Tufts University School of Dental Medicine

# Accuracy of Periodontal Probing Depth and Calculus Detection Through the use of the Kinoshita Nissin Periodontal Dental Model

Thesis submitted in partial fulfillment of the requirement for the degree of Master of Science.

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## Abstract:

Dental education is a continually evolving process. This study seeks to develop evidence-based practices for the instruction of dental students to accurately probe periodontal pockets and detect dental calculus.

The purpose of this study was to evaluate the effectiveness of the Kinoshita Dental Model (KDM) as a pre-clinical training tool for pre-doctoral education in periodontal probing and calculus detection.

Prior to this study, students at Tufts University School of Dental Medicine (TUSDM) had been trained primarily through lecture in techniques for periodontal pocket probing and calculus detection. The KDM was specifically modified by the authors of this study to facilitate hands on instruction of probing depth measurement and calculus detection.

Study participants were second year TUSDM students. Participants were given a hands-on lecture and workshop on correct techniques for periodontal probing and calculus detection using one of two KDM models. Three workshops were given. In each workshop participants received a KDM with different simulated gingiva. The three preclinical groups were trained on KDM models with translucent gingiva, opaque gingiva, or both translucent and opaque gingiva models. At the end of each workshop students were tested on opaque gingiva KDMs to determine their accuracy in both periodontal probing and calculus detection.

The pre-clinical results of this study indicate that students preformed comparably on each model type with no statistically significant differences between groups for

probing depth measurement. Significance was reported between groups for the total number of correctly identified surfaces of calculus however, no pair of groups could be identified as exhibiting a significant difference once accounting for more stringent statistical measures with Bonferroni correction.  Preclinically, the opaque group performed better than the group trained with both translucent and opaque gingiva ($p<0.05$) for calculus detection.

Clinical results showed no statistically significant differences between groups for mean probing depth values or the number of correctly identified surfaces for calculus detection. However, Generalized Estimating Equation (GEE) analysis showed a significant difference ($p<0.0001$) in students' ability to properly identify sites without calculus as compared to sites with calculus for all groups.

This study brings us insight as to the effectiveness of each KDM as a teaching tool for periodontal probing and calculus detection as well as student performance on these tasks in a clinical setting.

## Introduction

***Literature Review:***

As dental science and technology have advanced, so too has dental education in both substance and technique[1]. Over the course of the past hundred and fifty years, dentistry has advanced from apprenticeship to a comprehensive graduate education prrogram[1]. Formal dental training in the United States began in 1840 with the opening of the Baltimore College of Dental Surgery and the first university based dental program in 1867 at Harvard University[2]. However, as dentistry has evolved into a more sophisticated field, there is still a paucity of literature available to support evidence-based dental education.

Due to the lack of evidence based teaching practices in dentistry this study seeks to develop evidence based practices for the instruction of dental students to accurately probe periodontal pockets and detect dental calculus. Through the use of evidence based teaching tools we can more effectively facilitate pre-clinical learning.

Accurate probing depth measurement and calculus detection are crucial in an examination to make a correct diagnosis and to provide comprehensive dental care. The most frequent dental diseases, dental caries and periodontal infections, have common etiology in the toxins formed by bacteria in dental plaque[3]. Our understanding of the pathogenesis of periodontal diseases has changed over the last 30 years[4]. It is now recognized that periodontitis is an infectious disease associated with microorganisms that exist in a subgingival biofilm[5]. The subgingival microflora in patients with periodontitis provides a significant concentration of toxin, and thus there is a persistent challenge to the periodontium from toxins produced by gram-negative bacteria[6]. This bacterial biofilm attaches to and colonizes on tooth surfaces both supra and subgingivally often mineralizing and forming dental calculus. Plaque and calculus cause periodontal inflammation, which can result in attachment loss and the eventual loss of teeth[7].

In addition, there appears to be an association between periodontal inflammation and systemic diseases, which in some instances may contribute to cardiac problems, strokes, preterm low birth weight babies, and other chronic diseases. It is well understood that periodontal disease is a chronic inflammatory disease, which involves the inflammation and ulceration of the sulcular epithelium within the periodontal pocket. In patients with generalized moderate periodontitis, it is estimated that the surface area of sulcular epithelium exposed to bacterial attack is approximately the size of the palm of an adult hand and even larger as the disease process progresses[4]. Due to ulceration of exposed periodontal pockets, bacteremia is common during daily function[8]. This chronic inflammatory process and insult to the systemic circulation through the bacteremia and the effect of inflammatory cytokines is the source of the systemic effects seen as a result of periodontitis.

This study is designed to further the use of evidence-based dentistry in the education of dental providers in both probing depth measurement and calculus detection, which are crucial diagnostic elements in developing a treatment plan to halt the progression of periodontal diseases. Assessing, appraising, and applying new clinical information are the most significant factors in the practice of evidence-based dentistry[9]. Therefore, a targeted prevention-based approach is ideally realized through comprehensive clinical education, which leads to an accurate diagnosis and a thorough and effective therapy[10, 11].

The primary etiology of gingival inflammation is bacterial plaque[12] from which calculus is formed[13]. Calculus is classified into supragingival and subgingival calculus based on location. Subgingival calculus is located below the crest of the marginal gingiva and therefore is not often visible on a clinical exam. The location and extent of subgingival calculus may only be evaluated by careful tactile perception with a delicate dental instrument like an explorer[14]. Calculus detection therefore is an acquired skill that must be mastered by clinicians. Both supra- and subgingival dental calculus occurs in the majority of adults worldwide, and its removal remains the cornerstone of periodontal therapy[7]; however, few attempts have been made to improve intra- and inter clinician reliability in detecting calculus[15] even though previous research has shown low agreement in calculus detection between clinicians[16-19].

