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Current Strategies for Dental Calculus Detection: A Review

Dr. Sharayu R Dhande, Dr. Sangeeta D muglikar, Dr. Rashmi V Hegde, Dr. Prerna S Ghodke, Dr. Raunak S Baksh, Dr. Azhar Shaikh

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ABSTRACT: Dental plaque is main etiologic agent in initiation and progression of periodontal disease. Further the mineralized plaque that is calculus initiates the periodontal disease. Subgingival plaque covering calculus is recognized as major cause of periodontitis. Visibility, location and inflamed gingival conditionsare the crucial factors that limit the detection of subgingival calculus. Clinicians at times tend to remove excess amount of root structure due to hampered visibility to achieve smooth root surface. To forestall the above stated problem, a plentitude of calculus detection systems have been developed over the period of time.

KEYWORDS : Calculus, detection, spectroscopy, laser

I. INTRODUCTION :

Periodontal disease is considered among the most common chronic diseases which have plagued humans for centuries. Subgingival plaque covering calculus is recognized as major cause of periodontitis. The word 'Calculus' was derived from Latin word which means pebble/stone. Calculus can be defined as a hard concretion that forms on the teeth or dental prostheses through calcification of bacterial plaque (Glossary of Periodontal Terms 2001). Visibility is the major factor that limits detection and removal of dental calculus. Dental calculus due to its inherent porous nature has ability to retain bacterial products, retain substantial levels of endotoxins which further aggravates the periodontal disease process and their products (Nyman et al 1986).[1]

Earlier calculus was thought to be the main etiological factor for periodontal disease, but from the landmark study of Loe at al (1965), plaque was considered to be chief etiological factor for periodontal diseases. Dental calculus provides a niche/nidus which harbors bacterial plaque and further causes irritation to surrounding periodontal tissues further distending the periodontal pocket wall. Thus, elimination of supragingival as well as subgingival plaque and calculus is the cornerstone of periodontal therapy.[2,3]

Supragingival Calculus is tightly adhering calcified deposit that forms on the crowns of the teeth above the free gingival margin. Also known as Supramarginal calculus, extragingival calculus, coronal calculus, visible calculus, salivary calculus. It is white, creamy yellow in colour that darkens with age and upon exposure to food and tobacco with hard clay like consistency and is firmly attached to the underlying tooth surface. While subgingival calculus is calcified deposit that forms on the tooth surface below the free margin of gingiva and extends into the periodontal pocket. Other names for subgingival calculus aresubmarginal calculus, serumal calculus, invisible calculus.Usually dark brown, black or dark green in colour& stains from blood pigments from diseased pockets. It is firmly embedded in to the root surface due to its dense flint like consistency.

Conventional methods and devices developed are hardly effective in completely detecting and eliminating calculus from diseased root surfaces. Certain factors like dental arch location, gender, age and race are known to affect the accuracy and feasibility of variety of calculus detection techniques. Such integrated systems will prove advantageous over others as they can minimize loss of healthy tooth structure, decrease chairside time and increase operator efficiency in oral prophylaxis. This will indirectly increase patient compliance towards further dental treatments and aid in education and motivation of patients.

Calculus Detection Technologies in a nutshell:

Calculus detection only	Visual examination	Visual examination under dental chair light
	Tactile examination	Different types of Periodontal probes and explorers
	Radiographic Examination	Intra-OralPeri-apical Radiograph(IOPA), Bitewing radiographs, Ortho-pantomogram (OPG)
	Fiberoptic endoscopy	Perioscopy
	Spectro-optical technology	DetecTar
	Fluorescence	VistaCam system
	Autoflourescence	Diagnodent
	Laser	Keylaser 1
		Keylaser 2
	Fluorescence Microscopy	Single and Multi-photon microscopy

CALCULUS DETECTION TECHNOLOGIES:

1**] Visual Examination-**

Presence of good quality dental chair light is one of the must criteria for visual examination. Gingiva must be dried before accurate observations. Since, light reflection from moist gingiva obscures details. Supragingival calculus is chalky white which can be detected by direct vision or indirect vision. Subgingival calculus is dark brown in color which shows dark edge of calculus at or just beneath the gingival margin. Further gingival tissue color change also helps in detecting subgingival calculus. In inaccessible areas of oral cavity, use of mouth mirror further enhances the visual examination of dental calculus. Transillumination, gentle air blast and gingival tissue color change also aid in visual detection of dental calculus.

