SUBGINGIVAL DENTAL CALCULUS DETECTION WITH A WHO PERIODONTAL PROBE: AN IN VITRO EVALUATION.

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ABSTRACT

Objectives: The ball-tipped World Health Organization (WHO) periodontal probe is widely employed to measure periodontal probing depths, and to detect dental calculus and overhanging margins of dental restorations, in epidemiologic surveys of periodontal status in population groups. However, the ability of the WHO probe to reliably identify subgingival dental calculus on tooth root surfaces has received little attention. This study assessed, using an in vitro typodont model system, the ability of a WHO periodontal probe, as compared to an ODU 11/12 dental explorer, to accurately detect the presence of subgingival dental calculus.

Methods: Three typodont models of the human oral cavity, comprised of white plastic teeth emerging from pink silicone gingival and palatal soft tissues, and presenting a total of 108 subgingival sites on mandibular posterior plastic teeth, of which 57 (52.8%) had artificial dental calculus deposits, were mounted in manikin phantom heads with simulated soft tissue mouth shrouds. Supragingival typodont tooth surfaces were covered with artificial saliva to simulate typical oral cavity conditions in humans. The 108 subgingival surfaces were then evaluated for subgingival dental calculus with a WHO periodontal probe and an ODU 11/12 dental explorer in duplicate by a primary examiner, who was a newly-trained specialist in periodontics. A board-certified periodontist with 31 years of clinical specialty experience also scored all of the subgingival tooth surfaces with both instruments once as a secondary examiner. Reproducibility, sensitivity, specificity, positive predictive value, negative predictive value, and accuracy (diagnostic effectiveness) of the two instruments for identification of subgingival dental calculus were calculated and compared.

Results: The WHO periodontal probe exhibited only fair to poor intra- ($\kappa = 0.40$) and inter-examiner ($\kappa = 0.37$) reproducibility between the two periodontist examiners, which was lower than that found with an ODU 11/12 explorer ($\kappa = 0.61$ and $\kappa = 0.43$, respectively). For both periodontist examiners, the WHO probe also yielded lower sensitivity (86.0% versus 96.7% for primary examiner; 63.2% versus 84.2% for secondary examiner), lower specificity (49.0% versus 51.1% for primary examiner; 88.2% versus 90.2% for secondary examiner), lower positive predictive value (65.3% versus 72.0% for primary examiner; 85.7% versus 90.6% for secondary examiner), lower negative predictive value (75.8% versus 92.3% for primary examiner; 68.2% versus 83.6% for secondary examiner), and lower overall accuracy (diagnostic effectiveness) (68.5% versus 76.9% for primary examiner; 75.0% versus 87.0% for secondary examiner) than an ODU 11/12 explorer for detection of subgingival calculus on mandibular posterior tooth surfaces.

Conclusions: The diagnostic performance of the WHO periodontal probe was inferior in all evaluated aspects to an ODU 11/12 dental explorer for in vitro identification of subgingival dental calculus. These findings suggest that epidemiologic periodontal surveys employing the WHO periodontal probe likely underestimate the true occurrence of subgingival dental calculus on examined teeth.

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CHAPTER 1

INTRODUCTION

The World Health Organization (WHO) in 1982 developed a new periodontal probe for clinical evaluation of the periodontium (Ainamo et al. 1982). The WHO periodontal probe was designed with a hemispheric-shaped tip 0.5 millimeters in diameter, and has several markings. The first marking is a solid black band extending from 3.5 millimeters to 5.5 millimeters from the end of the probe tip, a second marking as a black ring at 8.5 millimeters from the probe tip, and a third marking as a black ring at 11.5 millimeters from the probe tip (Figure 1).

