporated into a modified Michigan O-type periodontal probe to measure CAL, PD, BOP, and sulfide levels. When the sensor-integrated probe tip encounters sulfides in the GCF, the system provides information in three ways: a four-color light bar, an audible tone, and a sulfide level.

## CHAIRSIDE BIOMARKER DETECTION

Biomarker assays help to identify periodontal pathogens, provide readout of disease activity, assess disease severity, and evaluate the prognosis after treatment.

### Biochemical Assay Kits

1. **PerioSafe and ImplantSafe** - can measure active matrix metalloproteinase-8 (aMMP-8), a major mediator of tissue destruction in periodontitis. The PerioSafe and ImplantSafe tests qualitatively measure aMMP-8 levels in oral rinse and GCF, respectively. Both qualitative and quantitative analysis can be done in 5 minutes using the automated digital device. They are useful for distinguishing between active and inactive sites with fast and easy analysis and detecting asymptomatic, ongoing periodontitis before clinical and radiographic signs appear.
2. **PerioGard** and **PocketWatch** - assess Aspartate aminotransferase (AST) level in GCF. AST is an enzyme that is abundant in human gingival epithelial cells and gingival fibroblasts. Upon cell death, a large amount of AST is released from the cell cytoplasm into the GCF thereby, the level of AST in GCF can be used as a strong indicator of gingiva tissue destruction. In both products, the activity of AST is evaluated based on the enzymatic catalysis reaction by comparing the color of the collected GCF from patients with that of the controlled AST positive group.
3. **The SillHa** and the **Salivary Multi Test** can measure multiple saliva indicators (blood, leukocytes, and proteins) related to gingival health. Both products consist of test strip kits and an automated wavelength reflectometry device that reads color changes on the test strips within five minutes.
4. **Electronic taste chip** detects Salivary C reactive protein levels.

### Microbiological Assay Kits

The onset of periodontitis is related to pathogens such as Porphyromonas gingivalis (Pg), Treponema denticola (Td), Tannerella forsythia (Tf), Actinobacillus actinomycetemcomitans

(Aa), Prevotella intermedia (Pi), Fusobacterium nucleatum (Fn), and Filifactor alocis (Fa). These bacteria generally co-locate in periodontal pockets with a wide distribution and increased numbers suggesting that these can be potential biomarkers.

1. BANA-Enzymatic test - Pg, Td, Tf, and some Capnocytophaga species, produce bacterial trypsin-like proteases by utilizing the hydrolysis reaction of **BANA** (N-Benzoyl D-L Arginine -2 Naphalamide) in the biofilm. This test is based on this hydrolysis reaction.
2. The **Evalusite** is a rapid microbiological assay kit that detects three recognized pathogens: Aa, Pg, and Pi. By collecting a subgingival plaque, the kit detects the presence of the pathogens based on an antibody-bounded sandwich-type enzyme-linked immunosorbent within 10 minutes.
3. **TOPAS** (Toxicity Prescreening Assay) is a chairside test kit for indirectly detecting bacterial toxins and proteins. This test relies on the detection of actively dividing and growing pathogens which can be assessed through the metabolic activity of these organisms in GCF. It can differentiate active and inactive periodontal disease as indicated by the change in colour intensity based on the fact that metabolic activity increases as the concentrations of these toxins increases.
4. As a chairside diagnostic platform, **OMNIgene, iai PadoTest , MyPerioPath, micro-IDent plus11, and Perio Diagnostik** have also been introduced. They detect several periodontal disease-related pathogens in collected saliva, oral rinse, or plaque based on nucleic acid-based assays. However, the microbial assay kits are available in laboratories with expensive equipment.

**Genetic Assay Kits**

Analyzing the genetic "susceptibilities" may help identify or anticipate the potential risk of periodontal disease initiation and progression. It has been known that the polymorphism in the interleukin-1 (IL-1) gene has been shown to be proinflammatory causing periodontal disease. To identify the genetic risk of periodontal disease, multiple test kits have been introduced in the market, including **PerioPredict, and MyPerioID** (IL-6 and IL-1). However, these tests require significant laboratory equipment or additional time to deliver the sample to the manufacturer's laboratories for data analysis. Thus, these kits cannot be truly recognized as chairside diagnostics.