2] **Tactile Examination-**

Tactile exploration requires skilled use of probe or explorer in order to detect subgingival calculus deposits. The modified pen grasp with light pressure is usually preferable for subgingival examination. Slight vibrations are felt by operator's pad of thumb and middle finger through shank of the instrument. Method for tactile examination- Initially, a stable finger rest is established, which further helps insertion of instrument tip in to the periodontal pocket. On contact of the dental calculus with probe, the tip of the probe is inserted more apically and light exploratory strokes usually in a vertical direction are activated until complete removal of calculus from root surface.

Although supragingival calculus can be detected with the help of visual examination, clinical detection of subgingival calculus relies on tactile examination of tooth surfaces with an explorer. The conventional method for detecting subgingival calculus is tactile examination carried out using a periodontal probe.[4]

Clerehugh 1996 used WHO # 621 probe and a fine subgingival explorer in tactile examination.[5]The tip of the probe should be walked across the root surface, checking for areas of roughness or irregularities (Jones et al 1972).[6]

Tactile examination is prone to false negatives (from burnished calculus that appears smooth to the touch) and to false positives (from instrument- induced irregularities on the root surface). (Folwaczny et al. 2004).[6] A false positive result will lead to overtreatment, with consequential removal of healthy cementum and dentine, and risks of dentinal hypersensitivity. Tammaro et al. 2000).[7]

Tactile examination results have limited reproducibility between various operators because they are influenced strongly by clinician skill and experience (Pippin & Feil 1992).[6]

In contrast, with a false negative result, deposits of subgingival calculus will be overlooked, leading to refractory or persistent inflammation. However, the conventional tactile perception of the subgingival root surface without the visual accessibility lacks sensitivity, specificity and reproducibility.[6]

3**] Radiographic Examination-**

Intraoral radiographs have been generally preferred because of their sharpness and ability to demonstrate better structural details. (Barr 1966).[8]

Criteria for radiographic calculus detection were subjective along with inter-examiner and intra-examiner agreements. Radiographic detection of dental calculus was determined by certain factors such as- step height of the deposit, the total percentage of the root surface covered by the deposit and tooth type; but it is hardly influenced by the amount of attachment loss, probing depth, mesial or distal proximal surface along with location in the maxillary and mandibular arches.[9]

Calcified deposits are detected as spikes, fins and spurs on Intraoral periapical radiographs, bitewing radiographs and orthopantomograms, they appear as radio-opaque projections in the interdental space. Since the apical location of plaque is not sufficiently calcified to be visible on radiographs, hence the location of calculus does not indicate the bottom of the periodontal pocket. Hence, conventional radiographs have been proved as poor diagnostic aids in detection of subgingival calculus.[9]

Digital radiography does not significantly improve radiographic detection of dental calculus. But the factors like, amount of area covered with calculus on the root surface along with size of calculus deposits help increase sensitivity of detection of calculus.[10]

4] **Fiberoptic endoscopy (Perioscopy)**

The world Endoscopy was derived from Greek words- ‘‘Endo’’ meaning ‘‘inside’’ and ‘‘Skoopein’’ meaning to ‘‘see’’. In the year 2000, traditionally used endoscope for medical diagnostic purpose was modified for detection of dental calculus. The fiberoptic endoscopy is currently used in only one device perioscopy. Also named as Perioscopy, since it is used for periodontal diagnostic purposes, like visualization of subgingival root surface area during subgingival debridement. [11]

It is a miniature periodontal endoscope that consists of 10,000- pixel fiberoptic bundle of 1mm diameter, surrounded by multiple illumination fibres along with a light source, an irrigation system along with a display monitor with liquid crystal. It is minimally invasive and helps in visualization of subgingival root surface between magnifications 24-48x and also helps to magnify images 15-46 times of their actual size and thus aid clinician in locating residual calculus spots during subgingival debridement.The miniature size of endoscope results in minimal tissue trauma. The tip of endoscope is covered by a single use sterile sheath for clinical application on each patient.[11,12]

Endoscopes also have prism infront of the lens to alter the direction of visualization and a video camera attachment that allows the clinician to view the subgingival area on a monitor. It is possible to view other pocket contents like sulcular tissues, root caries, subgingival deposits and root surfaces. Hand-held metal handles further help to control the position of the fiber-optic tip and sheath when inserted into the sulcus. The operator can magnify images till 48 times during subgingival examination and view on computer monitor and can also be saved. This system requires additional time period of 8 hours for learning the procedure and subsequent practical experience of 4 weeks to master this system. Although, perioscopy system is advantageous, it is hardly used in day-to-day practice owing to its high cost and requirement of trained personnel.[11,12]

Several studies have carried out a comparative study using periodontal endoscope and periodontal probe to evaluate the amount of pain reported by patients after detection of calculus.