As mentioned previously, bacterial toxins released from subgingival plaque and calculus can initiate periodontal destruction. This destruction is one of the causes for periodontal pocketing and is highly associated with the location and extent of calculus in susceptible patients. The epithelial attachment made between a tooth and the base of the periodontal pocket is referred to as the junctional epithelium and apical to the junctional epithelium is the connective tissue attachment to the tooth. These structures collectively are referred to as the gingival attachment apparatus. The thickness of this attachment, referred to as the biologic width, is fairly constant and provides an average distance of ~2.00 mm, which is not breached by dental calculus[20]. This finding suggests that the bone-resorbing activity induced by bacterial insult is exerted as a result of inflammation within these tissues. In order to properly measure the extent of periodontal destruction or clinical attachment loss that has occurred we must probe to the base of the periodontal pocket and touch the tip of the probe against the most coronal extent of the epithelial attachment.

The periodontal pocket, defined as a pathologic deepening of the gingival sulcus, is one of the most important clinical features of periodontal disease[6]. However, pockets may be classified into two subcategories, the gingival pocket or periodontal pocket. A gingival pocket is formed by gingival enlargement without destruction of the periodontal tissues whereas a periodontal pocket is formed due to an apical migration of the attachment apparatus and a subsequent destruction of supporting PDL and alveolar bone. The only reliable method for locating periodontal pockets and determining their extent is careful probing[6]. Without the consideration of the underlying structures and clinical recession it can be difficult to differentiate between a gingival and periodontal pocket through probing depth alone. Pathologic changes such as color, texture, and bleeding on probing must be taken into account.

Periodontal probing is considered the single most important examination method in detecting periodontal disease and evaluating periodontal therapy[21, 22]. Precise probing depth measurements are important to treatment planning and patient outcomes. Matuliene et al. found that patients with 5mm, 6mm, and 7mm residual probing depths are associated with 7.7, 11, and 64.2 times higher rate of tooth loss respectively over an 11 year period than teeth with physiologic probing depths of 3mm or less[23]. Schatzle et al. 2004, found that teeth that exhibited consistent bleeding on probing from the gingiva were 46 times more likely to be lost over a 26 year period than teeth that did not show gingival bleeding[24]. These studies along with others show that periodontal disease is a progressive disease if left untreated.

The etiology of periodontal disease progression causing deep probing depths is multifactorial. In order for patients to maintain gingival health they must frequently mechanically dislodge plaque from the tooth surface through thorough brushing, flossing, and other supplemental hygiene techniques. If dental plaque is allowed to colonize the tooth surfaces and within gingival sulci, gingivitis will occur within 10-21 days[25]. Patients who exhibit periodontal disease and probing depths deeper than 3mm are not able to properly cleanse to the base of the periodontal pocket with standard hygiene techniques and devices and re-colonization of periodontal pathogens will return to baseline in as quickly as 2 days post-professional prophylaxis[26]. With an inability to properly cleanse the pocket and high concentrations of periodontal pathogens colonizing the site, periodontal disease progression can occur.

One of the major etiologic factors for this disease progression is the change in bacterial flora associated with increasing pocket depth. As a periodontal pocket deepens bacterial profiles change from aerobic to anaerobic species; most notable in these species are the "red complex" bacteria first described by Sigmund Socransky in 1998[27, 28]. The red complex bacteria, which include *P. gingivalis*, *T. denticola*, and *T. forsythia*, are invasive bacterial species associated with increased pocket depth, bleeding on probing, and clinical attachment loss. Due to the potential progressive nature of periodontal disease, it is important to accurately monitor patients' periodontal status. Although probing is a common dental practice, examination of the periodontal sulcus is a sensitive procedure that can be affected by probe type, health of sulcular tissues, presence of biofilm, and sulcus morphology[29]. With proper operator training and calibration, the periodontal probing measurement is an effective and highly reproducible measure critical to comprehensive patient care[30].

The importance of a correct periodontal diagnosis is well documented in both the periodontal and dental literature;[31] however, there is a marked void in the literature for periodontal education and evidence based teaching instruments. Typodont dental models have been used as a teaching tool in dentistry for many years in order to orient students to simulated patient care. Nevertheless, after reviewing the literature the great majority of publications on the use of dental models in dental education are designed for prosthodontics and operative dentistry[32, 33, 34]. After performing a search of the Journal of Dental Education from 1968 to 2012 with inclusive search terms of dental model, typodont, dentaform, and dentoform there appeared to be only one article related to their use for teaching periodontics[35].

The Kinoshita Dental Model (KDM) (Model #: P15DP-500HPRO-P2B2S161) was introduced to Tufts University School of Dental Medicine (TUSDM) in January 2012. Since that time the Department of Periodontology has been working with the model to make design improvements to better educate our students in proper probing depth measurement and calculus detection. In the fall of 2012 the Tufts designed model was used to educate our students.

Previously, students at TUSDM were trained without a dental model specific for these tasks and all probing depth or calculus detection was done on fellow students, most of whom did not have periodontal disease and few exhibited subgingival calculus. The only dental model available at TUSDM was a Columbia Dental Model, which simulated a periodontally involved cadaver. No gingiva, gingival attachment apparatus, or normal morphology was present.