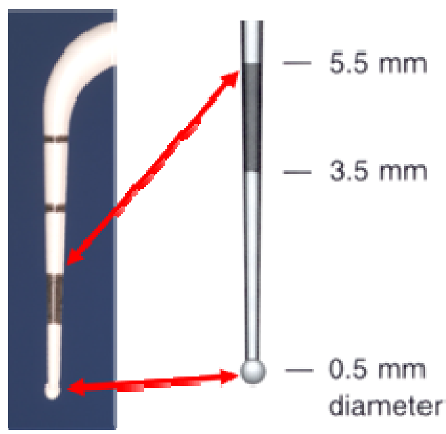

Figure 1. The WHO periodontal probe (left), with an enlarged view its hemispheric-shaped ball tip and black band (right).

The probe markings are used to make measurements of probing depth and clinical attachment level circumferentially around teeth in the oral cavity. The purpose of the hemispheric-shaped ball tip at the end of the probe tip is two-fold. First, the rounded end, as compared to a sharp-pointed end characteristic of dental explorers, is intended to limit the extent of soft tissue penetration that occurs when a periodontal probe is apically advanced into periodontal pockets where marked gingival tissue inflammation is present. This often results in probe penetration beyond the junctional epithelium into gingival connective tissues, resulting in a larger clinical measurement than the actual histologic size of the periodontal pocket (Listgarten 1980). Second, the interface of the ball tip at the terminal point of the probe with the probe shaft was to facilitate tactile detection of dental calculus deposits and overhanging margins of dental restorations on tooth surfaces (Ainamo et al. 1982).

The WHO probe has been widely used in periodontal diagnostics since 1982. Initially, the probe was employed for estimating periodontal treatment needs in population groups for the Community Periodontal Index of Treatment Needs (CPITN) (Ainamo et al. 1982). With CPITN, the WHO periodontal probe is used to examine and score six sites per tooth in each patient dentition sextant on a 0 to 4 hierarchical grading scale, with only the highest CPITN score per sextant recorded for documentation (Ainamo et al. 1982). Sextants with probing depths less than 3.5 millimeters at all tooth sites are assigned a CPITN score of either 0, 1 or 2, depending upon the presence of bleeding on probing, dental calculus deposits, and/or defective dental restoration margins in the sextant. Sextants with deepest probing depths ranging between 3.5 to 5.5 millimeters are assigned a CPITN score of 3, and sextants with at least one > 5.5 mm probing depth are given a CPITN score of 4 (Ainamo et al. 1982).

The WHO periodontal probe has been extensively utilized in numerous CPITN surveys in population groups around the world (Petersen & Ogawa 2012). In addition, the WHO periodontal probe is employed in other periodontal index systems derived from

CPITN, such as the Periodontal Screening and Recording (PSR) index system, introduced by the American Academy of Periodontology and American Dental Association (Landry & Jean 2002), the Basic Periodontal Examination method of the British Society of Periodontology (British Society of Periodontology 2016), and the World Health Organization Community Periodontal Index (CPI) (Beltrán-Aguilar et al. 2012).

Despite its wide utilization, no studies to date have evaluated the reliability of the WHO periodontal probe for detection of subgingival dental calculus. Subgingival dental calculus is an important risk factor in the pathogenesis of periodontitis, and sufficient removal of dental calculus deposits from subgingival tooth surfaces represents an important therapeutic objective in management of periodontitis patients (Akcali & Lang 2017). As a result, there is an urgent clinical need for reliable methods to detect subgingival dental calculus on tooth root surfaces (Meissner & Kocher 2011).

The present "gold standard" instrument in periodontal diagnostics for identification of dental calculus deposits on root surfaces is the Old Dominion University (ODU) 11/12 dental explorer (Huennekens & Daniel 1992; Kamath & Nayak 2014), which is employed by all regional dental licensure examining boards in the United States for subgingival dental calculus detection (Rams et al. 2017).

Since it is not known if the WHO periodontal probe has a high or poor level of reliability in detecting subgingival dental calculus, the present study assessed, using an in vitro typodont model system, the ability of a WHO periodontal probe to accurately detect subgingival dental calculus, as compared to an ODU 11/12 dental explorer.

