Review Article

Minimally Invasive Periodontal Therapy: An Overview

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ABSTRACT

Minimally invasive procedures in periodontal treatment represent alternative approaches developed to allow less extensive manipulation of surrounding tissues than conventional procedures, while accomplishing the same objectives. Minimally invasive periodontal therapy (MIPT) involves the use of minimally invasive non-surgical as well as surgical treatment concepts that preserves the dentition and supporting structures. Recently, many new procedures have been developed as a result of technologic advances and fundamental changes in hospital design and surgical training. This has enhanced the reality of minimally invasive surgery. Professional interventions that concentrate on biofilm disruption, with minimal effects on tooth structure, are included as part of Minimally Invasive Non-Surgical Periodontal Therapy. In order to increase surgical effectiveness, the use of surgical loupes, surgical operating microscopes and microsurgical instruments in terms of Minimally Invasive Periodontal Surgery (MIPS) has been suggested. This review, intends to summarize the currently available minimally invasive periodontal diagnostic and treatment modalities.

Keywords: Microsurgery, minimally invasive, nanotechnology, periodontal therapy

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INTRODUCTION

Until the mid-nineteenth century, surgical procedures were extremely brutal and ablative and had minimal application as they were governed by specific incisions and surgical principles. The introduction of anesthesia and improved surgical techniques enabled the surgeons to undertake complicated procedures; however minimal thought was given to the surgical trauma to the patient leading to morbidity. Since the early 1980s it has become evident that less invasive methods of interventional treatment can produce fewer complications with a reduced risk of death and morbidity. Scientific innovations and advances in technology have led to the idea that surgeries can be performed more precisely and less traumatically.[1] This realization has given rise to the idea of minimally invasive (MI) treatment with an aim to minimize trauma due to interventional process and still achieve a satisfactory therapeutic result. Recently, many new procedures have been developed as a result of technologic advances and fundamental changes in hospital design and surgical training. This has enhanced the reality of minimally invasive surgery. The development of new techniques for detecting the etiological factors in periodontally active sites have allowed a more accurate periodontal diagnosis resulting in a more rational therapy and a considerable increase in treatment benefits.[2]

METHODOLOY FOR SEARCH STRATEGY

A literature search Medline and PubMed databases were searched under the following key terms: “microsurgery,” “minimally invasive,” ‘nanotechnology,” “periodontal therapy,” and “laser therapy.” All keywords were restricted in title or abstract without the language limitation.

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Date of Submission: September 20, 2017
Review Completed: October 15, 2017
Date of Acceptance: November 16, 2017

Only highly relevant articles from manual and electronic databases were selected for the present review. The aim of this review is to summarize the currently available minimally invasive periodontal diagnostic and treatment modalities.

LITERATURE REVIEW

MINIMALLY INVASIVE PERIODONTAL PROBES

Periodontal probes have undergone extensive development since their introduction by Black and calibration by Simonton. Probe types were classified by Pihlstrom in 1992 into three generations:[3]

First Generation Conventional / Manual Probes: Do not control the probing pressure; Not suited for automatic data collection; e.g. Williams periodontal probe, The Community Periodontal Index of Treatment Need (CPITN) probe, the University of North Carolina-15 (UNC-15) probe, the Nabers probe etc.

Second Generation Constant-Pressure Probe: Pressure-controlled probes with visual measurement recording; Allow standardization of probing pressure; Pressure does not exceed 0.2 N / mm^2. Prototype – True Pressure Sensitive Probe (TPS).

Third Generation Automated Probes: Pressure controlled electronic probes with direct computer data capture and storage; Controlled probing pressure – 15 gms; Automated detection of CEJ; e.g. - The Foster-Miller probe (Foster-Miller, Inc, Waltham, MA), The Florida Probe (Florida Probe Corp, Gainesville, FL), The InterProbe (The Dental Probe Inc, Glen Allen, VA).