The KDM is specifically designed to educate students in periodontal probing and calculus detection skills. The KDM has many features built into its design to help facilitate pre-clinical learning. One unique feature is its simulated periodontal attachment, apparatus for tactile sensation of the base of the periodontal pocket. Along with the simulated attachment the KDM features periodontal defects, normal periodontal anatomy, gingival hyperplasia, periodontal recession, and removable gingiva. Because of these features the KDM simulates a truly periodontally involved patient with a high level of accuracy. Although exciting and highly promising, no studies have been done to assess its efficacy in training students to properly identify periodontal pockets or calculus. Moreover, with the ability to remove and replace gingiva on the KDM, no study has ever looked at what simulated gingiva, transparent or opaque, serves as the best teaching tool for students.

This study contributes to the dental literature by providing a basis for the use of a periodontally specific dental model in dental education. Dental models have been shown to improve student experiences by providing increased objectivity, conformity, and flexibility in evaluating student progress[36, 37]. To our knowledge the KDM is the only dental model with a simulated gingival attachment apparatus and this is the first study to evaluate its effectiveness. This study evaluated student performance in probing and calculus detection using the KDM as a teaching model pre-clinically as well as it's influence on students' ability to properly probe patients and detect calculus in a clinical setting.

***Purpose and significance:***

There is a paucity of literature available to support evidence based dental education. As a result of the lack of literature that is present to support dental education, this study seeks to develop evidence based practices for the instruction of dental students in learning to properly probe periodontal pockets and detect dental calculus. Through the use of evidence based teaching tools we can more effectively facilitate pre-clinical learning.

The purpose of this study was to evaluate the effectiveness of the KDM as a pre-clinical training tool for pre-doctoral education in periodontal probing and calculus detection as well as to determine how students trained on the KDM performed in the dental clinic working with their patients as compared with students who had no training with the KDM model. With the use of an accurate and effective training model to predictably train pre-doctoral students in precise probing depth and calculus detection techniques, we can better serve our patients and ensure proper periodontal diagnosis.

## Specific Aims and Hypothesis

***Hypotheses:***

1. It was hypothesized that when working with the KDM, dental students trained in calculus detection and pocket depth measurements with both transparent and opaque gingiva would be more accurate in determining probing depths and calculus detection

than those trained with transparent or opaque gingiva alone in the preclinical environment.

2. It was hypothesized that there would be greater accuracy of pocket depth measurement and calculus detection in the undergraduate clinic with students instructed using the KDM when compared with students who were not trained on the KDM.

***Aims:***

One aim of this study was to evaluate which of the three KDM groups used in preclinical training best helped to effectively promote proper probing depth measurement and calculus detection when students were examined at the end of training using an opaque model.

A second aim was to evaluate the effectiveness of the KDM as a pre-clinical training tool for pre-doctoral education by comparing clinical accuracy of students trained with the KDM to students who were never trained using the KDM in periodontal probing and calculus detection.

## Research Design and Methods

***Inclusion/Exclusion Criteria:***

*Inclusion-*

Part I:

1. Students enrolled at TUSDM in the graduating class of 2015 (D-15).

Part II:

1. Students enrolled in the D-13, D-14, D-15 classes.

2. Patients must have been seen at TUSDM and examined during an initial or recare exam (Dental code 150 or 120)
3. Patient must be over 18 years of age.

*Exclusion-*

Part I:

1. Dental students currently enrolled in the International Student Program

Part II:

1. Patients that ask not to be involved in the study
2. Patients with less than six teeth
3. Patients with no molar teeth or less than four posterior teeth
4. Patients with missing incisor teeth in one arch

***Pre-clinical Protocol:***

At TUDSM, a periodontal workshop was given to second-year dental students in a course entitled, "Introduction to Clinical Experience" (ICE). This pre-clinical or "simulation learning" portion of the curriculum is given in the TUSDM Simulation Clinic. In this course, the second-year class was divided into thirds and each student attended one of three identical lectures. A description of the lecture is outlined below.

Daniel Coleman (DC) and calibrated dental faculty instructed students on how to accurately measure pocket depths and detect dental calculus on the KDM using a UNC 1-15 periodontal probe and TU-17 explorer. In each workshop participants received a Nissin Dental Products KDM with different simulated gingiva as a training device for probing depth measurement and calculus detection. The three preclinical groups were trained using translucent gingiva, opaque gingiva, or both translucent and opaque gingiva models. The two model types, translucent and opaque, differed only in the simulated gingiva applied to each model. Each of the models had identical simulated bony and gingival anatomy. In addition to simulated normal anatomy, the models contain localized periodontal defects and localized gingival enlargement. All models also contain a simulated attachment apparatus. The simulated attachment is composed of 2mm of silicone over the simulated crest of the bone that provides a tactile sensation similar to that of probing the base of a periodontal pocket. All models have simulated subgingival calculus, which is located on the same teeth and the same sites on each tooth. All of the workshops were done on a Tuesday evening from 4:30-7pm.

a. The first workshop group was taught using clear translucent gingiva.
b. The second workshop group was taught on pink opaque gingiva.
c. The third group was taught with both model types, one translucent model and one opaque model.

***Faculty Calibration:***

In order to ensure proper calibration, faculty participants had no knowledge of the periodontal pockets or location of calculus prior to calibration. During calibration each faculty member made six measurements on each of the six "Ramfjord Teeth" (#3,9,12,19, 25, 28). The Ramfjord teeth are the maxillary right and mandibular left first molars, maxillary left and mandibular right first premolars, and maxillary left and mandibular right central incisors. Cross-sectional studies have found a good correlation between mean values from the Ramfjord index teeth and whole-mouth scores for dental plaque, supragingival and subgingival calculus, inflammation and probing depth[38]. At the time that the Ramfjord teeth were selected by DC for testing in this study there was no knowledge of the bony morphology of the selected sites or of the pocket depths. Four faculty corroborated proper probing depth measurement to provide a key with accurate measurements for all of the 36 sites. All faculty members for this study had to correctly probe 90% of sites to within 1mm of the values provided by the key in order to pass calibration standards. Calculus was added to 5 specified sites selected and applied by DC on each model. These sites are specified in Appendix C. The faculty were blinded to the areas that calculus has been added and had to retest until they had accurately identified all 5 areas of calculus prior to completing calibration.