CHAPTER 2

MATERIALS AND METHODS

Laboratory Facilities

All procedures in this study were performed using non-human and non-animal materials in the Graduate Periodontology Clinic at Temple University School of Dentistry in Philadelphia, Pennsylvania. The data collected for the study was non-clinical and laboratory-based, without any intervention or interaction with living individuals, and did not involve any identifiable private information of patients. As a result, the research performed did not involve human subjects, as defined by United States Department of Health and Human Services regulations at 45 CFR part 46.116(f), and did not require a human subjects institutional review board approval, as determined by the Temple University Human Subjects Protections Institutional Review Board.

Typodont Tooth Root Surfaces

This study used a typodont model system previously employed for in vitro subgingival dental calculus detection evaluations (Rams et al. 2017). Three typodont models of the human oral cavity, which are comprised of white plastic teeth emerging from anatomically-accurate pink silicone gingival and palatal soft tissues, were obtained from a manufacturer (Kilgore International, Inc., Coldwater, MI). A total of 108 subgingival root surfaces on 27 mandibular premolar and molar teeth were selected to be evaluated with a WHO probe and an ODU 11/12 explorer. Mandibular posterior teeth were exclusively used to reduce potential problems with access to and visualization of tooth surfaces by examiners unrelated to the efficacy of the calculus detection instruments. A total of 73 (67.6%) of the 108 subgingival root surfaces had artificial dental calculus deposits. The teeth were mounted within the three typodont models, with each typodont containing nine teeth to be evaluated for subgingival dental calculus (Figure 2).

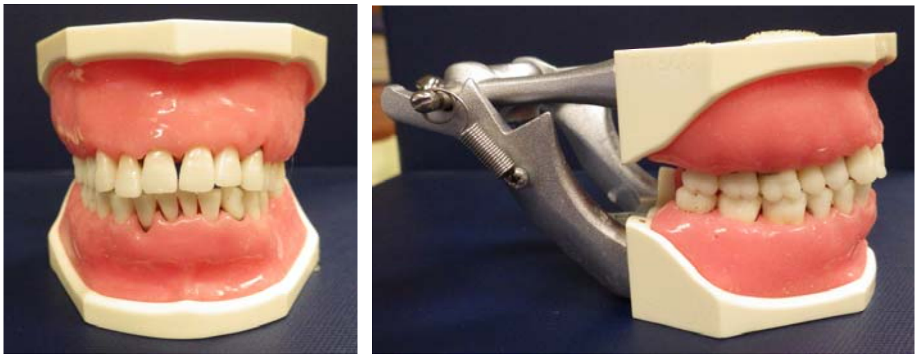

Figure 2. Front (left), and side view (right) of typodont model.

Plastic teeth with and without artificial dental calculus deposits were distributed in a random pattern throughout the posterior mandibular portions of the three typodont models, with the dental calculus placed onto subgingival root surfaces (Figure 3).

Figure 3. Example of subgingival location (left) of calculus-free mesial surface and calculus-positive buccal surface (right) on mandibular typodont molar tooth.

Each typodont was attached to a phantom head with simulated soft tissue mouth shrouds to mimic the head and neck of a human being. Artificial saliva (Aquoral Spray, Bi-Coastal Pharmaceutical Corp., Red Bank, NJ) was sprayed onto supragingival typodont tooth surfaces to further reproduce in vitro the normal hydrated human oral cavity environment.

<u>Subgingival Dental Calculus Assessments</u>

The 108 test subgingival surfaces were evaluated for subgingival dental calculus with a WHO periodontal probe and an ODU 11/12 dental explorer in duplicate by a primary examiner, who was a newly-trained specialist in periodontics (Dr. Marc Manos) (Figure 4). Duplicate assessments were performed only after all three typodonts were initially evaluated. Thus, an approximately 60 minute or more period separated initial and duplicate assessments of each typodont.

Figure 4. Primary examiner performing subgingival dental calculus assessments.

