Instrumentation Effectiveness of Modified, Area-Specific Hand Scalers During Non-Surgical Periodontal Therapy on Teeth Presenting with Moderate to Severe Periodontitis

by

Bethany A Palesh, RDH, BSDH

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Thesis Committee:

Clinical Assistant Professor/Director of Graduate Dental Hygiene Program, Dr. Danielle Furgeson, Thesis Chair
Clinical Professor, Dr. Robert Eber, Committee Member
Clinical Associate Professor, Dr. Suncica Travan, Committee Member
Clinical Associate Professor, Dr. Carlos Gonzalez-Cabezas, Committee Member

Bethany A. Palesh

paleshba@umich.edu

Dedication

This thesis is dedicated to the individuals who provided me with the support I needed throughout this educational journey and believed in my potential to accomplish more than I could ever imagine, my family.

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CHAPTER I

INTRODUCTION

1.1 Problem Statement

Periodontal disease (PD) is considered to be the most common oral disease resulting in tooth loss affecting adults around the world.[1] Although statistics vary pertaining the prevalence and incidence of PD,[2] the National Health and Nutrition Examination Survey (NHANES) states that approximately 42% of American adults have some form of periodontal disease.[3] PD is defined as a chronic inflammatory disease of the oral tissues that leads to the destruction of the periodontium, which includes loss of soft tissue clinical attachment (CAL) and supporting bone.[4-6] The initial stage of PD is gingivitis, where inflammation is limited to the gingival tissues. If untreated, gingivitis may progress to periodontitis, where inflammation causes loss of soft tissue attachment and bone support, which leads to deepened periodontal pockets around the teeth. Periodontitis is initiated by dysbiosis of the bacterial biofilm, commonly known as plaque, and is modulated by the patient's host response. Due to the progressive and complex nature of periodontitis,[4,5] treatment, starting with nonsurgical treatment and including surgical treatment if necessary, should focus on attaining oral health conditions that patients can maintain over time with support from their dental providers.[7]

There are many different phases and treatment options available for treating periodontitis. However, the foundation of periodontal treatment begins and continues through the following years with nonsurgical periodontal therapy (NSPT). NSPT is the mechanical removal of biofilm and calculus via hand and ultrasonic instrumentation from the crown and root surfaces of the tooth, thereby creating root surfaces, free from plaque-retaining factors, that promote healing of the gingival tissues.[8] NSPT is considered the foundation of periodontal treatment because it is a preferred method of treating PD by patients, less invasive in nature and may be more cost-effective than surgical treatment if it is the only periodontal therapy needed, thereby making it the ideal first phase, and continued phase, of periodontal therapy . The removal of causative agents like biofilm helps to decrease inflammation contributing to periodontitis which is the essence of NSPT; it also includes evaluations that allow providers the opportunity to assess the need for surgical treatment to gain access to deeper pockets for debridement.[9] The two types of NSPT are scaling and root planing (SCRP), and periodontal maintenance (PM).

High quality SCRP is fundamental to the success of periodontal therapy[10] and must be performed by a skilled clinician utilizing tactile senses and a variety of well-maintained hand scalers, curettes and ultrasonic scalers. Clinicians performing SCRP must be knowledgeable regarding tooth and root surface anatomy in order to effectively use their instruments to attain complete removal of subgingival calculus and biofilm. PM follows initial periodontal therapy treatment (whether nonsurgical or surgical) at three to four-month intervals in order to assist the patients with maintaining their oral health.[11] Consecutive PM appointments include NSPT methods of biofilm and calculus removal using a variety of instruments that will allow them to complete their task efficiently and effectively and include clinical assessments, specifically evaluating the health of the periodontium through periodontal chartings and radiographs. The appointments during this phase of periodontal therapy are beneficial to both clinician and patient as it allows continual monitoring of an individual's periodontal health and monitors of changes that may occur with disease progression.

In the past, studies have shown that hand instruments used for NSPT are limited in their effectiveness in removing subgingival calculus and biofilm from periodontal pockets that are deeper than 4 mm.[12-18] When instruments are utilized for NSPT, their efficiency in removing etiologic factors such as calculus and biofilm are limited to a shallow depth when conducted without the access of a gingival flap, due to limited visual access and root anatomy.[12-14, 19-21] Nagy et al. (1992) concluded that the average curette is effective in the removal of etiological substances in pockets that range from 1 to 3.46 mm, whereas Stambaugh (1981) found that limit to be 3.73mm.[12,18] Waerhaug (1978) and Rabbani (1981) both stated that as the pocket depth increases, the greater the chance of failure becomes in removing subgingival plaque during NSPT.[13,14] Sherman et al. (1990) noted that following SCRP treatment, 57% of all tooth surfaces within the study had residual microscopic calculus remaining and thus suggest the impossibility of complete calculus removal from deep pockets.[15]

Many researchers have stated that many limitations exist during NSPT making it difficult to remove biofilm and calculus thoroughly from subgingival surfaces. Lack of visualization and operator control[14] have been deemed major limitations that prevent clinicians from having the ability to see where residual biofilm and calculus or burnished calculus may still be. Using tactile sensitivity can help overcome some of these barriers, although Sherman and colleagues stated that a limitation to NSPT is the inability for the clinician to detect remaining calculus following instrumentation due to tooth anatomy and root concavities being difficult to adapt to.[15]

Instrument modifications for hand scalers used in NSPT have occurred through the years in order to meet the needs of clinicians treating patients in clinical practice. Specifically, standard, area-specific instruments, such as Gracey curettes, have undergone significant design modifications in the last two decades (**Figure 1**). The main idea behind instrument modifications was to help clinicians overcome the challenges and limitations presented by traditional hand instruments during NSPT. The shank design, cutting edges, and angles of the working ends have all been redesigned and engineered in a way that will allow dental providers to effectively remove biofilm and subgingival calculus from root surfaces that are greater than 3 mm.[22] Tooth anatomy and root structures have all been given due consideration when designing these instruments. The Gracey curettes are familiar, area-specific, instruments that are often used in periodontal treatments; with the modifications of these instruments, they should be considered an asset for use by dental professionals. The improvements of these curettes include extending the shank length and creating a smaller working end in order to gain access to root concavities in deeper periodontal pockets. Although current researchers state that modified, area-specific curettes may be more effective in the removal of subgingival calculus and biofilm due to their design and ability to adapt better to the anatomy of the tooth, there is limited evidence to support the claim and warrants further studies in order to confirm their true effectiveness.[23]

1.2 Goal Statement

The goal of this study is to determine how effective modified, area-specific curettes are in removing calculus and biofilm from subgingival root surfaces in pockets that are 5 mm or greater. The results of this study will determine whether or not having these modified, area-specific curettes in a dental clinician's armamentarium would be of benefit during nonsurgical periodontal therapy procedures for calculus and biofilm removal from subgingival periodontal pockets.

1.3 Specific Aims

Specific Aim 1: To determine how effective modified, area-specific curettes are in non-visual scaling and root planing for calculus removal in periodontal pockets 5mm or greater.

Hypothesis: Modified, area-specific curettes such as Mini Five® and Micro Mini Five® Gracey Curettes remove more subgingival calculus during non-visual scaling and root planing than standard Gracey curettes and piezo ultrasonic scalers in periodontal pockets that are 5 mm or greater.