***Second-Year student instruction:***

Examiner DC served as the lead instructor for the workshops and calibrated examiners Drs. Jeong, Levi, Meinzer, Marcuschamer and Rudy provided course instruction for all second year pre-doctoral students ICE workshops.

During the lecture portion of the workshop students were taught the rationale for the use of the dental model and a description of periodontal disease, clinical attachment loss, and the composition of dental calculus. Students were also taught specific instruments and the correct techniques for measuring periodontal sulci or pockets (Hu-Friedy UNC 1-15mm Periodontal Probe) and for the detection of supra and subgingival calculus (Hu-Friedy TU-17 Explorer). These techniques include paralleling of the dental instrument, accurate probe angulation and the use of finger rests.

During and following the lectures on periodontal probing and calculus detection, students were asked to use their KDM models to utilize the techniques that they were taught through lecture. The students worked in pairs. Students were given 30 minutes to use the model for probing and 30 minutes for calculus detection. During this portion of the workshop calibrated faculty provided hands on instruction in probing depth measurement and calculus detection techniques.

Following the instruction of pocket depth probing and calculus detection, thirty minutes of the workshop was allotted to testing the students on probing and calculus detection techniques that they were taught during the lecture. The test was administered using the opaque KDM for all three groups. The students were tested independently, and the class was divided in half at random; one half of the room made up one test group while the other half of the room made up the second group. Dividing the group was done to ensure that there were enough opaque dental models so that each student had an opaque model for testing purposes. Each student was individually tested for accuracy in probing depth measurements and calculus detection using the Ramfjord teeth.

The students were instructed to use the UNC 1-15mm periodontal probe and TU-17 for examination purposes. For probing depth measurement each tooth was measured at six sites, mesial facial, mid facial, distal facial, distal lingual, mid lingual and mesial lingual. Students were asked to record the probing depth measurement that they found at each site to the nearest millimeter.

For calculus detection ten surfaces of subgingival calculus were applied throughout the model for student detection. Five surfaces were applied to Ramfjord teeth and used for testing. Students were asked to identify calculus based on 4 distinct tooth surfaces, mesial, distal, buccal or lingual. Students were asked to Answer “Yes” if calculus was present and “No” if calculus was not present on each of the 24 tooth surfaces tested

The examination forms provided 36 and 24 spaces respectively (Appendix A) for students to provide probing depth measurements and the presence or absence of calculus, which was corrected by a single examiner (DC). Each student was given 30 minutes to complete the examination. All groups were tested in the same manner.

***Clinical Protocol:***

The clinical portion of this study served to develop a control for the training of the D-15 students in the pre-clinic. Utilizing the students in the classes of D-13 and D-14 who had been trained in ICE with lecture and the Columbia dental model, without any gingiva or attachment apparatus, during their instrumentation workshop and also on themselves, DC tested their accuracy in pocket measurements and calculus detection on patients in the clinic utilizing the Ramfjord teeth.

The D-15 students were also examined by DC when they began their clinical experience in the fall of 2013. This provided data to be compared with the non-KDM trained students in the D-13 and D-14 classes.

Students completed periodontal examinations for their patients in the standard protocol for TUSDM clinic by completing a periodontal charting, calculus detection, and other periodontal assessments prior to asking a periodontal instructor to review their findings. Examiner DC evaluated these students by assessing the students’ probings and calculus detection of the Ramfjord teeth on their patients.

***Second, third, and fourth-year dental student examination:***

DC assessed the third and fourth-year students in the dental clinic for their accuracy in pocket probing, calculus detection, and all other periodontal findings, as is normally done by the periodontal instructors in the dental clinic. Although examiner DC evaluated the entire mouth, only the Ramfjord teeth or appropriate substitutes were used for the study. A total of six teeth were examined and had to include four posterior teeth and at least one molar. Students were not aware of the selected teeth for examination prior to evaluation. DC did not evaluate the student until they had completed their periodontal examination in full and used the same examination form that the second-year predoctoral students used in the ICE program for recording purposes (Appendix A). A similar examination of the D-15 students took place in fall of 2013 after they had entered the clinic.

***Dental Model:***

The training device used for this study was a Nissin Dental Products Dental Model designed by Atsuhiro Kinoshita. The KDM is unique in that it has a simulated soft attachment apparatus (a 2mm silicone bead at the most apical extent of the sulcus/pocket), and it allows for the use of transparent and/or opaque gingiva. Both maxillary and mandibular models have localized areas of bony periodontal defects and normal bony anatomy, which was identical for all models. The models exhibit in the maxillary right posterior teeth and mandibular left posterior teeth normal bone morphology. The mandibular left posterior gingiva has enlarged gingival anatomy for teaching purposes. No dental model prior to this design has utilized all of these factors in properly simulating a periodontal patient.

***Instruments:***

All participants were instructed on the use of the following instruments.

1. UNC 1-15 mm periodontal probe (Hu-Friedy)
2. TU-17 explorer (Hu-Friedy)
3. Dental mirror size 5 (Hu-Friedy)

The UNC 1-15mm periodontal probe was used for probing depth measurement while the TU-17 was used for calculus detection.

