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REVIEW ARTICLE

Detection, removal and prevention of calculus: Literature Review



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Abstract Dental plaque is considered to be a major etiological factor in the development of periodontal disease. Accordingly, the elimination of supra- and sub-gingival plaque and calculus is the cornerstone of periodontal therapy. Dental calculus is mineralized plaque; because it is porous, it can absorb various toxic products that can damage the periodontal tissues. Hence, calculus should be accurately detected and thoroughly removed for adequate periodontal therapy. Many techniques have been used to identify and remove calculus deposits present on the root surface. The purpose of this review was to compile the various methods and their advantages for the detection and removal of calculus.

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1. Introduction

Bacterial plaque and calculus are accepted etiological agents in the initiation and progression of periodontal disease (Ash et al., 1964). Their accumulation and attachment are facilitated by a roughened root surface (Zander, 1953; Waerhaug, 1956; Mamoru et al., 2004). The rough calculus surface may not, in itself, induce inflammation in the adjacent periodontal tissues, but may serve as an ideal substrate for subgingival microbial colonization (Jepsen et al., 2011).

Cause-related anti-infective therapy aims to eliminate the microbial biofilm and calcified deposits from diseased root surfaces through root surface debridement (Jepsen et al., 2011). Because of its porous nature, calculus can adsorb a range of toxic products and retain substantial levels of endotoxin that can damage the periodontal tissues. These toxins are found on, but not within, the periodontally diseased root surfaces; hence, the surfaces should be treated carefully without extensive removal of the underlying cementum (Nyman et al., 1986).

Current subgingival root debridement techniques involve the systematic treatment of all diseased root surfaces by hand, sonic, and/or ultrasonic instruments. This step is followed by tactile perception with a periodontal probe, explorer, or curette, until the root surface feels smooth and clean. The drawback of traditional tactile perception of the subgingival environment is that the clinician may lack visibility and accessibility before and after treatment, leading to residual calculus and/or the undesirable removal of cementum. The location and inflammatory status of the gingiva also impact the detection and subsequent removal of deep-seated calculus.

Clinicians are frequently uncertain about the nature of a subgingival root surface while performing periodontal instrumentation. Correct evaluation of a cleaned surface is a key to thorough debridement. To enhance treatment planning and efficacy, several systems for calculus detection and/or elimination have been developed, based on different technologies (Meissner and Kocher, 2011; Bhusari et al., 2013). Numerous in vivo and in vitro clinical studies have been performed to determine their efficacy of calculus removal.

2. Calculus detection systems

2.1. Perioscopy

Currently, perioscopy is the only available method for detecting calculus (Perioscopy Inc., Oakland, CA, USA). Based on the principle of medical endoscopy, perioscopy is a minimally invasive approach that was introduced in the year 2000. The perioscope is a miniature periodontal endoscope. When inserted into the periodontal pocket, it images the subgingival

root surface, tooth surface, and calculus (Figs. 1a and b). Components of the perioscope include fiber-optic bundles bound by multiple illumination fibers, a light source, and an irrigation system. Perioscopic images can be viewed on a monitor in real time, captured, and saved in computer files. Although it causes minimal tissue trauma, perioscopy is not widely used, owing to its high cost and the need for a rigorous training period prior to use.

2.2. Optical spectrometry

The Detec-Tar (Dentsply Professional, York, PA, USA) calculus detection device utilizes light-emitting diode and fiber-optic technologies. An optical fiber in the device recognizes the characteristic spectral signals of calculus caused by the absorption, reflection, and diffraction of red light (Kasaj et al., 2008). Advantages of the device include its portability and emission of audible and luminous signals upon calculus detection.

2.3. Autofluorescence-based technology

Calculus contains various non-metals and metals, such as porphyrins and chromatophores. Due to their differences in



Figure 1a Perioscopy system.