Null hypothesis: There is no significant difference in percentage residual calculus and biofilm after scaling and root planing *In Vivo* with Mini Five®, Micro Five®, Standard curettes and piezo ultrasonic scalers in pockets that are deeper than 5 mm.

Specific Aim 2: To determine how effective modified, area-specific hand curettes are in non-visual scaling and root planing for calculus removal between 5 and 7mm.

Hypothesis: Modified, area-specific curettes such as Mini Five® and Micro Mini Five® Gracey Curettes will remove more subgingival calculus during non-visual scaling and root planing than standard Gracey Curettes and the piezo ultrasonic scaler in the periodontal pocket space 5 to 7mm.

Null hypothesis: There is no significant difference in percentage residual calculus and biofilm after scaling and root planing *In Vivo* with Mini Five®, Micro Five®, Standard curettes and piezo ultrasonic scalers in the periodontal pocket space 5 to 7mm.

1.4 Significance

Dental hygienists and periodontists are licensed oral health care professionals skilled and trained in the prevention and maintenance of oral health diseases such as periodontal disease.

Clinicians are looking for the latest in research that will bring about positive outcomes during treatment of PD and reduce stress during patient-care. This thesis research project will add to the current evidence supporting periodontal therapy, especially the nonsurgical phase of treatment, where a more conservative approach to treating periodontal disease is preferred by many patients and can be completed by a licensed dental hygienist. The study design for this research was clinically based using the latest standard and modified instruments as well as using the most updated computer software for data collection. The findings in this study will allow dental professionals to have a better understanding of how effective modified, area-specific curettes maybe in the removal of subgingival calculus and biofilm during nonsurgical periodontal therapy for individual patients.

1.5 Thesis Overview

The following is an outline of this thesis project and allows for a clearer understanding of this importance of this study in the treatment and care of periodontal disease. Chapter II is a comprehensive Review of the Literature that reviews information pertinent to the understanding of periodontal disease, how to treat it, and how to maintain it. Chapter II also includes a range of information thoroughly covering the topic of nonsurgical periodontal therapy and different approaches of how nonsurgical periodontal therapy is completed by dental professionals. Chapter III reviews the Materials and Methods and the protocol put in place in order for the study to be carefully carried out. Chapter IV discusses the Results and Findings of this study and addresses the specific aims that were presented early on. Chapters V and VI are the sections of Discussion and Conclusion of this study followed by the Appendices and Bibliography which then conclude this thesis research project.

CHAPTER II

REVIEW OF THE LITERATURE

2.1 Definition and etiology of periodontal disease

Periodontal disease (PD) is an inflammatory disease of the oral tissues that leads to the destruction of the periodontium causing clinical attachment loss (CAL) and loss of bone support.[4-6] The World Health Organization (WHO) has stated that periodontal disease, along with dental caries, oral cancer, and other oral infectious diseases, are current global burdens affecting many different populations today.[24] Mariotti et al. (2015) suggested that a healthy periodontal status should be defined as a periodontium that is stable and comfortably functional for the individual.[25] PD can negatively impact an individuals' psychological and social well-being due to tooth loss, pain, difficulty eating because of malpositioned teeth, as well as their overall systemic health.

Dental plaque has been noted as the primary etiological factor in the causes of gingival inflammation and the development and progression of gingivitis, which in turn can ultimately lead to PD.[12,13,17,26-29] There are also non-plaque induced gingival conditions that are associated with periodontitis affecting individuals today, such as drug-induced gingival inflammation and systemic conditions causing gingival inflammation, but are not as common as plaque-induced gingival diseases.[30] Periodontitis is not a simple infection that is easy to treat, but rather, is multifactorial in nature and quite complex.[4,5] Optimal outcomes for periodontal health and stability require multifaceted treatment, including assessments, surgical and nonsurgical interventions, re-evaluation, and patient compliance with good oral hygiene. Roncati states that "the ultimate therapeutic goal of any periodontal treatment, both surgical and nonsurgical, is to attain the ideal oral health conditions that can be maintained over time in a satisfactory manner to both patients and clinicians."[7] According to Lang et al (2018), there are three key factors affecting periodontal health: the individuals' oral microbiota; host immune response; and other environmental contributing factors such as smoking, medications, or stress.[4] It has already been established that gingivitis- an inflammatory condition caused by the accumulation of biofilm leading to redness and bleeding on probing (BOP) of the gingival tissues- is a precursor of periodontal disease.[31] Dental biofilm is composed of bacterial deposits that form on the surfaces of teeth;[29] inflammation is the response reaction from the host when dental biofilm is not removed effectively around hard and soft tissues.[32] It should be noted that gingival inflammation in its early stages is considered a physiologic response to the bacteria within the dental biofilm rather than the pathology of periodontitis.[33] Inflammation of the periodontium occurs initially as a protective response against the bacterial biofilm but can eventually become chronic in a susceptible host, thus resulting in PD.[33]

Evidence has suggested that individuals with periodontal inflammation have higher concentration of pro-inflammatory and anti-inflammatory cytokines, such as Interleukin 1 and tumor necrosis factor- *a*, found within the gingival crevicular fluid.[32] Following the initiation of the immune and inflammatory processes, a variety of inflammatory molecules are produced that have an active role in the destruction of the periodontium. Matrix metalloproteases are released in different cell types that have been linked to the development of periodontal disease; as the disease advances structural changes are evident such as clinical attachment loss and increased probing depths due to the destruction of collagen fibers and connective tissue attachment around the tooth. These processes in due time lead to the trigger of the resorptive process of bone loss, being the key characteristic of PD.[32]

Inflammation is a key clinical characteristic of PD as well and includes BOP. Understanding the definition and etiology of periodontal disease leads to better clinical judgment when seeking treatment options for patients affected by it. Clinicians are also able to comprehend the current incidence and prevalence of this inflammatory disease from a global perspective and seek new approaches on how to effectively decrease the incidence and progression of periodontitis.

2.2 Incidence and prevalence of periodontal disease

PD is considered to be the most common oral condition among the world population, in the past and in the present.[1,2] Unfortunately the statistics surrounding the incidence and prevalence of periodontal disease have experienced some variations due to case misclassification, bias, and evaluation of teeth and sites examined.[2,3] The World Health Organization (WHO) has emphasized the fact that periodontal disease is considered a global burden in many developing countries and that intervention programs should be implemented in order to gain an effective control of periodontal disease.[34] Sanz et al. (2012) suggests that anywhere between 20-50% of the world's population may be affected by PD,[35] and Eke et al. (2018) stated that 42% of the adult US population is affected by PD.[3]

Evidence has suggested that periodontitis may affect certain ethnic groups and people in lower socioeconomic status more so than others. Between 2009-12 the National Health and Nutrition Examination Survey (NHANES) found that PD was more common among Hispanics and non-Hispanic blacks compared to non-Hispanic whites.[36] Rozier et al.(2017) also stated that lower socioeconomic status was found to be a common association in those with periodontitis, likely due to lack of dental care, financial instability, and less years of education.[36]

The incidence and prevalence of periodontal disease as a global burden has been a difficult diagnosis to make correctly due to the variability and bias found within different classifications of periodontitis as well as the misclassification of different cases.[2,3] Periodontal classifications have evolved through the last 30 years in order to easily identify the stages and grading of this condition in different individuals by clinicians. According to Tonetti et al.(2018) the primary objective of a case definition system for periodontal disease is to simplify identifying, treating, and preventing an individual's diagnosis of periodontitis.[5]