In 2000, Watts extended this classification by adding fourth and fifth generation probes:[4]

Fourth generation Three-Dimensional (3D) Probes: Currently under development; Attempts to take into account the continuous and 3D pocket being examined

Fifth Generation UltraSonographic Probe: Aim to identify the attachment level without penetrating the junctional epithelium; UltraSonographic (US) probe (Visual Programs, Inc, Glen Allen, VA) devised by Hinders and Companion at the NASA Langley Research Center.

DetecTar: DetecTar is a tabletop electronic device and is purported to be the "first and only objective calculus detector" overcoming the problem of inaccurate detections of clinically identifiable calculus. This optical device was developed by NEKS Technologies Inc, Lavan, Quebec. The DetecTar has the ability to identify the characteristic optical signal of dental calculus, even in the presence of contaminants. An LED light (of extremely narrow wavelength = 20 - 40 nanometers) is emitted from the probe tip. The light returned off the root surface is picked up by a fiber optic lead and converted into an electrical signal for analysis. A computer-processed algorithm determines whether the probe is in contact with dental calculus and activates a signal to notify the clinician of the presence of the calculus.[2] The DetecTar has been proven to be ~91% efficient at detecting calculus.[5]

Periodontal Endoscope: Historically, visual access to the subgingival root surface could only be attained through a periodontal flap procedure or extraction of the tooth. Advancements in fiber-optic technology, coupled with modifications of the periodontal armamentarium (e.g., curettes, periodontal probe, ultrasonic scaler) have led to the development of a technology, the Endoscope which provides the clinician with a direct real-time visualization, access and magnification of the subgingival root surface (up to 95% better access and visibility)[6] and sulcus contents thereby improving the diagnosis and management of periodontal disease in a more conservative and non-invasive manner. Subgingival soft tissue, including the gingival attachment, sulcus wall, and sulcus contents, can be assessed. Subgingival caries, root fractures, tooth root deposits, post perforations and open restoration margins can easily be identified and located.[7]

The Dental Endoscope was originally developed by Dentalview Incorporated (Irvine, Calif.) and is currently available from Perioscopy Incorporated. A family of dental instruments including curettes, explorers, and ultrasonic scalers have been designed to accept the imaging system. Combined with a simple array of micro ultrasonic instruments, endoscopic debridement can be accomplished in a conservative, minimally invasive way by the periodontist.[8]

PERIODONTAL ULTRASONOGRAPHY

In view of the non-invasive nature and the avoidance of ionising radiation, ultrasonography could have a valuable place in periodontal diagnostics for measuring pocket depth and thus assessing periodontal health.

Periodontal Ultrasonography have been used for the determination of alveolar crest height, periodontal bone morphology, width of the periodontal ligament, thickness of gingival tissue and also to assess the dynamics of mucosal dimensions after root coverage procedures. Ultrasonography plays a significant role in osteotomies and sinus lift procedures by its piezoelectric ultrasonic vibrations. In addition, low intensity pulsed ultrasound appears to be effective in periodontal healing and demonstrates the potential for periodontal regeneration.

Clinical applications

Scaling and root planing: Microstreaming or acoustic mainstreaming generated by ultrasound in the presence of a fluid disrupts bacterial cell walls and thus is effective in removing bacterial plaque. Ultreo® (Ultreo Inc, Redmond, WA, USA) is a revolutionary power toothbrush that combines ultrasound waveguide technology with precisely tuned sonic bristle action.

Imaging for periodontal assessment: The ULTRADERM® (Longport International Ltd, Silchester, UK) ultrasonic scanner enables suitable assessment of the periodontium.

Application to regrow teeth: High intensity focused ultrasound has shown to stop bleeding in blood vessels non-invasively, whereas low intensity pulsed ultrasound (LIPUS) has been reported to be effective in liberating preformed fibroblast growth factors, stimulating angiogenesis, enhancing bone growth into titanium porous implants, accelerating healing of resorption by reparative cementum and enhancing bone healing after fractures.[9]

Vector™ Ultrasonic System: The Vector™ system (Duerr Dental, Bietigheim-Bissingen, Germany), is a linear oscillating device, in which the addition of hydroxylapatite particles to the irrigation suspension (Vector fluid polish) removes subgingival deposits and polishes the root surface by hydrodynamic forces.[9]