***Equipment:***

1. Nissin Dental Model (Provided by TUSDM)
2. Dental loupes (Provided by the participants)
3. Hu-Friedy mirror, explorers, and periodontal probe (Provided by TUSDM)
4. “Simulation Laboratory” operatory (Provided by TUSDM)
5. Operatory light or dental headlamp (Provided by TUSDM)
6. “Simulation Laboratory” audio visual equipment (Provided by TUSDM)

***Participants:***

163 second-year predoctoral students at TUSDM were participants for the preclinical portion of this study.

33 second-year (10 opaque trained students, 13 translucent trained students, and 10 both translucent and opaque trained students), 18 third year, and 21 fourth year dental students were used for the clinical application of this study.

***Data Collection:***

The preclinical study data came from the examinations given to each student after completion of course instruction in each of the three ICE workshops. Answers to the exam provided the data sets for analysis of probing depth accuracy and calculus detection for each of the three training groups.

Clinical data was gathered from the D-13, D-14, and D-15 students examined in the TUSDM undergraduate clinic. The student's recorded probing depths, calculus detection and the examiner's (DC) like findings were collected for analysis.

***Data Analysis:***

From the data collected a mean absolute difference (MAD) in probing depth was calculated as well as total number of correctly identified surfaces for calculus detection. This was further broken down in the preclinical group to total number of correctly identified surfaces with and without calculus.

The MAD was used for grading of probing depth measurement for both preclinical and clinical evaluations.

In order to evaluate calculus detection, the total number of correctly identified and recorded surfaces of calculus plus the total number of correctly recorded non-calculus containing sites was added for a total possible score of 24. The number of correctly identified answers was used for grading student performance for both preclinical and clinical evaluations.

SAS version 9.2 as well as SPSS version 19 was used for data analysis. For probing depth measurement an average MAD of each of the three groups was made. For the calculus detection data there were three group averages: one average for number of correctly identified surfaces without calculus, one for number of surfaces with calculus, and one group for total number of correctly identified surfaces.

For both pre-clinical and clinical MAD data a one-way ANOVA was used after determining normal distribution by histogram analysis. Levene's test was used to verify the assumption of equal variance. A Kruskal-Wallis non-parametric test was used for pre-clinical calculus data due to a non-normal distribution of data as identified by histogram analysis as well as clinical "total number of correctly identified surfaces for calculus detection" data. Mann-Whitney U tests with Bonferroni correction were used as post-hoc tests for any significant Kruskal-Wallis test. Finally, a generalized estimation equation (GEE) analysis was done for clinical data in order to compare groups in terms of correctly identified non-calculus and calculus containing sites.

***Power Calculation:***

***Preclincal:***

A power calculation was conducted using nQuery Advisor (version 7.0). Assuming a difference of 0.5 between the average MAD of the best performing group and the other two groups, as well as a common standard deviation of 0.5 (difference determined to be clinically significant), a sample size of n=40 per group (or more) was adequate to provide a type I error rate of 5% and a power over 80%.

***Clinical:***

A power calculation was conducted using nQuery Advisor (version 7.0). Assuming a difference of 0.5 between the worst group and the other four groups, as well as a common standard deviation of 0.5 (difference determined to be clinically significant), a sample size of n=21 D13, n=18 D14, n=10 D15 opaque trained, n=13 translucent trained, and n=10 trained with both opaque and translucent was adequate to provide a type I error rate of 5% and a power over 80%.

## Results:

The present study involved two arms, a preclinical study population as well as a clinically based study population. Both populations combined gave a total of 235 reporting subjects in the study.

The preclinical arm of the study was comprised of 163 preclinical study participants from the second year TUSDM class (D-15). Of those 163 participants there were 53 students trained on opaque dental models, 56 trained on translucent dental models, and 54 students trained on both opaque and translucent models.

The clinical data contained 33 D-15 students, 18 D-14 and 21 D-13. Of the 33 D-15 students 10 students were previously trained on opaque KDM models, 13 students were trained on translucent KDM models and 10 students were trained on both opaque and translucent KDM models.

Results are reported based on data collected using the student survey instrument both in the pre-clinical and clinical arms of the study. Representative samples of this instrument can be found in Appendix A of this document.

Pre-clinical results of this study as shown in Table 1 indicate that students performed comparably in the accuracy of probing depth measurement on each model type with no statistically significant differences between groups as measured by mean absolute difference of probing depth value.

Table 1:

Mean Absolute Difference of Probing Depth Values - Preclinical

| Group | n | Mean | SD | p |
|---|---|---|---|---|
| Opaque | 53 | 0.81 | 0.28 | |
| Translucent | 56 | 0.89 | 0.30 | |
| Both | 54 | 0.93 | 0.28 | 0.104 |

Statistical significance was reported between groups for the total number of correctly identified surfaces of calculus, found in Table 2, when using the Kruskal-Wallis test. However, no pair of groups could be identified as being significantly different in post-hoc Mann-Whitney U tests once accounting for more stringent statistical measures via the Bonferroni correction. Mann-Whitney data are represented as a footnote to Table 2.

Table 2:

Total Number of Correctly Identified Surfaces for Calculus Detection - Preclinical

| Group | n | Median | IQR | p |
|---|---|---|---|---|
| Opaque | 53 | 21.0 | 3.0 | |
| Translucent | 56 | 20.0 | 3.0 | |
| Both | 54 | 20.5 | 3.0 | 0.044 |

* Opaque v Translucent: p = 0.043, Opaque v Both: p = 0.021, Translucent v Both: p = 0.988

Similar to probing depth data, students performed comparably in identifying surfaces without calculus independent of the KDM model used during training. Table 3 presents these data.