2.3 Periodontal disease classifications

Over the course of the past year (2017), members from the American Academy of Periodontology (AAP) and the European Federation of Periodontology (EFP) were chosen to develop a case definition and new classification system for periodontal disease that could be implemented into clinical practice as well as research. In order to properly classify periodontitis, it was decided that based on pathophysiology there are three different forms of periodontitis as follows: necrotizing periodontitis, periodontitis associated with a systemic disease, and periodontitis.[5] Once the proper form of periodontitis has been identified, the individual case can be graded in stages; stage I periodontitis was classified as a combination of gingivitis and early attachment loss indicating periodontitis as a result of gingival inflammation. An early diagnosis of stage I periodontitis can allow for opportunity of cost-effective treatment, such as nonsurgical periodontal therapy, that can provide proper monitoring. Stage II periodontitis is considered to be periodontitis that is established with damage to the supporting periodontium; treatment at this stage can still be completed via nonsurgical periodontal therapy for many cases. Continued reinforcement of homecare and consistent supportive periodontal maintenance visits are also key to preventing further progression of this stage. Stage III periodontitis is severe with the possibility of tooth loss; at this stage, surgical intervention may be warranted in addition to nonsurgical periodontal therapy. Stage IV periodontitis is much more advanced, results in tooth loss, and can affect mastication for the individual. Treatment and management for this type of periodontitis requires stabilization and restoration of masticatory function.[5]

It is beneficial for dental clinicians to understand periodontal classifications when determining the best course of periodontal therapy for their patients. It would not be wise for NSPT to be the only choice of treatment for a patient suffering from Stage IV periodontitis with evidence of multiple mobilities and furcation involvement that would not result in the best outcomes. On the other hand, an individual presenting with Stage II periodontitis may benefit from NSPT as the primary choice of treatment for their periodontal condition.

2.4 Periodontal Therapy

The goal of periodontal therapy for an individual suffering from periodontitis is to preserve their periodontium, which includes their natural dentition and soft tissues.[8] It is also important to note that an individual must be compliant in their oral hygiene care as evidence suggests that the success of any periodontal therapy includes proper plaque control.[37] According to the AAP guidelines, the way to achieving a stabilized periodontal condition should be done in a way that is “the least-invasive and most cost-effective manner possible.”[38] There are many different treatment options for periodontal therapy in order to treat the different stages of periodontal disease including NSPT and surgical periodontal therapy.

Periodontal therapy consists of multiple phases allowing clinicians to provide treatment beginning with the least-invasive and most cost-effective treatment that could potentially benefit the individual patient. Evaluations typically follow each phase of periodontal therapy approximately six weeks after treatment to allow the clinician to assess the success and outcomes of the treatment and the stability of the periodontal condition. Considerations are made as to whether individuals require surgical periodontal therapy in order to further treat a patient's periodontal condition.

NSPT is part of the first phase of periodontal therapy and is carried out by a skilled clinician, such as a dental hygienist. SCRP treatment is the mechanical removal of plaque-retaining factors from root surfaces of the tooth,[10] performed to the best ability of the clinician using a variety of instruments and tactile sensitivity. SCRP treatment requires skill and knowledge of tooth and root surface anatomy for effective subgingival calculus and biofilm removal. Surgical periodontal therapy is the second phase necessary in specific cases of periodontal disease. Circumstances surrounding the need for surgical therapy include the need for better pocket management, bony contours not conducive to a healthy periodontium, furcation involvement of multi-rooted teeth preventing ease of access during oral hygiene care, and incomplete removal of subgingival calculus. Surgical periodontal therapy should be approached tactfully due to the invasive nature of treatment and financial strain it may cause some individuals. It is also worth noting that healing time differs between NSPT and surgical therapy due to how invasive surgical therapy is when compared to NSPT.

Phase three of periodontal therapy includes restorations necessary for the supporting hard tissue, which typically involves restoring over-hanging margins that allow better tissue contouring and the need for fixed or removable prosthodontics. Clinicians understand that gingival health is necessary in order to provide individuals with the most esthetically pleasing restorative results. Gingival health is also beneficial for new restorations that will not be a calculus or biofilm-retaining factor that can result in an unstable periodontal condition.

The fourth and final phase of periodontal therapy is known as the maintenance phase, or periodontal maintenance (PM) and is a branch of NSPT. The purpose of PM is to maintain regular dental hygiene care in order to prevent a relapse or progression of periodontal disease. PM should be the final goal to periodontal therapy and achieving a stable periodontal condition that the individual can maintain through meticulous oral hygiene care. This phase of periodontal therapy is also considered to be the most important treatment phase due to the lifelong commitment required in order for periodontal therapy to be considered successful.[7]

PM is defined by the AAP as those "procedures performed at selected intervals to assist the periodontal patient in maintaining oral health."[38] In 1984, a retrospective study revealed that periodontal therapy without a PM phase was of no benefit to the patient.[39] PM appointments typically consist of updated medical and dental histories; a review of updated radiographs; a complete oral exam, including extraoral and intraoral evaluation; complete periodontal charting; scaling of the hard tissues with biofilm and calculus removal; and an oral hygiene home care review with the patient.[9,40] PM intervals are made to benefit the patient and their periodontal health outcomes; it is important that serious thought is given when choosing an interval for PM that is based upon the oral hygiene of the individual, their compliance, and the state of their periodontal health at the time of each visit.

Many studies have shown how effective PM can be in preventing or limiting the recurrence of PD,[41-43] and how patients who adhere to a personalized PM plan can decrease their risk of further attachment loss of their periodontium.[43,44] PM and timely intervals are especially important for patients with periodontal disease due to the need for constant removal of biofilm and biofilm-retaining factors that initiate inflammation and progression of periodontal disease. In order for NSPT to bring about successful outcomes of a stable periodontal condition communication and collaboration is a key element.[45] It is important for the individual patient to be aware of the seriousness of their periodontal health and how it can affect their overall health. Stressing the severity of the disease and discussing the essentials of patient compliance is just one way to promote successful outcomes of NSPT.

NSPT such as SCRP and PM are considered to be the sustaining element of periodontal therapy. These treatments are the most cost-effective for individuals and can achieve some outstanding clinical results over time if completed by skilled clinicians and patients are compliant with oral hygiene home care. These are just a few reasons why NSPT is considered to be the "foundation" of care in periodontal therapy.

2.5 Nonsurgical periodontal therapy as the "Foundation" of periodontal treatment

The purpose of nonsurgical periodontal therapy is to remove biofilm and calculus, thereby eliminating endotoxins from teeth suffering from periodontitis and creating smooth root surfaces that allow healing of the soft tissues.[46] NSPT is considered the foundation of periodontal therapy and is usually the first approach to treatment for a multitude of reasons.[8,46,47] NSPT is less-invasive and more cost-effective for many individuals; it is also the most effective treatment to control biofilm.[8,37] Evidence has shown that SCRP alone shows pocket reduction and an increase in attachment levels, but these outcomes are based on complete and thorough removal of subgingival calculus and biofilm.[8,47,48] Studies have shown significant improvements with

SCRP treatment such as a decrease in probing depths up to 3 mm, a 25% decrease in bleeding, and clinical attachment gains in areas that had significantly deeper pockets.