Optical Coherence Tomography: Optical coherence tomography (OCT), is an effective optical diagnostic tool because it is a noninvasive, nondestructive, non-radiated, and real-time monitoring method.[10] Dental OCT detects qualitative and quantitative morphological changes of dental hard and soft tissues *in vivo*. It can also be used for early diagnosis of dental diseases, including caries, periodontal disease and oral precancerous and cancerous lesions, because of the excellent spatial resolution. Various functional OCT systems are available such as Doppler OCT (DOCT), polarization sensitive OCT (PS-OCT), endoscopic OCT and acoustic OCT. These functional systems can also provide specific optical characteristics like blood flow velocity and tissue orientation. With the aid of OCT, early detection of periodontal disease and monitoring of periodontal treatment could be very helpful.

PERIODONTAL VACCINES

The objective of periodontal vaccine is to identify the antigens involved in periodontitis against which antibodies would be evoked to exert protection. It also aims to induce mucosal antibody response with little or moderate doses of vaccine. The availability of periodontal vaccine would not only prevent and modulate periodontal disease but also enhance the quality of life for those in whom periodontal treatment cannot be easily obtained.

Types of periodontal immunization

Active immunization: The whole bacterial cell, its sub unit or a synthetic peptide is inoculated into the host as antigens.[11]

Passive immunization: Antigens are injected into vectors that produce antibodies which are then inoculated into the host. E.g. Murine monoclonal antibody and Plantibodies.[11]

Genetic immunization: It is the insertion of genes into individual cells and tissues to treat a disease by using genetic engineering or recombinant DNA technology. E.g. Plasmid vaccines and live,viral vector vaccines.[11] Examples of periodontal vaccines include Vancott′s vaccine and Inava endocarp vaccine. As yet, there are no periodontal vaccine trials that have been successful in satisfying all requirements.

GENE THERAPY IN PERIODONTICS

Gene therapy is the genetic modification of cells for therapeutic purposes. With the advent of gene therapy in dentistry, significant progress has been made in controlling the periodontal disease and reconstruction of damaged periodontal tissue.

This approach is becoming possible owing to the increased understanding of the molecular basis for many diseases and the advances in the technology of gene transfer. Implications of gene therapy in periodontics[12] include Guided tissue regeneration and use of vector-encoding growth factors. Gene therapy is being used in periodontics for development of periodontal vaccination, avoidance of biofilm antibiotic resistance, in-vivo gene transfer by electroporation for alveolar remodeling, antimicrobial gene therapy and designer drug therapy.

PROBIOTICS

Given the widespread emergence of bacterial resistance to antibiotics, the concept of probiotic therapy has been considered for application in oral health. Dental caries, periodontal disease and halitosis are among the oral disorders that have been considered as targets for probiotic therapy in recent years.[13] Probiotics, most commonly belong to the genera: Lactobacillus and Bifidobacterium.

The novel approach of Guided Pocket Recolonization (GPR) may provide a valuable alternative to the armamentarium of treatment options for periodontitis. This approach holds that repeated application of commensal oral streptococci after SRP significantly suppresses the re-colonization of periodontopathogens.[14]

Commercially available Probiotics for periodontal disease management include Gum PerioBalance, PeriBiotic, Bifidumbacterin, Acilact, Vitanar, Wakamate D, Prodentis.[13]

LOCAL DRUG DELIVERY

Local Drug Delivery (LDD) is a less invasive approach to antimicrobial therapy wherein the suspected periodontopathogens are controlled by administering an antimicrobial agent into the periodontal pocket[15] where its concentration can be established and maintained at any desired level for any duration required. LDD can attain 100-fold higher concentrations of the drug at the subgingival sites thereby reducing the total patient dose by 400 fold. Local drug delivery agents include devices with tetracycline, doxycycline, minocycline, metronidazole, and chlorhexidine.[16] Statins like simvastatin (SMV) & lovastatin etc. are also being used in the form of LDD as they modulate bone formation by increasing the expression of bone morphogenetic protein-2. Various herbal formulations like aloevera, neem, tulsi, propolis, cocoa husk, *Harungana madagascariensis* leaf extract (HLE), pomegranate, cranberry etc. are being used widely these days.[17] *Gengigel*, a high molecular weight Hyaluronan, is being widely used for oral conditions associated with soreness and inflammation. Various local drug delivery systems used in treatment of chronic periodontitis include fibers, film, injectable systems, gels, strips and compacts, vesicular systems, microparticle system, nanoparticle system etc. (Table 1).