Despite several efforts on finding biomarkers, biomarker-based detection has been occasionally applied in dental offices. One reason for the low practical use of biomarker-

based techniques is the **lack of standardized assays and FDA-approved saliva diagnostic test or point-of-care technology** for clinical diagnosis of periodontal diseases.

In the **2017 World Workshop, the introduction of biomarkers** was strongly encouraged as a supportive indicator to identify periodontal disease and to estimate its stage and grade. So far, the specific biomarkers and their thresholds have not been established yet, but we expect they will be incorporated and used in periodontal disease grade assessment as evidence will become available soon. Efforts to accelerate the development of chairside periodontal assay kits or automated biosensors by combining clinically relevant biomarkers with lab-on-a-chip or point-of-care technologies are still active.

Compared to conventional labor-intensive and time-consuming laboratory procedures, the automated chairside periodontal assay methods are believed to provide immediate analysis results related to the disease. Moreover, technologies will evolve toward improving diagnostic sensitivity and accuracy by analyzing multiple analytes simultaneously, although the size of the biosensor is reduced. Furthermore, the ability of chairside analysis of biomarkers for accurate diagnosis and prognosis of the disease will be an important advantage in preventing irreversible damage to periodontal bones and tissues.

**Lab-on-a-Chip (LOC)** has been developed which integrates several laboratory assays in a single miniature device, including sampling procedure, preparation of the sample, detection and measurements of multiple biomarkers, and analysis. The drawbacks of using a combination of biomarkers includes the complexity of interpreting the results and the manufacturing process, together with the considerable cost implications, which contradict the WHO's ASSURED criteria (affordable, sensitive, specific, user-friendly, rapid and robust, equipment-free and deliverable to end-users) for POC devices. However, the evidence from the aforementioned studies supports the potential for improvement in diagnostic accuracy by including more than one biomarker in a cost-effective POC tests.[10]

## DIAGNOSIS WITH THE IMAGING TOOLS

### 2-Dimensional Imaging with Radiography

The common types of dental 2D radiography are panoramic and intraoral X-ray. The primary purpose of radiograph for periodontal disease assessment is to measure the level of alveolar bone together with the observation of the factors including bone level, bone destruction pattern, marginal contour, and extent of bone loss.

Digital radiography overcomes the shortcomings of traditional film-based radiography, such as time and space constraints for printing. It can reduce the amount of radiation dose to the patient due to the high sensitivity of the digital imaging detectors. Digital radiographs can be instantly displayed, stored, printed, and sent to other electronics. The changes in bone density or volume can be easily recognized by the contrast difference, i.e., lighter area refers to large bone density, and darker area refers to bone loss. Furthermore, computer-aided image processing software enables high precision analysis allowing easy assessment of disease severity and progression.

**Digital subtraction radiography (DSR)** can record and superimpose two images of the same object obtained at different time points, allowing for a visualized direct comparison. An algorithm can then subtract the image intensities from the identical pixel and automatically highlight the area that has any differential. This technique allows the clinicians to easily diagnose tissue or bone loss in a specific area by fading out of unchanged areas.

One form of subtraction radiography widely is **computer-assisted densitometric image analysis (CADIA)**. It uses a computerized video camera and an image analyzing processor to measure the light that is transmitted through the radiographs. The light signals that are converted to greyscale images can be mathematically processed. The quantitative information results in two radiographs of the same anatomical location compared via superimposition.[11]

**3-Dimensional Imaging with Computed Tomography(CT)**

CT can build 3D image models without superimposition of structures by assembling 2D cross-sectional images obtained from all planes of interest. Although CT offers high quality 3D images with improved accuracy, increased radiation exposure and high cost are concerns in adopting this periodontal disease diagnosis technique in dental clinics.