2.6 Expected outcomes of nonsurgical periodontal therapy and limitations

Evidence has shown the efficacy of NSPT such as SRP and SPT in the treatment of periodontitis to result in decreased probing depths, reduction of bleeding on probing and an increase in clinical attachment levels.[46,49,50-52] It should be noted that the expected outcomes of NSPT differ based upon the periodontal classification of the individual undergoing treatment, but evidence has shown pocket depths can decrease by 1-2 mm and have increased clinical attachment levels by 0.5-2 mm in individuals with moderate generalized periodontitis, or Stage II periodontitis.[51]

Aimetti (2014) stated that some limitations to NSPT included "long-term maintainability of deep periodontal pockets, the risk of disease recurrence, and the skill of the operator."[46] Other limitations that exist in NSPT include limitations with instrument use due to root anatomy, furcation involvement, or the narrowing of the apical portion of the pocket denying access for proper removal of calculus and biofilm.[44,45] A prominent limitation that should be noted by all clinicians is the lack of visual control during NSPT; multiple authors have suggested that completely removing all subgingival calculus and biofilm is quite challenging due to the lack of visual control from the clinician.[46,47] With the lack of visual control for the operator and without the use of a dental endoscope, it is likely that complete calculus removal will not occur. Evidence has shown that residual calculus can hinder proper healing of the periodontal pockets, which may result in further treatment such as periodontal surgery.[48,49]

Tooth anatomy and root surface concavities are another concern for clinicians during NSPT. In 1979 Bower reported that 58% of furcation areas are smaller than standard curettes and are considered to be an obstacle for effective calculus removal during NSPT.[50] Research stresses concerns with furcation areas and suggests teeth that have furcation involvement have a poor prognosis compared to teeth without furcations because of the difficulty with accessing these areas for complete calculus removal.[51] Another factor that may cause less-than-desirable outcomes following NSPT include a non-compliant patient when it comes to their ability to maintain good oral hygiene and their inability to maintain their supportive periodontal maintenance recalls.[52,53] It is important that a patient who has decided to follow through with periodontal therapy must remain disciplined in a meticulous oral hygiene routine and comply with their scheduled SPT appointments.

NSPT may be the choice of treatment for many due to financial burdens affecting many individuals today. NSPT is considerably less invasive than surgical therapy and many individuals may fear the thought of surgical interventions due to the nature of treatment alone. NSPT also requires less healing time and post-operative care than surgical therapy, which may make it another prime choice for many. The success of NSPT is based on many different aspects of treatment such as patient compliance, the skill of the operator, and complete biofilm and calculus removal. Education is integral to helping patients understand the importance of periodontal therapy and the effects PD can have on their systemic health. The skill of the operator is based on their clinical experience and technique. The complete removal of biofilm and calculus is also based on the skill of the operator, but also includes the operator's knowledge and understanding of their instrument armamentarium.

2.7 Instruments used during nonsurgical periodontal therapy

NSPT requires skill and knowledge from the clinician along with the best tools to work with in order to be an effective method of treating PD. Dental hygienists are skilled clinicians when it comes to hand or powered instrumentation; having a vast knowledge of what tools to use during NSPT is crucial in positive treatment outcomes. Hand instruments and ultrasonic scalers play a specific role in NSPT in order to adapt to specific tooth and root surfaces in the mouth for the effective removal of biofilm and subgingival calculus.

Area-specific curettes are specifically designed to access areas of difficulty during NSPT; standard area-specific curettes were originally designed for effective calculus removal in subgingival areas by lowering the cutting edge of the scaler 20% in relation to the shank than the nonworking side.[53] Extended shank area-specific instruments were then designed to include a longer terminal shank, a thinner blade and a decrease in blade length over the course of the past 20 years. The different types of extended shank area-specific instruments introduced throughout the years include the extended shank curettes, mini-bladed curettes, micro mini-bladed curettes, and the Vision Curvette®. These instruments differ to their standard counterpart in that they were designed with a longer terminal shank by approximately 3 mm, in order to access periodontal pockets that are 5 mm or greater.[53]

Over 25 years ago Nagy et al. carried out a clinical study that compared standard are-specific curettes to rigid longer shank are-specific curettes.[12] The study included subjects scheduled for extractions where the periodontal pocket was at least 6 mm; 140 tooth surfaces were scaled and root planed using standard and rigid area-specific curettes for a maximum time of 15 minutes. Following the extraction of the scaled teeth, they were evaluated using a stereomicroscope to identify residual calculus. The findings of this study concluded that there was no significant difference between the two area-specific curettes at the time.[12]

Ultrasonic instrumentation has been shown to be effective for subgingival biofilm removal during NSPT. According to Breininger et al. (1987) ultrasonic instrumentation was shown to be effective in plaque removal from deep periodontal pockets during a clinical study that was conducted .[17] This study also revealed that following ultrasonic use and after evaluation that residual calculus was still visible, clinically, and under a microscope, and therefore was not as effective for subgingival calculus removal.[6] These results coincide with a previous study conducted when Nishmine and O'Leary (1979) compared hand instruments to ultrasonic instruments for the efficacy of endotoxin removal. Their results were similar to Breininger and colleagues, in that residual calculus remained on teeth that were instrumented using hand instruments and ultrasonic scalers, but endotoxin reduction was eight times greater in the ultrasonic group.[58]

Hand and ultrasonic instruments are primarily the instruments of choice by most clinicians during NSPT, but there are instruments that are available for use with proper training and certification for periodontal instrumentation. Diode lasers and dental endoscopes are now being used in NSPT for more effective subgingival biofilm and calculus removal. The positive outcomes of these additional instruments, although costly, should be considered for use during NSPT, although further studies are warranted.

The dental endoscope allows dental clinicians to visualize subgingival calculus and root anatomy during NSPT, thereby overcoming one of the major limitations to effective calculus removal during NSPT, that is, the inability to see below the gingival margin. The use of the dental endoscope allows clinicians to access furcations, concavities, and around line angles that have previously been an area of limited access to dental professionals with hand and ultrasonic instruments.[49] With high magnifications, the dental endoscope allows even the smallest piece of calculus to be viewed and scaled away by the clinician.[49]

Another new instrument that may be beneficial to NSPT is a diode laser; its ability to interact with inflamed tissues and enhance biological effects for the promotion of healing is considered promising in periodontal treatment, however, further research is warranted on this topic. According to Roncati, there are a number of positive outcomes that are associated with the use of a diode laser. Some of the effects include: decreased bleeding, kills bacteria, desensitizes tissues, promotes coagulation, and prevents edema.[59] In regard to calculus removal, a diode laser uses a photochemical effect to weaken the chemical adhesion that occurs between calculus and the root surface, thereby aiding in calculus removal with hand instrumentation.[59]It has been recommended by many that the use of a laser in NSPT should precede hand instrumentation for the most effective use and best outcomes.

Many studies through the years have been conducted as a way to prove instrumentation effectiveness in biofilm and calculus removal. Studies have shown statistics of how effective instruments are in NSPT in regard to calculus removal and why surgical interventions may be warranted. There are, however, gaps in the literature that fail to address the effectiveness of modified, area-specific curettes that may prove to be effective in biofilm and subgingival calculus removal and how beneficial NSPT may be if these instruments are used.