A board-certified periodontist with 31 years of clinical specialty experience also scored all of the subgingival tooth surfaces with both instruments once as a secondary examiner (Dr. Thomas Rams).

Subgingival dental calculus deposits were detected holding the WHO periodontal probe and the ODU 11/12 explorer parallel to the long axis of teeth. With the WHO periodontal probe, the ball tip was placed in contact with the subgingival tooth surface, advanced to the most apical probing depth, and moved repeatedly with a light touch into and out of the periodontal pocket along the tooth root surface (Figure 5).

Figure 5. Initial placement (left), apical advancement (center), and withdrawal (right) of WHO periodontal probe from subgingival tooth surface.

With the ODU 11/12 explorer, the side of its curved tip was adapted to the contour of subgingival tooth surfaces to facilitate dental calculus detection (Figure 6).

Figure 6. Curved tip of ODU 11/12 dental explorer (left), adapted to contour of tooth root surface for dental calculus detection (right).

Then, the instrument was moved repeatedly in vertical and oblique strokes in an apical-coronal direction to engage subgingival dental calculus deposits for detection (Figure 7).

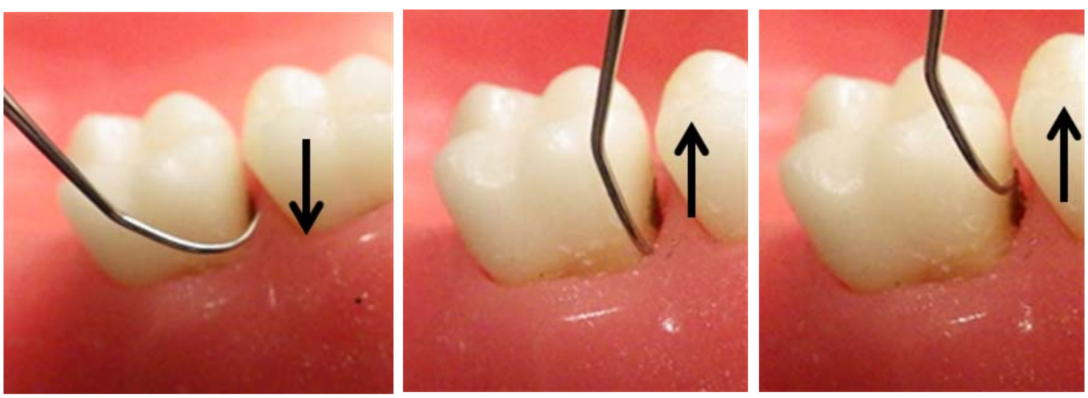

Figure 7. Initial placement (left), apical advancement (center), and withdrawal (right) of ODU 11/12 explorer from subgingival tooth surface.

Dental calculus was tactically detected by the examiners as a bump or irregularity occurring as the WHO periodontal probe or the ODU 11/12 explorer were repeatedly moved along the subgingival root surfaces, similar to criteria previously employed in subgingival calculus detection studies (Rams et al. 2017).

Data Analysis

Using 2x2 contingency table analysis, sensitivity, specificity, positive predictive value, negative predictive value, and accuracy (diagnostic effectiveness) were calculated to assess the diagnostic performances of the WHO periodontal probe and the ODU 11/12 dental explorer relative to in vitro detection of subgingival dental calculus (Shaikh 2011).

As detailed by Shaikh (2011), sensitivity was defined as the probability that assessments by the calculus detection instrument (i.e., WHO periodontal probe or ODU 11/12 explorer) will be positive when root surface calculus is detected (true positive rate). Specificity was defined as the probability that assessments by the calculus detection instrument will be negative when root surface dental calculus is not detected (true negative rate). Positive predictive value was defined as the probability that root surface calculus is detected when assessments by the calculus detection instrument are positive. Negative predictive value was defined as the probability that root surface calculus is not detected when assessments by the calculus detection instrument are negative. Accuracy (diagnostic effectiveness) was the proportion of tooth root surfaces correctly categorized by assessments of the calculus detection instrument (Shaikh 2011).