Table 3:

Number of Correctly Identified Surfaces without Calculus - Preclinical

| Group | n | Median | IQR | p |
|---|---|---|---|---|
| Opaque | 53 | 18.0 | 2.0 | |
| Translucent | 56 | 18.0 | 2.8 | |
| Both | 54 | 18.0 | 2.0 | 0.330 |

Although no differences between groups were observed for the “total number of correctly identified surfaces without calculus” there was a statistically significant difference between groups for the “total number of correctly identified surfaces with calculus” (Table 4). Pre-clinically, the opaque group performed better than the group trained with both translucent and opaque gingiva. This significance was confirmed through Mann-Whitney testing with Bonferroni correction as seen in the footnote of Table 4.

Table 4:

Number of Correctly Identified Surfaces with Calculus - Preclinical

| Group | n | Median | IQR | p |
|---|---|---|---|---|
| Opaque | 53 | 4.0 | 1.0 | |
| Translucent | 56 | 3.0 | 2.0 | |
| Both | 54 | 3.0 | 2.0 | 0.021 |

*Opaque v Translucent: p = 0.090, Opaque v Both: p = 0.006, Translucent v Both: p = 0.268

Clinical results showed that no statistically significant differences were seen between groups for MAD of probing depth values (Table 5).

Table 5:

Mean Absolute Difference of Probing Depth Values - Clinical

| Group | n | Mean | SD | p |
|---|---|---|---|---|
| Opaque | 10 | 0.50 | 0.19 | |
| Translucent | 13 | 0.57 | 0.17 | |
| Both | 10 | 0.54 | 0.21 | |
| D13 | 18 | 0.54 | 0.15 | |
| D14 | 21 | 0.57 | 0.17 | 0.820 |

Similar to clinical probing depth data, the clinical data for "total number of correctly identified surfaces for calculus detection" had no statistically significant differences between groups. These data are represented in Table 6.

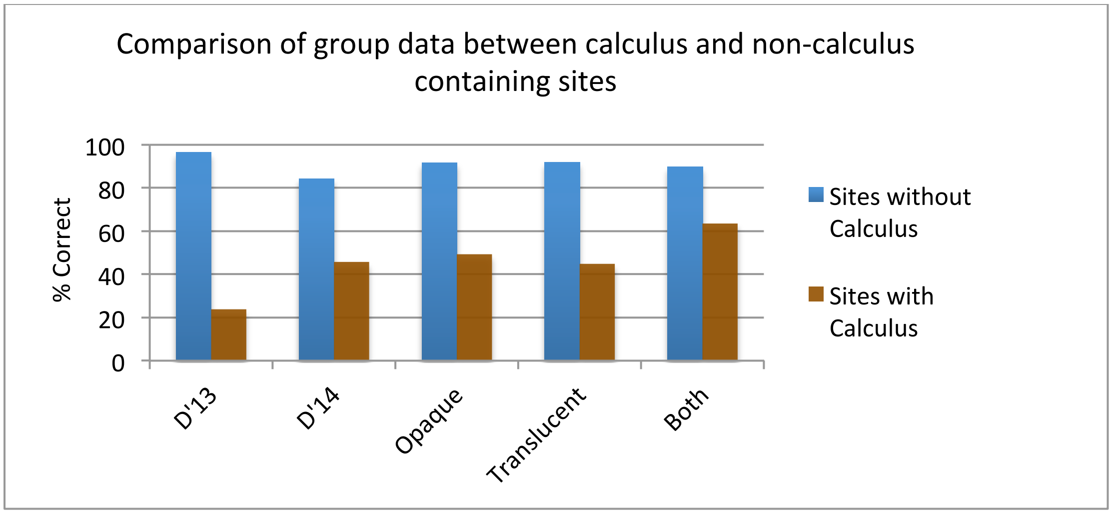
Table 6:

Total Number of Correctly Identified Surfaces for Calculus Detection - Clinical

| Group | n | Median | IQR | p |
|---|---|---|---|---|
| Opaque | 10 | 19.0 | 6.8 | |
| Translucent | 13 | 20.0 | 3.5 | |
| Both | 10 | 20.5 | 2.3 | |
| D13 | 18 | 19.5 | 4.3 | |
| D14 | 21 | 18.0 | 4.5 | 0.160 |

Clinical data were further broken down into group data between calculus and non-calculus containing sites. These data were analyzed using a generalized estimating equation (GEE), which showed a highly significant difference (P<0.0001) in students' ability to properly identify sites without calculus as compared to sites with calculus for all groups. In other words, students were more likely as a group to miss calculus-containing sites than sites without calculus. These data are represented in Figure 1.

Figure 1:




*Comparison of groups (sites with calculus): p=0.094, Comparison of groups (sites without calculus): p=0.155, Sites with calculus v sites without calculus: p<0.0001

Although a highly significant difference was identified when comparing "sites with calculus" and "sites without calculus" there was no significant difference between groups (D-13, D-14, Opaque, Translucent, Both) for "sites with calculus" (P>0.05) or "sites without calculus" (P>0.05).

## Discussion:

*Preclinical -*

The primary aims of this study were to determine which of the three KDM groups preformed best when tested on an opaque model at the end of pre-clinical training and to compare those groups to non-KDM trained students clinically.