2.8 Gaps in the Literature

Although it has been suggested that modified, area-specific curettes are designed to be more effective in calculus removal in periodontal pockets 5 mm or greater, there have been no clinical studies carried out to support the claim.[53] It is evident that more research is necessary in order to evaluate the effectiveness of these instruments designs during non-surgical periodontal therapy before clinicians decide whether or not to add these modified, area-specific instruments to their armamentarium.

The literature supporting NSPT is overwhelming and shows how effective it can be as a first choice of periodontal therapy when carried out by a skill clinician. If NSPT is to be considered the "foundation" of care among dental professionals, then the effectiveness of hand and ultrasonic instrumentation during NSPT procedures must be known to the clinician. The promotion of periodontal health and the stability of one's periodontal condition depend on this evidence.

2.9 Conclusions and summary

The concept of nonsurgical periodontal therapy is not foreign to dental professionals and has been an asset in treating patients with periodontitis. With periodontal disease being called a global burden it becomes of the utmost importance that cost-effective treatment options are available and easily accessible. The purpose of nonsurgical periodontal therapy is to mechanically remove and disrupt biofilm and subgingival calculus in order to decrease the gingival inflammation that leads to destruction of the periodontium.

Dental clinicians should have a broad knowledge of the instruments available to them for biofilm and calculus removal in order to provide effective biofilm and calculus removal to promote healing of the periodontium and continue with subsequent supportive periodontal maintenance intervals that include constant evaluation and monitoring of a patient's periodontal condition. Nonsurgical periodontal therapy is the cornerstone of periodontal therapy and requires communication and compliance with both clinician and patient in order to achieve the ideal results of periodontal health.

CHAPTER III

MATERIALS AND METHODS

3.1 Study Population

This study was approved by the UMHS/Medical School Institutional Review Board (IRBMED #- HUM00145158). According to G*power software, a minimum of 9 single or multi-rooted teeth treatment planned for extractions due to periodontal disease at the Graduate Periodontics Clinic and the University of Michigan School of Dentistry were required; at the conclusion of this study, 12 teeth were obtained from 7 subjects. The power analysis was conducted using information from classic literature for the condition of a one-way, fixed effects ANOVA assuming an effect size of f=1.5 for three instrument groups and where alpha=0.05 and power=0.8. This results in 3 samples per group for a total of 9 teeth. This power analysis allowed for overly generous assumptions for the outcome of the study.

All teeth involved in the study had periodontal pockets that were 5 mm or greater on at least one surface. The criteria for inclusion in the study was as follows: teeth from adult patients in good health, adult patients with well-controlled systemic conditions, and adult patients with a diagnosis of localized or generalized moderate to advanced periodontitis. Teeth were excluded from the study if the patient was not an adult, if the patient had an uncontrolled systemic disease, if the patient was taking anti-coagulant medications, third molars, teeth with internal or external resorption, teeth with carious lesions on the root surfaces, damaged roots that would interfere with a simple extraction, or if a tooth broke during the extraction. If a willing participant had more than one tooth that met the inclusion criteria and the participant was willing, than those teeth were also included in the study. Each participant received informed consent for the study and how their participation was beneficial to this study. Participants were then given the opportunity to sign the informed consent documentation in order to proceed with this study.

3.2 Study Design

As participants were added to the study, teeth meeting the inclusion criteria were randomly assigned to one of three different groups. The first group had teeth scaled and root planed using standard, area-specific Gracey curettes (G11/12, G13/14) with a maximum time limit of 15 minutes per tooth. The second group had teeth scaled and root planed using a piezo ultrasonic scaler (Forza V3 manufactured by Brasseler USA®) at settings that were based on the manufacturer's recommendations for the variety of tips used with a maximum time limit of 15 minutes per tooth. Multiple tips that were supported by the piezo ultrasonic scaler were utilized in this group. The third and final group had teeth that were scaled, and root planed using modified, area-specific Gracey curettes (SMS G11/12, SMS G13/14, SAS G11/12, SAS G13/14) with a maximum time limit of 15 minutes per tooth. The limit of 15 minutes per tooth was primarily based upon past studies methodology as well as the limitation of time for the Graduate Periodontics resident as some of the participants had other treatment to be completed in this appointment.

Prior to the scaling and root planing procedure for each group, a medical history update was completed, vital signs were taken, and local anesthetic was administered by either the graduate periodontics resident or the study examiner. Once the local anesthetic took full effect around the tooth (teeth) for this study, baseline measurements were collected. The baseline measurements included clinical attachment loss (CAL), recession, and probing depths (PD) of all proximal surfaces of the tooth (teeth) using a UNC-15 periodontal probe. The presence of subgingival calculus was verified using an ODU 11/12 explorer.

Following the collection of baseline measurements and administration of local anesthetic, scaling and root planing took place using the instruments indicated based on which group the tooth was randomly assigned to. One clinician with more than 9 years of clinical experience performed the scaling and root planing for all three groups with a maximum time of 15 minutes per tooth. After scaling and root planing was completed, additional local anesthetic was given if needed by the participant prior to the extraction procedure. The graduate periodontics resident performing the extraction used a No. ½ round bur to demarcate the free gingival margin on the tooth to be extracted, in order to provide a landmark for evaluation of the subgingival root surface when assessing under the microscope. The graduate periodontics resident then extracted the tooth as planned, with care to avoid excessive damage to the root surfaces. The extracted tooth was rinsed under running water for two minutes to remove any blood or soft tissue residue. After tooth extraction, the subject's active study participation was completed.

Methylene blue stain was applied to the subgingival areas of the extracted tooth as indicated by markings made with the bur and then rinsed again with running water for a few seconds to remove any excess staining. The purpose for the methylene blue stain was to allow the examiner the ability to differentiate residual hard deposits on the root surfaces from soft tissue adhesions that remained on the tooth. This protocol followed the recommendations of past studies for a more thorough analysis; areas where the methylene blue stain was a more vibrant blue indicated soft tissue adhesions, whereas the dark blue indicated residual calculus (**Figure 2)**.

The extracted tooth was then placed in a plastic vile container and biohazard bag for proper transportation from the Graduate Periodontics clinic to the lab for assessment and photo documentation for proper evaluation.

All the photos were taken at 10 times the magnification for proper evaluation of residual calculus on the root surfaces based upon previous studies as a reference. Each tooth had four photos taken of each proximal surface: buccal, lingual, distal, and mesial surfaces; every photo that was taken required the same camera settings for color, lighting exposure, and scene mode. Each photo was then exported for proper assessment using Image J software; surface area of each 2-dimensional proximal surface was calculated as was the residual calculus using a free-hand shape tool that allowed each individual speck of noticeable calculus to be outlined and pixels calculated into surface area. Once the total surface area and residual calculus surface area was determined, calculations were done to find the percentage of residual calculus remaining within that surface area and thus, resulting in the final data used for the SPSS statistical software.

3.3 Study Timeline and Clinical Procedures

All participants had one or two appointments during the study where informed consent was reviewed, baseline measurements were taken, and scaling and root planing along with tooth extraction was performed. One examiner (BP) performed all baseline measurements using a UNC-15 periodontal probe. All measurements were rounded down to the nearest millimeter.