Kappa values and their standard error (SE) (Hunt 1986) were calculated to quantify agreement beyond chance for the reproducibility of duplicate scoring of root surfaces by the primary examiner for subgingival dental calculus with either the WHO periodontal probe or the ODU 11/12 explorer, and also for the level of agreement in examinations conducted by the primary and secondary examiners. Kappa values less than 0.40 were considered to reflect poor agreement, between 0.40 and 0.75 representing fair to good agreement, and those > 0.75 indicating excellent agreement (Hunt 1986).

The PC-based STATA/SE 14.2 for Windows (StataCorp PL, College Station, TX) 64-bit statistical software package was used in the data analysis.

CHAPTER 3

RESULTS

Typodont Tooth Root Surfaces

Table 1 presents the results of the first pass by the primary examiner in evaluating the 108 tooth root surfaces with the WHO periodontal probe.

Table 1. Results of the first pass by the primary examiner of evaluated tooth root surfaces distributed by WHO periodontal probe outcome and presence or absence of dental calculus

		Root surface dental calculus present	Root surface dental calculus absent
WHO periodontal probe outcome	positive	49	26
	negative	8	25

Using 2x2 contingency table analysis, the WHO periodontal probe first pass outcomes, relative to the presence or absence in vitro of subgingival dental calculus, show a sensitivity (true positive rate) = 86.0%, a specificity (true negative rate) = 49.0%, a positive predictive value = 65.3%, a negative predictive value = 75.8%, and a diagnostic effectiveness (accuracy) = 68.5%.

The distribution of WHO periodontal probe outcomes scored between duplicate examinations of the 108 tooth root surfaces by the primary examiner is presented in Table 2.

Table 2. Distribution of WHO periodontal probe outcomes between duplicate examination of 108 tooth root surfaces by the primary examiner

		WHO periodontal probe outcome at second pass	
		positive	negative
WHO periodontal probe outcome at first pass	positive	63	11
	negative	16	18

Kappa analysis of these duplicate evaluations revealed intra-examiner reproducibility with the WHO periodontal probe to be only fair, with $\kappa = 0.40 \pm 0.10$ (SE).

Table 3 provides the results of the primary examiner analysis of 108 tooth root surfaces evaluated for subgingival dental calculus with the ODU 11/12 dental explorer.

Table 3. Distribution from the primary examiner analysis of tooth root surfaces by ODU 11/12 explorer outcome and presence or absence of dental calculus

		Root surface dental calculus present	Root surface dental calculus absent
ODU 11/12 explorer outcome	positive	59	23
	negative	2	24

Using 2x2 contingency table analysis, the ODU 11/12 explorer outcomes, relative to the presence or absence in vitro of subgingival dental calculus, show a sensitivity (true positive rate) = 96.7%, a specificity (true negative rate) = 51.1%, a positive predictive value = 72.0%, a negative predictive value = 92.3%, and a diagnostic effectiveness (accuracy) = 76.9%.

Table 4 displays the distribution of ODU 11/12 explorer outcomes scored between duplicate examinations of 108 tooth root surfaces by the primary examiner.

Table 4. Distribution of ODU 11/12 explorer outcomes between duplicate examinations of 108 tooth root surfaces by the primary examiner

		ODU 11/12 explorer outcome at second pass	
		positive	negative
ODU 11/12 explorer outcome at first pass	positive	73	8
	negative	8	19

Good level of intra-examiner reproducibility (κ = 0.61 ± 0.09 (SE)) was found in duplicate scoring by the primary examiner of subgingival dental calculus with the ODU 11/12 dental explorer.

Table 5 presents the results from the secondary examiner in evaluating 108 tooth root surfaces with the WHO periodontal probe.