It was demonstrated in Table 1 of the results section that all model types performed comparably for periodontal probing measurement. Comparable findings between training groups show that students were able to transfer their skills from the translucent model to the opaque model comparably to students trained with the opaque model type or both model types. This is encouraging because both model types regardless of gingiva type contained the same periodontal anatomy and simulated periodontal pockets. Because model types were identical other than gingival shroud color and translucency, comparable learning between groups can be expected.

Although probing depth measurements and "correctly identified surfaces without calculus" were comparable between groups, the "total number of correctly identified surfaces with calculus" exhibited a significant difference between the opaque group and the group trained on both model types. When looking at group outcomes overall, the group that tended to have better accuracy in detection of subgingival calculus was the group trained on the opaque model alone. The author, of this study speculates that this can be attributed to the tactile sensitivity necessary for calculus detection. Groups given the ability to train on translucent models had the ability to visualize the location of calculus prior to exploring for the tactile sensation of finding calculus without visual cues. Because the calculus could be visualized, groups trained using translucent models did not learn the skills of proper tactile sensitivity necessary for accurate calculus detection.

It should be noted that there was a strong positive response from students to each of the KDM models. Students were excited to use the models and eager to demonstrate newly learned skills in a simulation environment. Anecdotally there was a particularly positive response from students regarding the translucent model type. Students commonly remarked that the ability to visualize periodontal anatomy including periodontal defects, bone loss, gingival hyperplasia, recession and normal anatomy were helpful in their understanding of what they would need to look for and diagnose in their patients.

Due to the results of the preclinical study it is the author's recommendation that students train for probing depth measurement with the translucent KDM model. This provides students the ability to visualize differences in simulated periodontal anatomy and has comparable efficacy to the opaque model for accuracy in periodontal probing measurement as verified by this study. Through the use of the translucent model students will better understand the concepts of underlying periodontal anatomy being evaluated during periodontal probing.

Because of the increased performance of the opaque KDM model in "number of sites correctly identified" by newly trained students, an opaque model type should be utilized for purposes of calculus detection instruction. This will allow students to fully utilize tactile sensation in order to diagnose subgingival calculus.

*Clinical* -

Clinical data resulted in no statistically significant differences between groups for MAD of probing depths or "number of correctly identified calculus surfaces". These results might be attributed to the duration of time between the ICE pre-clinical training of students and their follow-up examination in the clinic when they were treating their patients. This time span could have been up to 12 months. The benefits that the students derived from training with the model could well have been lost due to the duration of time between training and the students' clinical use of the techniques. The lack of reenforcement of these trained skills during the hiatus between initial training and clinical application, and the influence of outside factors during this time period likely contributed to the lack of differences. These concepts will be further examined under the limitations section of this study.

The clinical data did reveal a highly significant difference ($p<0.0001$) between students' ability to properly identify sites without calculus versus sites with calculus. Two possible explanations can be given for these results. First, it can be speculated that students lack the tactile sensitivity and knowledge of normal tooth anatomy to properly identify tooth borne calculus. Interestingly, even groups trained with the KDM were inaccurate in their clinical identification of calculus containing surfaces even though these groups had performed with much better accuracy pre-clinically on the KDM model. A second reason for this discrepancy may be the number of recorded surfaces with calculus and a bias towards responding that calculus was not present. A much higher number of surfaces were calculus free thus conditioning students to respond that no calculus was present. Due to the high percentage of sites that were calculus free, students may have been less likely to thoroughly examine sites with calculus and report that calculus was not present. Many students incorrectly filled in entire exam sheets reporting no calculus present.

*Limitations –*

Study limitations have been broken down into preclinical and clinical categories. Beginning with preclinical limitations of the study, we will examine curriculum time dedicated to this simulation experience. Time dedicated to the education of these techniques is limited in the first two years of dental education. At TUSDM one course session in periodontal diagnostic instrumentation is offered over the entire course of dental education. When further examining this course, students training through lecture, the KDM model, and one on one instructor attention was limited. There was a total teaching time of approximately 2 hours given to simulation learning. This time was broken down into 30 minutes of lecture, 30 minutes of hands on probing of the KDM, 30 minutes of calculus detection on the KDM, and 30 minutes of student examination. Each session had 5 calibrated faculty teaching groups of slightly less than 60 students. With this ratio of students to faculty, if time was distributed evenly between students, each faculty had slightly over 2 minutes of hands on time per student per training technique. Dedicated training time for this study was given as evening sessions from 4:45-6:45pm after students had a full day of unrelated dental course work.

After simulation learning, students had a lag of approximately 8 months until using their trained probing and calculus detection techniques on patients and were not retested for the clinical portion of the study until between 11 and 12 months after initial simulation learning. Students were given no educational reinforcement of learned techniques over the 8 months prior to seeing patients. This lag between initial instruction and subsequent testing allows for the influence of maturation bias on the study results.

The long duration of time between preclinical and clinical data collection affects the internal validity of study results.

Internal validity of a study reflects the extent to which a causal relationship can be determined between the study and its conclusions. Maturation bias of a study group occurs when time elapses between data collection and outside factors may influence participants' answers to the study instrument. In this case, other dental classes teach the use of the TU-17 explorer for purposes other than calculus detection, such as caries detection. Students also spend many hours in simulation learning environments unrelated to periodontal instrumentation, and prior to collection of clinical data students had also had the opportunity to sit with patients and may have gained clinical instruction in techniques of periodontal probing or calculus detection by non-calibrated faculty.