A study conducted by Geisenger et al 2007 to evaluate residual calculus percentage in single rooted teeth after the extraction. The teeth were divided into two groups and were treated with hand instruments and ultrasonic instruments respectively. After subgingival debridement, the teeth were assessed with an explorer or a periodontal endoscope. The microscopic examination showed, higher percentage of residual calculus on root surfaces that were assessed with an explorer compared with an periodontal endoscope. The difference was statistically significant only when interproximal sites >6mm and buccal sites >4mm were assessed. The authors thus concluded that the subgingival sites assessed with periodontal endoscope shows less percentage of residual calculus when compared with explorer alone.[13]

Poppe et al 2014, carried out a comparative study using periodontal endoscope and periodontal probe to evaluate the amount of pain reported by patients after detection of calculus. conducted in-vivo, randomized, split- mouth design comparative study on 30 subjects to assess the amount of pain experienced by patients with 5-8mm pocket depths with atleast 4 sites, after tactile examination of calculus with periodontal endoscope and periodontal probe. Further, quadrants were assigned randomly for tactile examination of calculus with periodontal probe and the other for Periodontal endoscope. The Heft-Parker Visual Analogue Scale (VAS) was used to record subjects's pain experience, owing to its ability to measure pain on a continuum along with its validity, reliability and sensitivity. A pre-term survey was conducted in order to assess levels of anxiety as anxiety and pain were found inter-related. The authors thus concluded; statistically significant differences were found in pain perception of patients who had undergone tactile examination of calculus with Periodontal endoscope when compared with periodontal probe.[14]

5**] Spectro-optical technology: Optical Spectrometry-DetecTar**

Introduced by Ultradent Products, South Jordan, Utah. It is the first subgingival calculus automated detection system.

It uses high energy LED that emits light through its fiber optic probe. This device is available as a cordless handpiece with a curved periodontal probe which shows millimeter markings to measure pocket depths and comprises of high energy LED light which utilizes spectro-optical technology. This technology possesses 91% efficiency in detecting subgingival deposits as small as 0.1mm in size including tiny spicules, black ledges in pockets upto 10mm with a help of an audible beep. An angulation of either 0° to 10°, 45° or 90°between optical probe and the root surface is required in contact mode for detection of subgingival calculus. The subgingival calculus when irradiated with red light results in production of characteristic spectral signals emitted from subgingival calculus deposits by absorption, reflection and diffraction of red light.[15]

Method of instrumentation is similar to periodontal probes, but it relies on reflected light from tooth surface instead of tactile sensation and forwards signals to self-contained computer for analysis. The forwaded signal is now assessed by optical fibre and further converted into electrical signal which is then analysed by computer processed algorithm.

Certain advantages of using this technology are-

a) Ease in re-evaluation of root surfaces prior to placing any medicament

b) examination of subgingival area without application of any tactile pressure, ability to release audible and luminous signals upon detection of calculus,

c) portable in nature. Presence of saliva, blood and water do not alter detection of calculus deposits.

A number of studies have been done to evaluate efficiency of spectro-optical technologies. Krause et al conducted an invitro study and evaluated calculus detection potential of spectro-optical technology in 20 freshly extracted teeth affected by periodontitis. These teeth were checked with variable working tip angulations of the fiberoptic (0° to 10°, 45° or 90°) in presence of different fluids like saline or blood. The results thus obtained were compared with clinical and histological findings in which- specificity was 100% in blood and 95-100% in saline solution at all angulations. The sensitivity in saline solution was 100% at all angulations and sensitivity decreased in blood with change in angulations (100% sensitivity for 90°, 89% for 45° and 70°) for 10° to 0° angulations. The authors thus concluded, the combination of saline solution and a working tip angulation of 90°, gave most accurate assessment of calculus.[16]