3.4 Examiner Calibration

The examiner (BP) participated in an examiner calibration in September 2018, prior to the start of the study. Intra-rater examiner variability for the proper photographing technique and use of the stereomicroscope was evaluated using a convenience sample of 10 extracted teeth, without any intervention such as scaling and root planing. The collected biospecimen were stained with Methylene blue and transported to the lab for root surface evaluation. A Nikon SMZ 745T stereomicroscope was used at 10X magnification to capture still images of each proximal surface of the sample tooth. Image J computing software was used to measure the surface area of the root surface of the tooth; the scale for this calibration was set to measure the pixels of the frozen image of the tooth. It was important for this study that proper quantitation and use of Image J software produced reliable and consistent outcomes prior to the start of this study.

3.5 Data Collection Methods

Data collection for this study included demographics (age and gender of the participant), tooth number/location, probing depths, clinical attachment loss, surface area of proximal surfaces, and the amount of residual calculus remaining on root surfaces of extracted tooth.

3.6 Risks

This study included little to no risk for participants.

3.7 Limitations

Limitations within this study design include: small sample size, participation of only one operator may conclude results differing from other clinicians, and the examiner was also the operator and was not blinded to the procedure being performed.

3.8 Human Subjects

Subjects reviewed and signed an informed consent document prior to participating. Each individual understood their role in the study and that once their tooth (teeth) were extracted, their participation in the study was complete. Participants were also aware that they had the right to leave the study at any time without excuse.

CHAPTER IV

RESULTS

4.1 Subject Characteristics

7 subjects (4 males, 3 females, mean age: 63 years ranging from 55 to 81) with a diagnosis of generalized or localized moderate to severe periodontitis participated in this study. Subjects on average provided 6 tooth surfaces per subject for the first objective of the study and 4.6 tooth surfaces for the second aim of the study. In total, 12 single and multi-rooted posterior teeth were utilized in the study. Proximal surfaces were evaluated (mesial, distal, buccal, and lingual), resulting in a total of 48 surfaces; for specific aim 1, 6 tooth surfaces were excluded due to the pockets being <5mm providing a sample size of 42 tooth surfaces to be evaluated, and for specific aim 2, an additional 10 tooth surfaces were excluded due to not having PD's between the 5-7mm criteria providing a sample size of 32 tooth surfaces to be evaluated.

4.2 ANOVA and Linear Regression Results

Baseline measurements were recorded for each individual tooth within the study that included a collection of probing depths (PD) and clinical attachment loss (CAL) (all measured in millimeters), as well as tooth number. SPSS statistical software was used to analyze the data collected from this study; one-way ANOVA tests and linear regression tests were run controlling for different variables found within the study to assess for any significant differences among the three groups. The average PD among the subject teeth for the study was 7.13mm ± 2.84mm;

average CAL among the subject teeth was 9.71mm ± 3.58mm; the average surface area of the gathered proximal surfaces within the study was 40.14mm^2 ± 22.34 mm^2. **Table 2** provides an outline of the descriptive statistics found within the 42 proximal tooth surfaces evaluated as given through the one-way ANOVA test.

When assessing the amount of residual subgingival calculus found between groups alone, there was no significant difference between the instrument groups (p=.07). There was, however, a significant difference among the groups when assessing the surface area scaled during the study (p=.002). This finding was significant because it indicated that the small sample size lacked variability among the groups in what teeth were in each group. This result could simply indicate the fact that a larger sample size, with variability among the teeth within each group, could account for more significant findings in this study.

When evaluating the effectiveness of each instrument group within the study, there were no significant differences regarding the amount of residual calculus present on the teeth (p=.07). Despite the fact that no significant differences were noted regarding the amount of residual calculus on tooth surfaces between instrument groups it was evident that the operator through this study had less subgingival calculus present on mesial and buccal surfaces overall. The mesial surfaces of all teeth had a mean percentage of 14.88 and a standard deviation of 15.78 residual calculus; the buccal surfaces of all teeth had a mean percentage of 16.15 and a standard deviation of 10.47 residual calculus. The distal surfaces of all teeth had a mean percentage of 28.15 and a standard deviation of 19.76 residual calculus; the lingual surfaces of all teeth had a mean percentage of 18.82 and a standard deviation of 16.96 residual calculus (**Table 3**).

CHAPTER V

DISCUSSION

5.1 Summary

The primary purpose of this randomized clinical trial was to identify how effective modified, area-specific Gracey curettes were in the removal of subgingival calculus from root surfaces on teeth presenting with a diagnosis of moderate to advanced periodontitis and secondly, was to evaluate at what pocket depth they can be most effective when compared to standard Gracey curettes and the piezo ultrasonic scaler. This study demonstrated the difficulties that have been stated in multiple studies regarding the effectiveness of non-surgical periodontal therapy and confirmed the many limitations that dental clinicians face when performing non-visual periodontal treatment as the initial phase in periodontal therapy. NSPT is typically considered the first phase of periodontal therapy in treating periodontal disease and it is important that dental professionals are aware of what instruments are available to them in their armamentarium and how effective specific instruments are for the removal of subgingival calculus from different tooth surfaces.

Multiple clinical studies came to the same conclusion regarding NSPT and the effectiveness of calculus removal more than 20 to 30 years ago, stating the difficulties facing clinicians during nonvisual scaling. Waerhaug indicated that almost half of the teeth evaluated in his study had remaining plaque in the base of the periodontal pocket, likely due to the small space and the working end of the scaler not adapting to the root surface.[13] Another clinical study concluded that complete calculus removal from subgingival surfaces and furcation areas is limited when using conventional instruments.[16] Nagy and colleagues discovered no significant difference among the effectiveness of subgingival calculus removal when using either rigid longer shank Gracey curettes and rigid standard Gracey curettes.[12]

It has been stated that NSPT is the foundation of periodontal therapy and is more cost-effective and less invasive than surgical periodontal therapy. There is convincing evidence of the limitations of standard curettes in accessing areas with deeper pockets and complex root anatomy Many researchers have suggested that modified, area-specific Gracey curettes could be more effective than standard, area-specific Gracey curettes . These modifications included decreasing the blade length and increasing the shank length to allow for improved access in subgingival areas, root curvatures and furcations that were once difficult to access using standard curettes.

This clinical study set out to assess the effectiveness of modified, area specific Gracey curettes compared to standard curettes and ultrasonic scalers in removing plaque and calculus from teeth with pocket depths deeper than 5 mm *in vivo.* The results failed to show a significant difference between the instrument groups in plaque and calculus removal. A limitation of the study was a relatively small sample size. As the design of the modified, area-specific Gracey curettes were evaluated and considered as to why these instruments may not be as effective, it was noted that the blade length of these specific instruments was decreased by 10-20% when compared to the standard Gracey curettes. (Table 1). With this significant decrease in the blade length, it is obvious for dental professionals who are performing NSPT that many more overlapping strokes would need to occur in order to effectively remove subgingival calculus from the root surfaces. The findings of this study are consistent with past studies showing that the complete removal of subgingival calculus from periodontal pockets that are 5mm or greater is very difficult,[14] even with instrument modifications.