**Cone-beam computed tomography (CBCT)**

The dental CBCT system allows a conical Xray beam to capture data from rotating around the patient with a ten-fold reduction in radiation than conventional CT. These data are then used to reconstruct 3D images of the patient's dental and maxillofacial areas (transverse section, sagittal section, and buccal section) using software. These reconstructed 3D models help the clinician clearly understand the relationship between the lesion's size and the surrounding anatomical structures. It is also used to evaluate the progress of the disease and establish a treatment plan.[12]

**Tuned aperture computed tomography (TACT)** is designed to produce holographic images with 3D views of teeth and pathology. This equipment effectively detects the location of periodontal bone gain or loss, alveolar contour, and even recurrent caries.

**Cone-beam volumetric tomography (CBVT)** is another CT-based technique that offers high resolution and accuracy for assessment after regenerative therapy (e.g., bone fill or defect resolution).

**Quantitative computed tomography (QCT)** offers more detailed bone mineral density information with precise 3D anatomic localization of bone density assessment.

**Micro-focus CT** can provide adequate information about the alveolar bone structure and tooth morphology based on its fine spatial resolution (<10 μm). This technique enables faster 3D image reconstruction and allows minimal side effects. In addition, 3D imaging of interface in bone-implant has been reported using micro-focus CT.

**Ultrasonography**

Ultrasonography is a diagnostic imaging technique that exhibits the internal tissue structure using reflections or echoes of ultrasound signals and is thus, non-ionizing. The ultrasonic image uses a small probe to send ultrasound pulses (1~20 MHz in medical diagnosis) to the tissue and displays the acoustic impedance of a 2D cross-section of tissue based on the reflective properties of each tissue. In dentistry, ultrasound devices for intraoral diagnosis have been clinically utilised to measure gingival lesions, tooth fractures, soft tissue lesions, maxillofacial fractures, alveolar bone defects, and gingival thickness.

**US Probe (5$^{th}$ generation)** adopts the periodontal probe platform with the tapered tip, which produces a narrow ultrasonic beam profile (~0.5 mm) using a 1–20 MHz transducer. These ultrasonic waves are carried through an area created by a small water stream into the periodontal pocket. The US probe can provide PD information without probing pain as well as gingival tissue images with sufficient signal strength and penetration depth along the gingival line.

**Magnetic Resonance Imaging**

MRI has exhibited outstanding ability in soft tissue imaging. It has been utilized for temporomandibular joint or jaw lesion observation, pulp vitality evaluation, as well as endodontic treatment and implant planning. It is capable of detecting the histopathological

change that occurs in the gingiva during the early stage of periodontal disease. MRI provided significantly better images for periodontal structures like lamina dura as well as bone structure (e.g., cortical and trabecular bone), suggesting the high potential capability of MRI in periodontal disease detection, periapical lesion and furcation involvement observation.

Algarin et al. designed a special-purpose MRI scanner (DentMRI-Gen I) capable of producing high-quality combined images of soft and hard biological tissues at sub-Tesla fields (260 mT).[13] However, simultaneous imaging of soft and hard tissues using MRI requires more clinical validation, so there are remains opportunities for technology development. Some challenges that remain include the accessibility of equipment due to its high cost as well as the discomfort of its use during long scanning time. The magnetic field may also cause metal-based implants (e.g., hearing aid, cardiac pacemaker, or electrical stimulator) to malfunction and possibly result in an injury. Lastly, higher technological expertise is required for MRI utilization than for other imaging tools, which should be addressed to expand MRI application.

**Digital Dental Photography**

Digital dental photography is a type of macro-photography that provides information on the surface of the oral cavity as part of the patient workup. Digital photographs can be used for examination, diagnosis, treatment planning of oral diseases and photographic documentation to accurately record clinical manifestations of the oral cavity.