Another In-vivo study, was conducted by Kasaj et al- to assess the potential of DetecTar. A total of 44 teeth i.e 176 surfaces were assessed. Two groups were made- In group A (n=96)- clinical presence or absence of subgingival calculus deposits were determined using optical probe. Group B (n=80)- subgingival deposits were first recorded with optical probe followed by complete root surface debridement until the root surface was calculus free. Results of this study were- Group A- post extraction evaluation showed 89% and 90% detection of subgingival deposits while Group B- 17% surfaces even after subgingival debridement, detected calcified deposits. The authors thus concluded, spectro-optical technology detects subgingival deposits with high efficiency in clinical use and can be used as an adjunct to detect subgingival calculus deposits.[16]

6] **Autofluorescence (VistaCam)-**

The Fluorescence phenomenon of violet light elicits visible red light emissions from the calculus deposits.

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The VistaCam intraoral camera system is a fluorescence system emitting 405nm wavelength. This fluorescence system uses light emitting diodes that produce 405nm wavelength light of violet color. This particular wavelength detects calculus based on red emissions emitted from porphyrin molecules. This system enhances detection of dental caries and mature deposits of bacterial plaque. The violet excitation light is separated by a filter located infront of the sensor.

Further, the fluorescence signals are converted to numbers. This device helps to determine the endpoint of successful subgingival debridement (Shakibaie, George and Walsh; Shakibaie and Walsh 2015).[19]

7**] Autofluorescence (Diagnodent**) -

A variety of micro-organisms have presence of certain metabolites like porphyrins, metalloporphyrins and few other chromatophores and contain flourophores emitted from calculus and carious lesions.(Hibst et al). This ability of calculus of calculus to emit fluorescent light following irradiation with light of a particular wavelength enables the detection of calculus. [21]

Diagnodent is currently manufacture by Kavo Company, Germany. This device was primarily developed for detection of dental caries, and was later on modified to enable calculus detection. It is the diagnostic instrument that works on different autofluorescence intensities. An Indium gallium arsenide phosphate (InGaAsP) based red laser diode (< 1mW) emits light with a wavelength of 655nm through an optical fiber on to the tooth surface which is further induced to fluorescence.

Diagnodent readings inference according to the manufacturer-

Readings	Interpretation
≥ 40	Mineralized deposits
5- 40	Very small calcified plaque sites or residual calculus following partial cleaning
≤ 5	Clean root surface

These readings are indicated by a beep with an increasing audiotone frequency as the value increases.

This system has ability to measure wide range of fluorescence intensities that are further transferred to a digital monitor and calculus detection values from 0-99 are detected. The fluorescent light once emitted on to the tooth surface, is captured by surrounding optical fibres and further transmitted to a fluorescence detector i.e integrated photo diode. Band-pass filter is used to enhance the optical effects and thus modulate fluorescent light. The intensity of autofluorescence reduced in presence of blood and bacterial residues. This system efficiently distinguishes between calculus and cementum with high reproducibility.[17,18]

8] Lasers in detection of dental calculus:

The breakthrough for the use of dental laser systems in dentistry came back in late 1990's. The selection of specific laser is carried out according to its variety of wavelengths suited for soft and hard tissue procedures. Laser is an acronym for Light Amplification By Stimulated Emission of Radiation. Lasers detect calculus through a non-contact and minimally-invasive technology.[22] In Periodontology, laser has applications in Non-surgical and Surgical Periodontal Therapy.

Er:YAG laser was introduced in 1974 by Zharikov. One unique feature of Er:YAG laser is that it gets largely absorbed in water and causes less damage to hard tissues due to reduced heat production. [23]

Lasers for detection of dental calculus only: Keylaser 1 and 2

Earlier developed, Keylaser 1 and keylaser 2 comprising of Er:YAG laser only could be used for calculus detection. The Er:YAG laser (KEY II, KaVo, Biberach, Germany) has a therapeutic wavelength of 2.94 µm along with a pilot wavelength of 635 µm for laser irradiation. Certain instructions as given by manufacturer are that the laser is used in contact mode at energy levels of 120,140, 160 and 180 mJ/pulse at a repetition rate of 10 to 15 Hz along with water irrigation (15 ml/min). For subgingival application of this laser, the handpiece 2056 (KEY II, KaVo, Biberach, Germany) attached to a chisel shaped fibre tip having diameter 0.5mm-1.65mm. This fibre tip is moved from coronal to apical direction on the root surface. [24]