Irrespective of study design, inherent differences in probing depth and calculus detection must be taken into account when interpreting study results. Differences in probing depth measurements due to force control, probing technique, inflammatory status of the patient, and many other factors have been well documented within the literature[39]. Measurement is inevitably subject to error. The instrument used for measuring, the measurement technique, the examiner, or the object examined may produce probing error[39]. There is overwhelming evidence that, even after many repetitions, probing depth measurement is difficult to reproduce. For manual probes, errors for single probing depth measurement range between 0.30mm and 0.70mm[40, 41, 42]. With inexperienced dental students as the participants in this research probing depth error may in fact be larger than reported by the previously mentioned studies.

Although literature on the accuracy of dental calculus detection is more limited than that of proper periodontal probing literature, there are many articles on calculus removal and the efficacy of instruments in the removal of calculus at variable pocket depths. Stambaugh et al.[43] examined “curette efficiency”, the pocket depth at which a periodontal instrument could predictably remove all subgingival calculus, to be 3.73mm. This same study concluded “instrument limit”, the deepest that an instrument could remove any calculus deposit, to be 6.21mm. Many other studies have correlated increased pocket depth with insufficient calculus removal, due to poor detection and inability to properly adapt periodontal instruments to effectively remove subgingival calculus. Hence, one variable that may affect student and examiner performance in calculus detection is the depth of the periodontal pocket.

*Future research –*

The current results of this study helped to develop a number of future research questions. In order to better understand the effects of the KDM on pre-clinical education, a fourth group, trained through lecture alone, should be incorporated into the study to serve as a pre-clinical control. All groups would then be tested in the same manner using the testing instrument shown in Appendix A. This control group would help to determine the effects of simulation learning through the use of the KDM model as a direct comparison to students never given the opportunity to use either model type.

This fourth group would also add control to the pre-clinical portion of the study, eliminating the need to wait up to a year to test KDM trained students with non-KDM trained students in a clinical environment. By adding this pre-clinical control we would increase internal validity of the study and eliminate the influence of maturation bias.

The clinical study could then serve to observe the duration of effectiveness of student performance over time.

Curriculum changes at TUSDM are looking to incorporate students into clinical learning environments earlier in their educational process than was in effect for this study. This may allow for students to take information learned within the preclinical portion of the study and apply it clinically shortly thereafter. This would lend itself to a follow up study to determine performance of KDM trained students over multiple time points in dental student education.

## Conclusion:

The results of this study suggest that students preform comparably in probing depth measurement for all groups (opaque, translucent, or both), whereas students preform better when using the opaque model type for calculus detection purposes. Further research is needed in order to analyze the effects the KDM has on probing depth measurement and calculus detection as compared to control group participants.

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Appendix A: Copy of survey instrument

## Probing Depth Measurement Examination:

Please fill in each space with the probing depth measurement that you have probed for the specified site below.

Tooth #3

DF ________

F ________

MF ________

MP ________

P ________

DP ________

Tooth #19

DF ________

F ________

MF ________

ML ________

L ________

DL ________

Tooth #9

DF ________

F ________

MF ________

MP ________

P ________

DP ________

Tooth #25

DF ________

F ________

MF ________

ML ________

L ________

DL ________

Tooth #12

DF ________

F ________

MF ________

MP ________

P ________

DP ________

Tooth #28

DF ________

F ________

MF ________

ML ________

L ________

DL ________

Calculus Detection Examination:

Please fill in each space with a Y (Yes) or an N (No) to indicate if calculus is present on the specified site below.

Tooth #3

D ________

F ________

M ________

L ________

Tooth #9

D ________

F ________

M ________

L ________

Tooth #12

D ________

F ________

M ________

L ________

Tooth #19

D ________

F ________

M ________

L ________

Tooth #25

D ________

F ________

M ________

L ________

Tooth #28

D ________

F ________

M ________

L ________

## Appendix B

Lecture Outline:

**Introduction**

Purpose of course – This will give rationale for what students will learn in the workshop.

Description of periodontal disease

**Probing Depth**

Defining clinical attachment loss

Defining gingival hypertrophy

Interactive:

Model- Students will pick up the models; there will be a review of normal anatomy (upper right sextant of dental model), Also the effects of periodontal disease will be reviewed (upper left sextant of dental model).

Instrumentation- Students will be introduced to the UNC 1-15mm probe.

Finger Rest positions, probe angulation, and probing technique will be instructed to students and re-enforced on the dental model.

**Calculus Detection**

Defining calculus

Relationship between calculus and periodontal disease

Interactive:

Instrumentation- Students will be introduced to the TU-17

Detection technique and tactile sensation will be taught and re-enforced on the dental model.

**Examination**

30 minutes will be allotted at the end of the session for examination of the students on proper probing depth measurement and calculus detection.

Each student will be tested on an opaque dental model.

# Appendix C:

***Probing Depth Measurement Key (mm):***

Tooth #3

DF _3_______

F _2_______

MF _3_______

MP _3_______

P _3_______

DP _3_______

Tooth #9

DF _7_______

F _8_______

MF _5_______

MP _6_______

P _7_______

DP _7_______

Tooth #12

DF _3_______

F _4_______

MF _3_______

MP _3_______

P _5_______

DP _6_______

Tooth #19

DF _5_______

F _2_______

MF _5_______

ML _5_______

L _3_______

DL _5_______

Tooth #25

DF _5_______

F _2_______

MF _3_______

ML _3_______

L _2_______

DL _5_______

Tooth #28

DF _3_______

F _6_______

MF _3_______

ML _3_______

L _5_______

DL _4_______

***Calculus Detection Key:***

Ramfjord Teeth

#3: None

#9: Buccal

#12: Distal

#19: Mesial

#25: Distal

#28: Lingual