5.2 Impact of Results

When assessing the effectiveness of modified, area-specific Gracey curettes without any other factors, the results show no significant difference between the modified, area-specific instruments when compared to the standard, area-specific instruments and the piezo ultrasonic scaler. When controlling for tooth surface, tooth location, surface area, and average probing depths, we find that the modified, area-specific Gracey curettes are not significantly different than the reference groups, either. When assessing the effectiveness of modified, area-specific Gracey curettes in probing depths between 5 and 7mm without any other factors, the results revealed that the standard, area-specific Gracey curettes and the piezo ultrasonic scaler were technically more effective, but there was no significant difference to report. When controlling for tooth surface, tooth location, and surface area, we once again, find that the modified, area-specific Gracey curettes are not significantly different than the reference groups.

It is evident that the findings within this study are similar to those in the classic literature in stating that area-specific curettes, whether standard or modified, do not differ in their effectiveness in subgingival calculus removal in pockets that are greater than 4mm. Many limitations are presented throughout the course of the study that ultimately led to the results being as they were. These limitations included the fact that not all teeth had the same amount of subgingival calculus that needed to be removed in a 15 minutes time frame. Some teeth presented with very small amounts of subgingival calculus, and thus, had much less residual calculus remaining; other teeth, with much deeper probing depths, seemed to harbor heavy, tenacious subgingival deposits over a large surface area, thus increasing the likelihood of a higher amount of residual calculus remaining.

This study determined that NSPT has limitations, no matter what instruments are used for subgingival calculus removal. The inability to visually see, results in residual calculus in deeper periodontal pockets. When assessing the second objective of this study, it was determined that all instrument groups had residual subgingival calculus between 5 and 7mm pockets and there was no significant difference among the groups. The time constraint could have been considered a limitation within this study when compared to other similar studies where no time limit was given during scaling and root planing. Nagy et al., suggests that it is perhaps the amount of time spent on scaling and root planing, rather than the instrument itself, that may be considered the most important factor when assessing for subgingival calculus removal in deep pockets.[12] Table 2 compares this current study with those from the past, not only in methodology, but instruments used, time limits for scaling and root planing, and indicates the amount of tooth surfaces evaluated within those studies to determine their results.

Another limitation that was presented throughout this study that has been of concern throughout all classic literature surrounding the topic of NSPT is the fact that NSPT requires non-visual scaling and relies on tactile sensitivity to determine the cleanliness of the root surface. Dental professionals with many years of experience may find that their skills with tactile sensitivity is more effective than a dental professional with less clinical experience, thus resulting in residual subgingival calculus. Tooth location seemed to be a factor in the effectiveness of this study; right-handed clinicians tend to have ease of access when scaling specific teeth that a left-handed clinician may not be able to control for. Tooth surface was another limitation noted within this study as the time spent on each tooth remained the same, yet some teeth with less surface area had much less residual calculus than those with a greater surface area.

Currently, this study has a significant role in NSPT and to what extent NSPT can have positive outcomes of treatment when using instruments that will be effective. Subgingival calculus has been considered a local contributing factor to periodontitis and the removal of this causative agent plays a profound role in the reduction of periodontal pockets, the maintenance of the disease progression, and possibly, the regeneration of the supporting bone. The benefits of NSPT and its effectiveness when treating individuals with a moderate diagnosis of periodontitis have great benefit, though at times, may seem overwhelming to both the patient and the dental professional.

The limited findings within this study have given an idea of the expected outcomes that come from performing NSPT using modified, area-specific Gracey curettes. There are benefits in having these instruments as a part of a dental clinician's armamentarium, but they should not be the instruments most depended on. It is best to consider a variety of instruments for subgingival calculus removal in NSPT procedures. The sample size within this study may warrant further studies on this subject matter, perhaps in combination with ultrasonic scalers and how these instruments, when combined, can benefit the patient during NSPT.

When controlling for variables such as tooth surface, tooth location, surface area, average PD, we find that modified, area-specific instruments are not significantly different ($p=.573$) than the reference group (difference of -3.96 mm^2, relative to standard, 95% C.I. [-18.2 mm^2, 10.3 mm^2]). There were significant differences noted between PD's, which may contribute as a factor to the difficulty of subgingival scaling in these areas. There may be true differences among instrument groups that we would see with a larger sample size, however, the differences apparently are not large enough in magnitude that we can see them with the sample size we have.

The differences are probably not considerable or dramatic but may prove to be present. Thus, further studies are warranted to further explore this topic.

A consideration to make when assessing the effectiveness of modified, area-specific curettes in this study is the fact that some of the subject tooth surfaces in this study had heavy, tenacious subgingival calculus. Due to the randomization process within the study design, these teeth fell within the modified, area-specific curette group. Dental clinicians use clinical judgment when performing NSPT and typically follow a sequencing of different instruments that would best allow them to remove causative agents from the periodontal pocket in the most effective way. For example, if heavy, tenacious subgingival calculus is identified to be present within the periodontal pocket, a clinician would initially begin NSPT with the use of an ultrasonic scaler to break-up the debris, followed by area-specific standard instruments for further calculus removal, followed by modified, area-specific curettes that allow them to access furcations, root concavities, and the narrow base of the pocket for further calculus removal.

As we examine the outcomes found within the piezo ultrasonic group, we can see that this group had less residual calculus than the modified, area-specific group. An opinion of this may have been due to the fact that within this group were two multi-rooted teeth and two single-rooted teeth with less surface area to scale. The single-rooted teeth have less surface area to cover when performing NSPT, and thus, may have had better outcomes as a result. It is evident that tooth location plays a role during NSPT and even where most of the subgingival calculus may be found.

CHAPTER VI

CONCLUSION

The purpose of this study was to determine how effective modified, area-specific Gracey curettes are in the removal of subgingival calculus from periodontal pockets greater than 4 mm. In addition to this specific aim, a secondary purpose of this study was to evaluate at what depth are these modified, area-specific Gracey curettes no longer effective in removing subgingival calculus. This study was deemed necessary because there is little evidence in the literature showing that modified, area-specific Gracey curettes improve calculus removal, even though they have been available for over twenty years..

It was determined, through the course of this study, that modified, area-specific Gracey curettes were not more effective than standard, area-specific Gracey curettes or the piezo ultrasonic instruments during NSPT, alone, and no significant difference was noted among the three groups. The results of this study must be interpreted with caution due to the limited sample size. Further studies are warranted to determine whether these instruments would benefit from being used in combination with ultrasonic scaling and the use of other area-specific curettes in periodontal pockets greater than 4 mm for NSPT, with consideration for a larger sample size.