Laser Induced Fluorescence Spectroscopy:

Laser Induced Fluorescence (LIF) is an optical spectroscopic technique where calculus is excited with a laser, and the fluorescence emitted by the calculus is subsequently captured by a photodetector. Further, LIF is classified into Continuous wave or time-resolved LIF. The Continuous Wave (CW) LIF incorporates a continuous laser for excitation and is employed only when spectral signal is received. Whereas, in time-resolved LIF, a pulsed laser is used for excitation of the calculus and its emission (either a single wavelength or the full spectrum) is detected once the signal is received. [25]

Feedback Mechanism: In this mechanism, a laser fluorescence is coupled to an Er:YAG laser, as in the case of the KEYIII laser introduced by Kavo, selective calculus removal is facilitated. The control unit is known to release the laser beam only once the laser fluorescence confirms the presence of calculus, as the name suggests feedback mechanism. Once, the root surface is free from deposits, the laser is ceased and thus the surrounding sound tissue is prevented from ablation.

Studies carried out to assess the impact of feedback mechanism: An in-vitro study carried out at the University Clinic of Vienna. The buccal root surfaces of extracted teeth covered with calculus were treated with the Er:YAG laser in conjunction with activated feedback system. The control group comprised of the lingual surfaces of the extracted teeth covered with calculus treated with only Er:YAG laser keeping the feedback system deactivated. Both the treated surfaces were further assessed by scanning electron microscope. The results showed, root surfaces irradiated with the help of the feedback system, clearly showed signs of slight ablation and were smoother. [25]

9**] Multi-photon Fluorescence Microscopy**

The multi-photon fluorescence technology is invented by Denk et al in 1990. This technology helps in detection of tissue covered by subgingival calculus deposits that cannot be detected by one photon confocal fluorescence microscopy technology. The multi-photon or two-photon fluorescence microscopy is different from a one-photon fluorescence technique or single photon fluorescence microscopy, in which there is excitation by two photons simultaneously in a two-photon or multi-photon fluorescence microscopy. The single-photon fluorescence laser beam is known to have shallow penetration depth hence, multi-photon fluorescence is preferred. In multi-photon fluorescence the wavelength is not necessarily doubled, but only the volume illuminated by very high photon density is excited which emits fluorescence. Advantages of using this technology are– the ability to discriminate against fluorescence originating from regions outside the focal plane, such as gingiva and healthy tooth cementum, better penetration depth because of use of near infrared light along with excellent optical sectioning. In this technology, only the calculus emits fluorescence and hence better contrast is obtained, through this technology also a time-correlated mechanism is incorporated in multi-photon microscopy system to help reduce optical noise in the surrounding environment. Both the excitation and emission wavelengths are useful in several other biological applications.[5]

II. SUMMARY AND CONCLUSION:

Dental Calculus acts as a fixed nidus for retention of bacterial plaque. The role of dental calculus in periodontal disease can be summarized as-

- Primary effect is it acts as retention site for plaque. It brings the plaque bacteria closer to the supporting tissue.
- Provides fixed nidus for continuous accumulation of plaque & calculus.
- Interferes with local self-cleansing mechanism.
- Makes plaque removal difficult for the patient.
- Acts as a reservoir for irritating substances like endotoxins & products of tissue lysis due to its permeability & porous nature.
- It extends the bacterial front & shifts the zone of destruction more apically.

Detection and subsequent removal of this deep-seated calculus is hampered by the location, vicinity and inflamed gingival conditions.The traditional subgingival root debridement procedure consists of a systematic treatment of all the diseased root surfaces by using hand, sonic and / or ultrasonic instruments followed by tactile perception until the root surface feels smooth and clean. However, the traditional tactile perception of the subgingival root surface without the visual accessibility lacks sensitivity, specificity and reproducibility.

Thus, the subgingival debridement may lead to varying degrees of residual calculus, removal of root cementum or both. In order to overcome these shortcomings, a number of different technologies have been incorporated into dental devices for the purpose of identifying and selectively removing the dental calculus.

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