Table 5. Results from the secondary examiner of evaluated tooth root surfaces distributed by WHO periodontal probe outcome and presence or absence of dental calculus

		Root surface dental calculus present	Root surface dental calculus absent
WHO periodontal probe outcome	positive	36	6
	negative	21	45

Using 2x2 contingency table analysis, the WHO periodontal probe outcomes for the secondary examiner, relative to the presence or absence in vitro of subgingival dental calculus, show a sensitivity (true positive rate) = 63.2%, a specificity (true negative rate) = 88.2%, a positive predictive value = 85.7%, a negative predictive value = 68.2%, and a diagnostic effectiveness (accuracy) = 75.0%.

The distribution of WHO periodontal probe outcomes scored between examinations of the 108 tooth root surfaces by the primary and secondary examiners is presented in Table 6.

Table 6. Distribution of WHO periodontal probe outcomes between examinations of 108 tooth root surfaces by the primary and secondary examiners

		WHO periodontal probe outcome by primary examiner	
		positive	negative
WHO periodontal probe outcome by secondary examiner	positive	40	2
	negative	35	31

Kappa analysis of these evaluations revealed inter-examiner reproducibility between the primary and secondary examiners with the WHO periodontal probe to be poor, with $\kappa = 0.37 \pm 0.08$ (SE).

Table 7 provides the results of the primary and secondary examiner evaluations for subgingival dental calculus with the ODU 11/12 dental explorer.

Table 7. Distribution of ODU 11/12 explorer outcomes between examinations of 108 tooth root surfaces by the primary and secondary examiners

		ODU 11/12 explorer outcome by primary examiner	
		positive	negative
ODU 11/12 explorer outcome by secondary examiner	positive	54	3
	negative	27	24

Kappa analysis of these assessments show inter-examiner reproducibility between the primary and secondary examiners with the ODU 11/12 explorer to be fair, with $\kappa = 0.43 \pm 0.09$ (SE).

CHAPTER 4

DISCUSSION

The in vitro study findings question the reliability and clinical usefulness of the WHO periodontal probe for identification of subgingival dental calculus. The WHO periodontal probe exhibited only fair to poor intra- ($\kappa = 0.40$) and inter-examiner ($\kappa = 0.37$) reproducibility between the two periodontist examiners, which was lower than that found with an ODU 11/12 explorer ($\kappa = 0.61$ and $\kappa = 0.43$, respectively). For both periodontist examiners, the WHO probe also yielded lower sensitivity (86.0% versus 96.7% for primary examiner; 63.2% versus 84.2% for secondary examiner), lower specificity (49.0% versus 51.1% for primary examiner; 88.2% versus 90.2% for secondary examiner), lower positive predictive value (65.3% versus 72.0% for primary examiner; 85.7% versus 90.6% for secondary examiner), lower negative predictive value (75.8% versus 92.3% for primary examiner; 68.2% versus 83.6% for secondary examiner), and lower overall accuracy (diagnostic effectiveness) (68.5% versus 76.9% for primary examiner; 75.0% versus 87.0% for secondary examiner) than an ODU 11/12 explorer for detection of subgingival calculus on mandibular posterior tooth surfaces.

The typodont model system used in this study was previously employed to comparatively examine the efficacy of a DetecTar differential reflectometry device with an ODU 11/12 explorer (Rams et al. 2017). Using the same in vitro conditions and distribution of subgingival dental calculus deposits, the WHO periodontal probe produced a low overall accuracy (diagnostic effectiveness) of 68.5% for the primary examiner and 76.0% for the secondary examiner, in comparison to an overall accuracy of

80.6% for a DetecTar differential reflectometry device. In addition, the ODU 111/12 explorer yielded an overall accuracy in this study of 76.9% for the primary examiner, and 87.0% for the secondary examiner. This level of overall accuracy by the secondary examiner in this study compares comparably to the same examiner's overall accuracy of 85.2%, and that of another experienced periodontist (88.9%), with an ODU 11/12 explorer in the previous study by Rams et al. (2017). The lower overall accuracy of the primary examiner in this study with the ODU 11/12 explorer is likely due to the lesser clinical periodontal practice experience of the newly-trained periodontist, as compared to the 31 year of clinical periodontal specialty practice of the secondary examiner in this study, and the 45 years of dental hygiene/periodontics clinical background of the other experienced periodontist in the prior study by Rams et al. (2017).