Appendices

Figures

Figure 1. Comparison of Gracey curettes

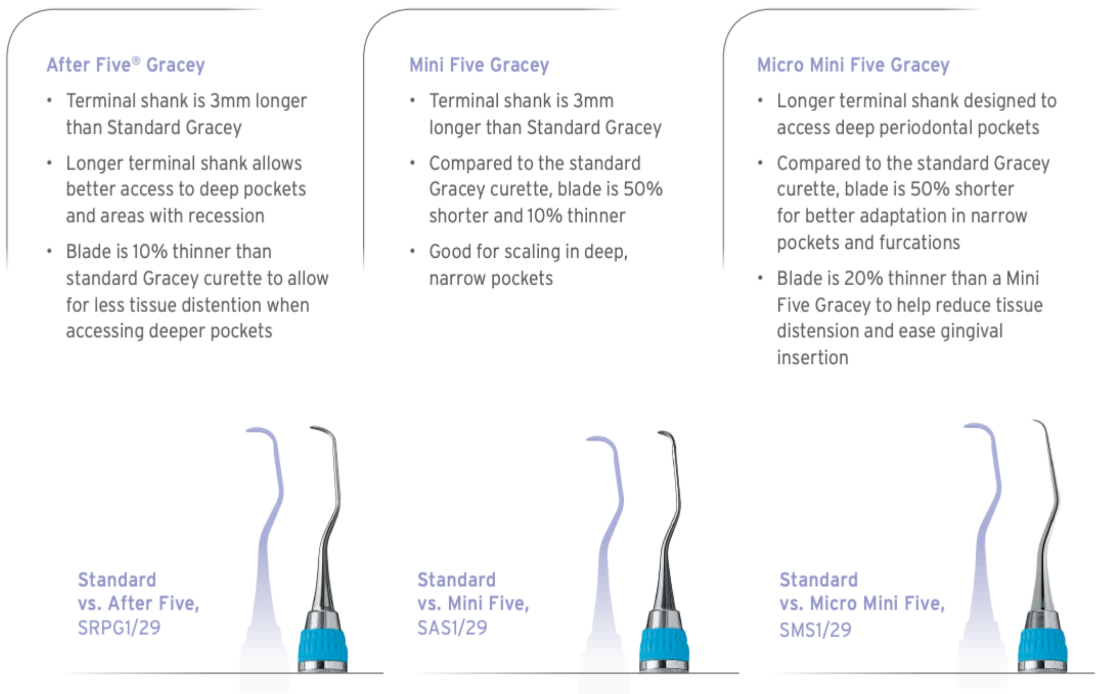
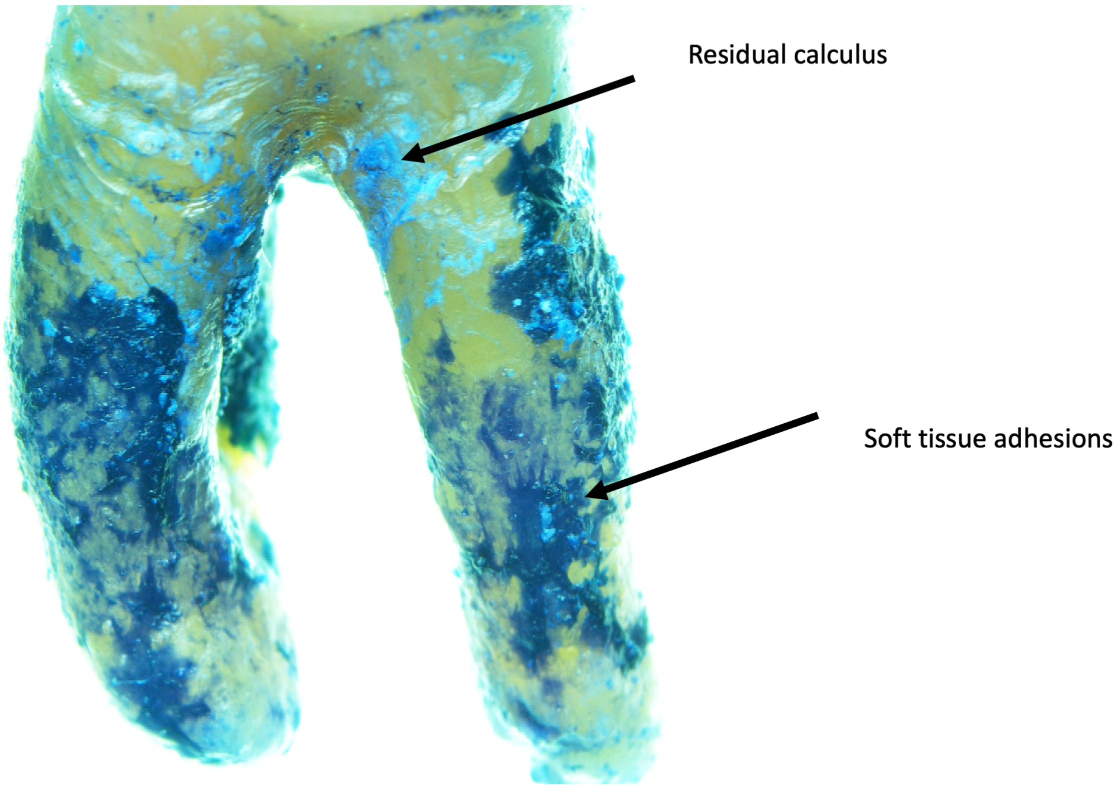


Figure 2. Differentiation of hard deposits from soft tissue adhesions using methylene blue stain



Tables

Table 1. Area-specific curette comparison

Curette Type	Shank Design & Diameter	Blade Length	Blade Width
Standard Curette	Standard	Standard	Standard
Rigid Curette	Standard design Increased shank diameter	Standard	Standard
Mini Five Curette	Longer terminal shank Standard diameter	Decreased by 50%	Decreased by 10% compared to standard
Micro Mini Five Curette	Longer terminal shank Increased diameter	Decreased by 50%	Decreased by 20% compared to Mini Five
Vision Curvette	Longer and straighter terminal shank	Decreased by 50% Increased blade curvature	N/A

Table 2. Descriptive Statistics Table

Descriptive Statistics	1 Standard Curettes	2 Piezo Ultrasonic	3 Modified Curettes
Deepest PD (mm)	8.93 ± 3.54	11.27 ± 2.94	6.38 ± 1.71
Average PD (mm)	7.02 ± 2.54	9.02 ± 2.92	5.05 ± 1.23
Deepest CAL (mm)	11.79 ± 3.02	13.33 ± 4.25	9.00 ± 2.27
Average CAL (mm)	9.40 ± 2.40	11.21 ± 3.83	8.32 ± 3.93
Average Surface Area ($mm^{2)}$	41.88 ± 21.53	52.49 ± 23.60	24.02 ± 8.78
Percentage of Residual Calculus (%)	14.32 ± 11.89	16.78 ± 14.17	27.69 ± 19.68

Table 3. Residual calculus percentages on proximal surfaces

Proximal Surface	Mean Percentage(%)	Std. Dev
Mesial	14.88	15.78
Buccal	16.15	10.47
Distal	28.15	19.76
Lingual	18.82	16.96

Table 4. Randomized clinical trial methodology comparison

	N= (tooth surfaces)	Instruments Used	Time Limit	Method of Assessing Residual Calculus
Instrumentation Effectiveness Study	42	Standard Gracey Curettes, Piezo, Modified Gracey Curettes	15 mins/tooth	Digital Software
Rabbani (1981)	248	Variety of Hand Instruments	N/A	10x10 ocular grid
Nagy (1992)	140	Rigid Long Shank and Rigid Standard Gracey Curettes	15 mins/tooth	10x10 ocular grid
Sherman (1990)	461	Standard Gracey Curettes, Cavitron	N/A	Digital Software
Stambaugh (1981)	42	Gracey and Horzel Curettes, Hoes, Files	N/A	Light microscope evaluation
Waerhaug (1978)	124	Curettes, Hoes, Slow Rotating Diamond Points	N/A	Stereomicroscope
Fleischer (1989)	325	Standard Curettes, Cavitron	N/A	10x10 ocular grid

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