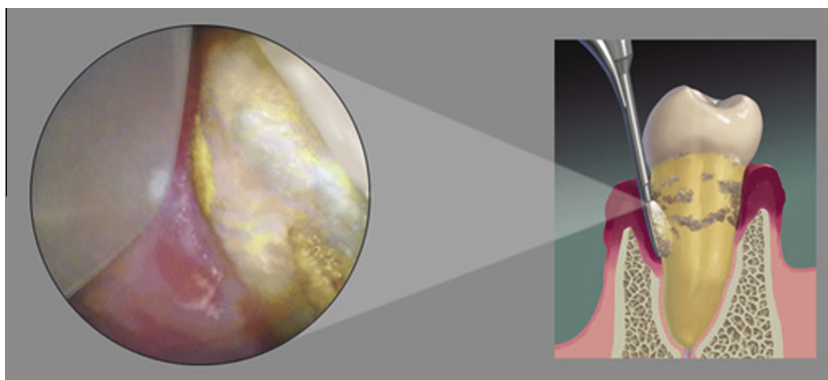


Figure 1b Visualization of subgingival calculus using perioscopy system.

composition, calculus and teeth fluoresce at different wavelength ranges (628–685 nm and 477–497 nm, respectively). Diagnodent™ is a commercially available calculus detection device (Meissner and Kocher, 2011). The InGaAsP-based red laser diode used in Diagnodent™ emits a wavelength of 655 nm through an optical fiber, causing fluorescence of calculus (Hibst et al., 2001).

3. Calculus removal systems

3.1. Mechanical debridement

Conventional non-surgical therapy is considered to be the cornerstone of periodontal treatment. Its effectiveness is based on reducing the bacterial load from the periodontal pocket and

removing hard deposits (e.g., calculus) that can aggravate the infection. Studies have concluded that the effectiveness of different treatment modalities in thorough calculus removal from root surfaces is impossible (Egelberg, 1999; Oda et al., 2004).

3.1.1. Hand instruments

Different hand instruments are used for non-surgical periodontal therapy. Scalars and curettes have the most access to subgingival calculus (Figs. 2, 3a, b, 4 and 5). Curettes can be used for root planning and effective debridement of subgingival calculus. Different aspects of hand and ultrasonic instrumentation methods have been compared (Claffey et al., 2004). In one study, ultrasonic instrumentation consumed less time for calculus removal than instrumentation by Gracey curettes (Copulos et al., 1993). Another found that there was no microscopic difference between the Cavitron™ ultrasonic scaler and Gracey curettes (Oosterwaal et al., 1987).

3.1.2. Ultrasonic instruments

Ultrasonic instruments are the principle treatment modality for removing plaque and calculus. These power-driven instruments oscillate at very high speeds, causing micro vibrations



Figure 2 Supragingival scalars. (A) Surface scalar, (B) anterior sickle scalar, (C) Posterior sickle scalar, (D) universal scalar.

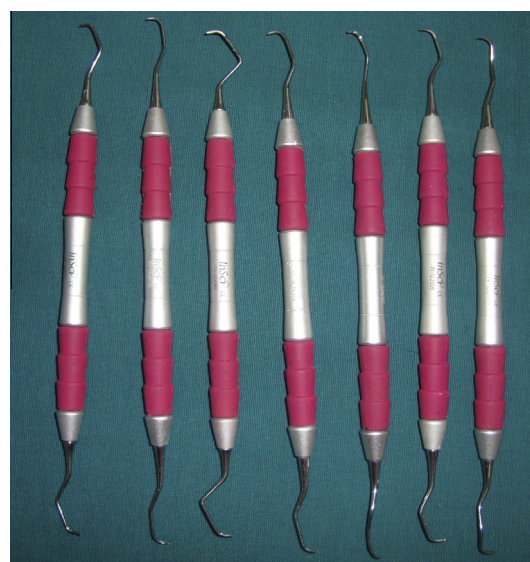


Figure 3a Gracey curettes for subgingival scaling (area specific curettes).

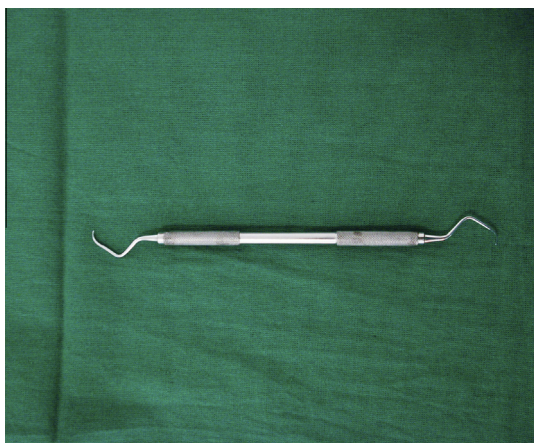


Figure 3b Universal curette.