The correct color rendition of the photographs is an excellent method for distinguishing between healthy and diseased soft tissue, including white patches, inflammation, ulceration, carcinoma. In addition, digital photographs of sufficient resolution can distinguish between healthy and diseased tissue by providing morphological information such as gingival clefts and recession.

**Intraoral Scanners**

Intraoral scanners were developed to replace conventional dental impressions used in prosthodontics, orthodontics, and restorative dentistry. It projects a light source onto the object to be scanned and sends morphological information to a connected computer system to render the 3D model with a digitized form. Also, it is capable of real-time scanning and visualization, allowing rapid diagnosis and communication based on the digitized result without concern of potential deformation.

The digital assessment method using the intraoral scanner can be possibly used in gingiva health assessment, to measure periodontal defects and evaluate tooth mobility. Zhang et al. reported that gingival volume change in patients with periodontitis after therapy could be recorded using an intraoral scanner.[14] The results were positively correlated with other parameters, including PD, bleeding index, and keratinized gingival width. Intraoral scanning can also assess gingival health or tissue regeneration by identifying the color difference in soft tissue.

Considering that there is a color difference between keratinized and nonkeratinized tissues, it is possible to evaluate the keratinized mucosa's dimensions. Lee et al. claimed that the digital scanning could more accurately measure the keratinized tissue width than using a periodontal probe.

**Endoscopic Capillaroscopy**

Another imaging technique for periodontal health assessment is endoscopic capillaroscopy. This technology can image and record the microvasculature of the periodontal pocket and gingival crevice in vivo by inserting a sub-millimeter-sized optical fiber into the periodontal pocket. It uses a green light with a wavelength of 520 nm for illumination absorbed by both oxygenated and deoxygenated blood. The blood vessels with red blood cells appear dark on a green background, allowing the high-resolution imaging of the periodontal pocket microcirculation. Although no cases have been reported for actual periodontal disease evaluation, it is expected that the combination of capillary examination and optical fiber technology can be used to observe the size change of microvessels caused by periodontal disease.[15]

## FUTURE DIRECTIONS

Manual periodontal probing and 2D radiography have been the two major diagnostic tools for periodontal disease. Over the years, various new technologies have been incorporated into these two diagnostic tools in attempts to improve their accuracy, reproducibility, speed, and patient comfort.

For periodontal probing in clinical examination, early attempts at improvements were derived from the incorporation of advanced mechanical and electrical technologies that enabled **accurate and automated assessment**. Various **sensors** are being **integrated into the**

**periodontal probe** platform to provide new information inside the periodontal pocket for a comprehensive analysis.

With the development of microfabrication and nanotechnology in the coming years, these sensors are further expected to be miniaturized and integrated disease research community. Lastly, with the integration of **state-of-the-art image processing algorithms and artificial intelligence technology**, higher accuracy in diagnosis and better prediction in prognosis are expected.

As radiography technology is becoming more developed, the radiograph imaging of the periodontal lesions has gained more significance in periodontal health assessment. In particular, the development of 3D imaging technology like CBCT allowed accurate visualization of bone destruction, which then enabled the precise diagnosis of disease severity and progress. As an alternative to ionizing radiation, other imaging technologies without ionizing radiation (e.g., ultrasonography or MRI) are being actively studied.

Recent advances in biomarkers propose a new possibility in early-stage detection and rapid diagnosis. To date, largescale laboratory assays and many clinical trials have been conducted to identify candidate biomarkers. Moreover, some promising biomarkers have been reported for simultaneous multi-analyte sensing to promote diagnosis accuracy. Based on these developments, it is plausible to believe that automated chairside diagnostic protocols with effective biomarkers will soon be available.

## CONCLUSION

Overall, the diagnosis methods for periodontal diseases have continuously advanced with the incorporation of various technologies. With more technological advancement and pathological/biological understanding, this trend will continue. By embracing new technological developments, clinicians may expand their chairside toolkits for early identification and management of periodontal diseases, thereby preventing irreversible damage to periodontal tissues.

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