Table 1: List of commercial periodontal products presented in various dosage forms [17]

Antimicrobial Agent	Commercial available form	Description
Tetracycline	Actinide	Non resorbable fiber
	Periodontal AB plus	Resorbable fiber
Doxycycline	Atridox	Biodegradable mix in syringe
	Atrigel	Gel
Minocycline	Arestin	Biodegradable powder in syringe
	Dentamycin	Biodegradable mix in syringe
Metronidazole	Elyzol	Biodegradable mix in syringe
Chlorhexidine gluconate	Periochip	Insert

LASERS

Use of lasers in the nonsurgical treatment of periodontal disease include sulcular and/or pocket debridement (a.k.a. laser curettage), reduction of subgingival bacterial loads (a.k.a. pocket sterilization) and, scaling and root planing (SRP).[18] There is abundant evidence to indicate that there is markedly less bleeding particularly of highly vascular oral tissues during laser surgery. Laser created wounds heal more quickly and produce less scar tissue than conventional scalpel surgery.

Clinical applications

Oral Soft Tissues: These procedures include frenectomy, gingivectomy and gingivoplasty, de-epithelization of reflected periodontal flaps, removal of granulation tissue, second stage exposure of dental implants, lesion ablation, incisional and excisional biopsies of both benign and malignant lesions, irradiation of aphthous ulcers, coagulation of free gingival graft donor sites, and gingival depigmentation.[19]

Wound healing: Laser treatment provides a better intra-operative and post-operative experience for both the clinician and the patient by offering a dry surgical field, tissue sterilization, decreased pain, post-op swelling, and scarring and faster healing.

Oral Hard Tissues: Erbium lasers show the greatest potential for effective root debridement (SRP). LANAP - This no-cut, no-sew technique, performed using the Nd-YAG laser, allows for laser-induced new attachment through regeneration of cementum, periodontal ligament and supporting alveolar bone, and leads to significant decrease in subgingival pathogenic bacteria.[19]

Low Level Laser Therapy (LLLT)

Low level laser (also called ‘soft laser’) is a red light or infrared light whose wave length has a low absorption power in water and is capable of penetrating into soft and hard tissues in a depth of 3mm-15mm. Mechanism of action of LLLT involves laser light absorption in the sub-cellular photo-receptors, especially the electron transfer in the respiratory chain of the mitochondria membrane.[20]

LLLT is capable of reducing inflammation following scaling. It has been suggested as a method for post-op pain reduction. When used after gingivectomy and gingivoplasty procedures, it result in increased epithelialization and better wound repair.[21] LLLT with modified widman flap (MWF) would result in reduction of pain and post-operative edema.[22] It may also be used to heal the wound in the palatal graft door site.[23] The second-stage surgery of submerged implants can also be performed with soft tissue lasers with minimal bleeding, trauma, and pain.

Photodynamic Therapy: Photodynamic Therapy (PDT), also called photoradiation therapy, phototherapy, or photochemotherapy, has been considered as a promising novel non-invasive therapeutic approach for eradicating pathogenic bacteria in periodontal and peri-implant diseases. This process is defined as Antimicrobial Photodynamic Therapy, Photodynamic Antimicrobial Chemotherapy (PACT) and Photodynamic Disinfection or Lethal Photosensitization.

PDT basically involves three non-toxic ingredients:[24] Visible harmless light of suitable wavelength, a nontoxic photosensitizer: porphyrins, toluidine blue, methylene blue, etc., and oxygen. It is based on the principle that a photosensitizer (i.e. a photoactivatable substance) binds to the target cells and can be activated by a suitable light following which, singlet oxygen and other very reactive agents are produced that are extremely toxic to certain cells and bacteria.