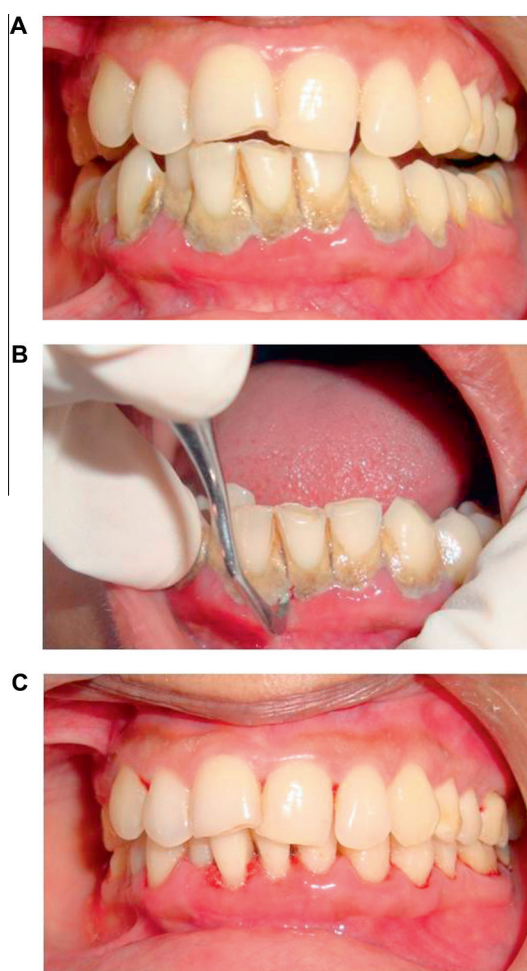


Figure 4 Supra gingival hand scaling (pre and immediate post operative) (A) Preoperative (B) Scaler in place (C) Immediate post operative.

that aid in calculus and subgingival plaque removal. Two different mechanisms are used to create these oscillations of the ultrasonic tip. Comparisons of magnetostrictive, piezoelectric, and hand instruments have had inconclusive results (Figs. 6–8). Arabaci et al. (2007) found that the piezoelectric



Figure 5 Supragingival scaling tips for implant surface.



Figure 6 Magnetostriuctive scaling unit and tips.

system was more efficient in calculus removal compared to magnetostrictive and hand instrumentation, but they left tooth surface rougher. Other studies have shown contradictory results with each other. Hence, it is not clear which treatment modality is more efficient for removing plaque and calculus from the root surface (Cross-Poline et al., 1995).



Figure 7 Piezoelectric scaling unit and tip.

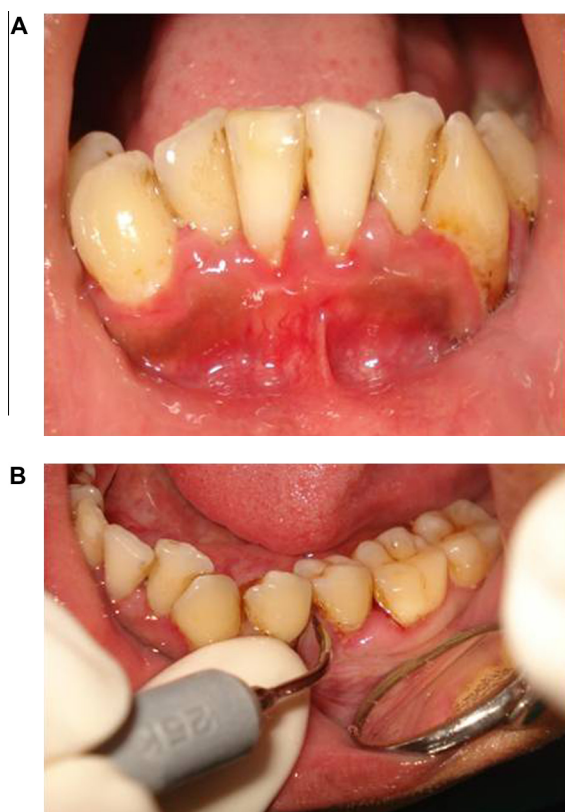


Figure 8 Supragingival scaling using ultrasonic scaler. (A) Preoperative, (B) Ultrasonic scaler in place.

3.2. *Vector™ system**

The Vector™ system was specially designed to treat periodontal tissues aggressively while reducing the amount of tooth surface loss. The uniqueness of this system lies in the oscillations produced by the ultrasonic tip. The Vector™ system is recommended for use in conjunction with irrigation fluids containing hydroxyapatite or silicon carbide. Although this system removes calculus efficiently (Braun et al., 2002), the efficiency of removal is dependent on the abrasive fluid used.