Overall, the diagnostic performance of the WHO periodontal probe was inferior in all evaluated aspects to the ODU 11/12 dental explorer for in vitro identification of subgingival dental calculus. The present study data provide additional in vitro validation supporting the clinical practice use of the ODU 11/12 dental explorer for identification of subgingival dental calculus in periodontal sites. These findings also suggest that epidemiologic periodontal surveys employing the WHO periodontal probe likely underestimate the true occurrence of subgingival dental calculus on examined teeth, as a result of relatively poor sensitivity compared to an ODU 11/12 explorer.

Further studies and clinical applications of the WHO periodontal probe are needed and warranted to further understand why the instrument failed to provide better subgingival calculus detection. One potential reason may be due to the manufacturing of the WHO periodontal probe with a flexible plastic tip material. In comparison to the metal ODU 11/12 explorer, the plastic WHO periodontal probe was noted by the examiners to be overly pliable and flexible during tooth root surface exploration, which diminished tactile discrimination between dental calculus positive- and negative tooth root surfaces, resulting is the instrument tip skipping over raised subgingival dental calculus deposits without creating a “bump” discernable to the periodontist examiners. Future studies should replicate tooth root evaluations with both plastic and metal versions of the WHO periodontal probe to see if this problem is overcome with a stiffer type of probe material. Another concern with the WHO periodontal probe is the dimension of the hemispheric ball tip having a 0.5 mm diameter. Clinical use of this instrument requires use of extensive overlapping vertical and oblique strokes along subgingival tooth roots to cover the entire surface area available to deposition of dental calculus. In comparison, the ODU 11/12 explorer’s ability to be adapted to the contour of the tooth root, across a markedly larger expanse than is possible at a single point by the WHO periodontal probe, enables clinicians to more rapidly evaluate a larger part of the subgingival root surface area for dental calculus. Both dental calculus detection instruments require considerable clinical training and experience to produce recognition of dental calculus-positive tooth root surfaces. Development of more automated instrumentation for subgingival dental calculus detection is urgently needed. One promising approach is use of a low-power indium gallium arsenide phosphide diode laser (DIAGNOdent, KaVo Dental Corp., Charlotte, NC) fitted with a periodontal probe-like sapphire tip and emitting visible red light at 655 nm wavelength. Recent studies have reported excellent intra- and inter-examiner reproducibility with DIAGNOdent laser autofluorescence intensity measurements, with dental calculus-positive root surfaces exhibiting significantly greater DIAGNOdent laser autofluorescence than calculus-free tooth roots, even with the laser probe tip directed parallel to root surfaces (Rams & Alwaqyan 2017).

CHAPTER 5

CONCLUSIONS

The diagnostic performance of the WHO periodontal probe was inferior in all evaluated aspects to an ODU 11/12 dental explorer for in vitro identification of subgingival dental calculus.

The WHO periodontal probe exhibited only fair to poor intra- and inter-examiner reproducibility between the two periodontist examiners, which was lower than that found with an ODU 11/12 explorer. For both periodontist examiners, the WHO probe also yielded lower sensitivity, lower specificity, lower positive predictive value, lower negative predictive value, and lower overall accuracy (diagnostic effectiveness) than an ODU 11/12 explorer for detection of subgingival calculus on mandibular posterior tooth surfaces.

These findings suggest that epidemiologic periodontal surveys employing the WHO periodontal probe likely underestimate the true occurrence of subgingival dental calculus on examined teeth. Based on these in vitro findings, the reliability of the WHO periodontal probe in dental practice for the detection of subgingival dental calculus is likely to be in doubt and questionable.

Additional in vivo clinical evaluations of the accuracy of the WHO periodontal probe for detection of subgingival dental calculus are urgently needed and recommended.

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