In periodontics, PDT has been used for photodynamic diagnosis (PDD) of malignant transformation of oral lesions, treatment of oral leukoplakia, oral lichen planus, and head and neck cancer and treatment of bacterial, fungal, parasitic & viral infections.[25] The future of PDT lies in the development of targeted therapy, bacteriophage-photosensitizer conjugates, and non-antibody-based targeting moieties.[26]

MINIMALLY INVASIVE IMPLANTS

Various types of minimally invasive implants have been introduced in the field of dentistry. These include:

1. Flapless Implants

2. Short Dental Implants (SDI)
3. Mini Dental Implants (MDI)
4. Narrow Diameter Implants (NDI)

Flapless Implants: The flapless technique has been associated with preservation of soft tissue architecture, improved patient comfort and satisfaction.[27] In addition, the intact periosteum maintains a better blood supply, thus reducing the likelihood of early bone resorption. It is now practical to perform implant surgery as well as sinus elevation surgery without the need for flaps or sutures by the simple use of a 5- or 6-mm tissue punch that permits access to the osteotomy site as well as to the sinus.[28]

Short Dental Implants (SDI): Literature defines implants shorter than 10 mm in length as short dental implants (SDIs).

The introduction of SDIs tends to overcome most of the difficulties experienced by the operator in carrying out complicated bone augmentation procedures. These are less invasive, require less chair side time and are more acceptable by the patient. They are also associated with less morbidity as compared to vertical bone augmentation procedures.[29]

Mini Dental Implants (MDI): These are ultra-small diameter implants that slip into minimal width islands and columns of bone. Osteotomy is done using minimally invasive starter drills avoiding encroachment of any vulnerable adjacent tissues. Overt penetration of any cortical wall is avoided with MDIs. These offer better prognosis for the peri-implant environment. MDI affordability can play a significant role in patient acceptance of a restorative treatment plan.[30]

Narrow Diameter Implants (NDI; Diameter < 3.75 mm): These implants may be used where bone width is reduced or in single-tooth gaps with limited mesiodistal space, such as for the replacement of lateral maxillary or mandibular incisors.[31] By using a NDI, the need for bone augmentation can be avoided.

PERIODONTAL MICROSURGERY

Periodontal microsurgery is the refinement of basic surgical techniques made possible by the improved visual acuity gained with the use of the surgical microscope. In the hands of a trained and experienced clinician, microsurgery offers enhanced outcomes not possible with traditional macrosurgery, especially in terms of passive wound closure and reduced tissue trauma.

Applications of periodontal microsurgery: Scaling and Root Planing, Esthetic periodontal plastic surgeries such as gingival augmentation and root coverage procedures using CTG or FGG, papilla reconstruction and pedicle grafts; regenerative procedure (viz. vertical and horizontal bone augmentations, Guided Bone Regeneration, and Guided Tissue Regeneration), extractions and ridge preservation procedures, sinus augmentation and repair, biopsies, flap surgeries, all phases of implant treatment.[32,33]

Future Perspectives: Robot-assisted minimally invasive surgery (RMIS) would greatly improve the accuracy and dexterity of a surgeon while minimizing trauma to the patient. Here, the surgeon manipulates the telerobot and watches the operation through a 3-D video.[34]

Videoscope-Assisted Minimally Invasive Surgery (V-MIS) provides direct visualization and greater magnification, resulting in a mean post-surgical increase in soft tissue height with a decrease in recession.[35]

TISSUE GLUES

New biomaterials and techniques are being developed with the aim of uniting and maintaining the stability of incised tissues and avoiding the penetration of foreign bodies.[36]

Tissue adhesives offer a unique and novel means of wound closure since they may result in equivalent tensile strength, improved esthetics of the scar, and lower infection rates. Also, the patient does not need to revisit the doctor for its removal.