Another advantage of this system is the reduction in pain perception for the patient. This advantage may be attributed to the vertical vibrations of the ultrasonic tip. The abrasive fluid forms a smear layer on the scaled tooth surface (Braun et al., 2003), which is responsible for reducing the postoperative hypersensitivity. The Vector™ system is least efficient when polishing fluid is used with a straight metal tip. Use of an abrasive fluid with this system has been shown to cause similar loss of tooth substance compared to hand instrumentation. Hence, the Vector™ system can be an efficient adjunct for scaling and root planning. Further studies are necessary to assess the efficacy of this system for in vivo use.

4. Combined detection and removal devices

4.1. *Ultrasonic technology*

Ultrasonic calculus detection technology is based on conventional piezo-driven ultrasonic scaling. Perioscan™ (Sirona, Germany) is an ultrasonic device that works on acoustic principles, similar to tapping a glass surface with a hard substance and analyzing the resulting sound to identify cracks in the glass. The tip of the ultrasonic insert in Perioscan™ oscillates continuously. Different voltages are produced depending on the oscillation that, in turn, depends on the hardness of the surface encountered by the device. Perioscan™ can differentiate calculus from healthy root surfaces according to the inherent difference in hardness between the materials. It provides the option of immediate calculus removal, simply by switching the mode from “detection” to “removal,” a technique that makes it unnecessary to relocate previously located calculus.

The Perioscan™ instrument is used in two different modes. When the ultrasonic tip touches the tooth surface, a light signal is displayed on the hand-piece and on the actual unit. The light signal is accompanied by an acoustic signal. A blue light is shown during calculus detection mode, and a green light is shown when the ultrasonic tip touches healthy cementum. Different power settings aid the clinician in removing tenacious calculus. The only clinical study available for this device reported a sensitivity of 91% and specificity of 82% (Meissner et al., 2008).

4.2. *Laser-based technology*

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. Maiman introduced the first laser device in 1960. The advantage of laser use is that it can concentrate light energy at a single point to target the tissues. In 1965, Kinersly et al. reported the first use of ruby lasers for calculus removal from the tooth surface. Since then, numerous types of lasers have been used in the field of dentistry (Braun et al., 2003). Which laser is used depends on the frequency at which the laser can cut hard or soft tissues.

The Food and Drug Administration (USA) approved the use of the Nd:YAG laser for soft-tissue surgeries in 1990 and for hard tissues in 1999. This laser can also be used for partial calculus removal from the root surface (Aoki et al., 2004). However, the laser ablates the hard tissues as it removes calculus, which has hindered its use in this capacity. Studies have also shown that calculus removal by Nd:YAG laser is insufficient as compared to that achieved by hand instrumentation (Radvar et al., 1995).

The Er:YAG laser has undergone extensive study since its introduction by Zharikov in 1974 (Tseng and Liew, 1990). This laser is largely absorbed in water, which causes less damage to the hard tissues, due to the reduced amount of heat production. Studies to assess the efficacy of lasers in calculus removal have shown comparable results with hand and ultrasonic instruments (Tseng and Liew, 1991). Er:YAG lasers cause comparable loss of root substance compared to hand instruments. However, recent studies have shown that dental tissues are not removed along with calculus (Koort and Frentzen, 1995). Lasers have been demonstrated to cause deep ablation of the cementum (approximately 40–136 μm) (Aoki et al., 2004). The efficacy of lasers in calculus removal has been shown to be inferior compared to ultrasonic instruments, and clinicians continue to debate the use of lasers in non-surgical periodontal therapy.

Keylaser3™ combines a 655-nm InGaAsP diode for detection of calculus and a 2940-nm Er:YAG laser for treatment. A scale of 0–99 is used for detection of calculus, with values exceeding 40 indicating the definite presence of mineralized deposits. The Er:YAG laser becomes activated when it reaches a certain threshold and is switched off as soon as the value falls below the threshold. Studies assessing the efficacy of the Keylaser3™ have shown that it produces a tooth surface that is comparable to those produced by hand and ultrasonic instrumentation (Aoki et al., 1994, 2000; Folwaczny et al., 2000). The major concern with laser use is its high cost.

5. Strategies for prevention of calculus formation

Strategies to prevent calculus formation may include measures to solubilize calculus and the organic matrix, or to inhibit plaque adhesion, formation, and mineralization (Meissner and Kocher, 2011). Although decalcifying, complexing, or chelating substances could dissolve or soften the mineralized deposits, these chemicals carry the risk of damaging the enamel, dentin, or cementum. Therefore, research has focused on inhibiting plaque attachment and altering its metabolic and chemical characteristics (i.e., developing early mineralized plaque) by using antiseptics, antibiotics, enzymes, and matrix-disrupting agents (Aoki et al., 2000; Folwaczny et al., 2000).