Fibrin sealant, a synthetic substance composed of fibrinogen and thrombin, is used to create fibrin clot. It has an anti-enzymatic effect which promotes fibroblast aggregation, growth and adhesion.[37]

Fibrin glue is "Fibrin Fibronectin Sealing System" (FFSS), commercially available as Tisseel VH (Baxter, U.S.A.) and Tissucol (Termotrattato, Wien). It promotes clotting with the formation and cross-linking of fibrin. Fibrin

Adhesive System (FAS) is a topical biological adhesive consisting of a solution of concentrated human fibrinogen, which is activated by the addition of bovine thrombin and calcium chloride.

Conventional sutures provide only a marginal fixation, while the fibrin sealing system makes the tissues adhere on its whole surface.

Advantages: Tissue glues promote an early and stable bond between the gingival flap and the exposed root. They are advantageous when used during periodontal plastic surgeries in the esthetic zone as they prevent apical migration of junctional epithelium thus avoiding gingival recession. They promote new attachment formation as well as wound healing. They can be used as local haemostatic agents in patients with bleeding disorders and those taking anti-coagulants. Osteoconductive potential of FFSS when used with bone graft material like β-TCP have been demonstrated in some studies.[37]

NANOROBOTICS

The emergence of a new field called Nanodentistry, will make it possible to maintain near-perfect oral health by the use of nanomaterials, biotechnology and nanorobotics, components of which are at or close to the scale of a nanometer (10^{-9} meters).[38]

Application of nanorobotics in Periodontology: Nanorobotic dentrifices (dentifrobots), delivered by mouthwash or toothpaste, help in maintaining oral hygiene and preventing halitosis. They metabolize trapped organic matter into harmless and odorless vapors and perform continuous calculus debridement.[39]

Nanorobots induce oral analgesia by instilling a colloidal suspension containing millions of active analgesic micrometer sized dental nanorobot 'particles' on the patient's gingiva. These ambulating nanorobots enter the dentinal tubules and proceed towards the pulp, guided by a combination of chemical gradients, temperature differentials and even positional navigation; all under the control of on-board nanocomputer as directed by the dentist.[40]

Dentin hypersensitivity can be relieved by reconstructive dental nanorobotics which uses native biological materials to selectively and precisely occlude specific dentinal tubules within minutes.

Nanotechnology aims to emulate bone's natural nanostructure for the development of nanobone, a Bone replacement material used to treat periodontal bony defects.

Local targeted drug delivery has been enhanced by use of nanosensors, nanoswitches, and other nano delivery systems. The main aim of nano drug delivery system is the entry of the drug into the cell by endocytosis only using nano particles as carriers and a targeted delivery of the drug to the desired tissue or cell so as to minimize the side effects. Nanomaterials such as hollow spheres, core-shell structure, nanotubes and nanocomposites have been widely explored for controlled drug release. Arestin i.e. minocycline incorporated into microspheres is used as LDD.

Other nano scale delivery vehicles that are now under investigation include polymeric particles, dendrimers, nanoshells, liposomes, magnetic nanoparticles, gold nanoparticles etc.

Disadvantages and Limitations: Minimally invasive procedures require special equipment which could be more expensive, specialist training, and more time as some procedures may take longer than usual, compared with conventional surgeries. Although there is adequate science to support the development and clinical use of minimally invasive periodontal treatment but the technology to perform it is not currently available. At best, even in the hands of highly skilled users, these techniques are cumbersome and have a steep learning curve.

CONCLUSION

Introduction of minimally invasive diagnostic and therapeutic modalities have various advantages such as less invasive procedures, shorter duration, favored healing, improved wound stability, and benefiting the patient with reduced pain and morbidity. The future promises further evolution towards a more primary preventive approach, facilitated by emerging technologies for diagnosis, prevention and treatment. However there are technical, cultural and economic obstacles to overcome for this to be fully realized in clinical practice.

Source of support : Nil

Conflict of interest : None reported

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To cite: Chandra V, Jhingran R, Bains VK, Madan R, Srivastava R. Minimally Invasive Periodontal Therapy: An Overview. Asian J Oral Health Allied Sc 2017;7(2):43-51.