More recently, concerns regarding the effectiveness or safety of the aforementioned substances (e.g., antibiotic resistance) have led researchers to examine ways to decrease plaque development by inhibiting crystal growth. Anti-calculus substances used in these efforts have included pyrophosphate, bisphosphonate, and zinc salts (e.g., zinc chloride and zinc citrate). As crystallization inhibitors are partially degraded in the oral cavity, they must be included at high concentrations in anti-tartar products (e.g., dentifrices, mouth rinses, and chewing gums). Use of anti-calculus agents in these products has been demonstrated to decrease the amount and nature of the calculus that forms (Jin and Yip, 2002). However, these inhibitors are not capable of dissolving existing deposits. Moreover, the effects of these anti-tartar products are mostly limited to the supragingival area.

Many currently used anti-calculus products contain triclosan, in combination with polyvinyl methyl ether (PVM) and maleic acid (MA) copolymer, and crystal growth inhibitors such as pyrophosphate with PVM/MA copolymer, zinc citrate, and zinc chloride (Jepsen et al., 2011). As a broad-spectrum antimicrobial agent, triclosan can prevent bacterial uptake of essential amino

acids, and, at higher concentrations, destroy the integrity of the cytoplasmic membrane. Triclosan also exerts both direct and indirect anti-inflammatory effects. Numerous clinical studies have confirmed the anti-calculus efficacy of triclosan (White, 1997).

Pyrophosphate decreases crystal growth by binding to the crystal surface. Moreover, it can impede the conversion of dicalcium phosphate dehydrate (DCPD) to hydroxyapatite and reduce pellicle formation. Bisphosphonates, which are stable synthetic analogs of pyrophosphate with resistance to hydrolysis, have also been used as anti-calculus agents (Shinoda et al., 2008; Sikder et al., 2004). When used as advanced mineralization inhibitors, polyphosphates (e.g., hexametaphosphate) can reduce calculus formation (Sikder et al., 2004). Phytate, which has structural similarities to pyrophosphate, is capable of inhibiting the formation of brushite and hydroxyapatite crystals in vitro and in vivo. A randomized, double-blind, three-period crossover clinical study examined the anti-calculus efficacy of a phytate-containing mouthwash (Porciani et al., 2003; Grases et al., 2000). The levels of calcium, magnesium, and phosphorus present in the residues obtained by dental cleaning were significantly reduced in the phytate treatment group compared with controls, demonstrating that phytate is an effective substance for prevention of calculus formation.

Zinc ions help to inhibit crystal growth by binding to the surfaces of solid calcium phosphates. They also affect the quality and quantity of calcium phosphate crystals. Zinc salts have been reported to reduce plaque acidogenicity and growth (Grases et al., 2006). Toothpastes containing zinc salts, such as zinc citrate and zinc chloride, have been shown to be effective in decreasing calculus formation. A significant reduction in supragingival calculus formation was found after chewing gum containing vitamin C, which could be due to the acidic properties of ascorbic acid (Oppermann et al., 1980).

Anti-calculus agents have been used at various concentrations, alone or in dentifrices. Their effects have been evaluated in various study populations, after various periods of time, and by using various study designs and controls. Future studies are required to search for even more effective anti-calculus substances, and for application modes that can affect subgingival calculus formation.

6. Conclusion

By providing an ideal porous medium for bacterial plaque retention and growth, calculus serves as a secondary etiological factor in periodontitis. Calculus must be detected and removed for adequate periodontal therapy and prophylaxis. Many techniques have been used to identify calculus deposits present on the root surface. The major drawbacks of these techniques include their cost, elaborative set-up, technique sensitivity, and the need for re-identification of the calculus before removal. Clinicians must rely on their ability to reproduce the results given by the detecting device, which may lead to a manual error.

An instrument that incorporates calculus detection and removal is highly desirable, as it could reduce the chair-side time, lead to efficient scaling, and prevent overzealous instrumentation. Such a device could increase patient compliance in further dental treatment and aid in patient education and motivation. Future research should focus on these limitations and requirements for forming new devices and techniques for calculus detection.

Conflict of interest

The author has no financial interest associated with the materials used in this study and declares no conflict of interest.

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