Comparative In Vitro Evaluation of WHO Periodontal Probe and #11/12 Dental Explorer for Subgingival Calculus Detection

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ABSTRACT

Aim: The World Health Organization (WHO) periodontal probe is recommended for epidemiologic surveys and periodontal screening, but its ability to identify subgingival dental calculus (DC) relative to a #11/12 explorer is not known. This study compared in vitro the ability of the WHO probe and a #11/12 explorer to detect subgingival DC.

Materials and methods: Three typodont models with randomly distributed artificial DC on mandibular molar and premolar root surfaces were assessed with a WHO periodontal probe and a #11/12 explorer by two periodontists. The diagnostic performance of the two instruments for subgingival DC detection was compared using 2 × 2 contingency table analysis.

Results: A #11/12 explorer provided better reproducibility, a higher level of sensitivity, higher positive predictive values, higher negative predictive values, and greater overall accuracy (diagnostic effectiveness) (76.9% vs. 68.5% for the first periodontist; 87.0% vs. 75.0% for the second periodontist) for detection of subgingival DC than the WHO probe.

Conclusion: The in vitro diagnostic performance of a #11/12 explorer was superior to the WHO periodontal probe for identification of subgingival DC.

Clinical significance: A #11/12 explorer, rather than the WHO probe, is recommended for identification of subgingival DC.

Keywords: Dental calculus, Diagnosis, In vitro, ODU 11/12 explorer, WHO probe.

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INTRODUCTION

Dental calculus (DC) on tooth root surfaces is considered a contributing factor in the development and progression of periodontal diseases, and sufficient removal of subgingival DC is an important therapeutic objective in the clinical management of periodontal patients.¹ As a result, dental professionals need reliable methods to detect DC in periodontal pockets.²

At present, a #11/12 explorer³,⁴ is regarded as the “gold standard” instrument for the detection of subgingival DC, and is employed in clinical qualifying examinations administered by all the US regional dental licensure examining boards.⁵ In addition to assessing tooth surfaces for DC, the pointed tip of the explorer may also be used for clinical diagnosis of dental caries, and its curved terminal end employed to check dental restorations for overhanging margins, assess the furcation entrance openings on molar teeth, and identify unstained dental plaque on supragingival tooth surfaces.⁶

An alternative instrument is the World Health Organization (WHO) periodontal probe,⁶ which has been extensively utilized in periodontal epidemiologic surveys around the world,⁷ and is recommended for clinical practice in the Periodontal Screening and Recording index system developed by the American Academy of Periodontology and the American Dental Association,⁸ and the Basic Periodontal Examination method of the British Society of Periodontology.⁹ In addition to colored band and ring markings to estimate probing depths and clinical attachment loss, the WHO probe has a hemispheric-shaped ball tip, measuring 0.5 mm in diameter for tactile detection of DC and overhanging margins of dental restorations.⁵ Clerrehugh et al.¹⁰ reported an 80% in vivo overall accuracy of the WHO periodontal probe for subgingival DC detection, but it is not known whether this degree of reliability is comparable to a #11/12 explorer. As a result, the aim of this study was to determine and compare the in vitro performance of the WHO probe and a #11/12 explorer with regard to their ability to accurately detect subgingival DC.

MATERIALS AND METHODS

This study was carried out at the Temple University School of Dentistry, Philadelphia, Pennsylvania, USA, and used a typodont model system for in vitro subgingival DC detection.³ Three typodonts with white plastic teeth emerging from pink silicone gingival soft tissues were obtained from a manufacturer (Kilogire International, Inc., Coldwater, Michigan, USA) (Fig. 1). Mandibular premolars and molars were evaluated on the typodonts, providing 108 root surfaces on 27 teeth (a total of 12 mandibular premolars, 6 mandibular molars, 6 maxillary premolars, and 6 maxillary molars) for evaluation of artificial DC. Fig. 1

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Subgingival Calculus Detection

Fig. 1: Typodont model of human dentition with artificial dental calculus randomly distributed on selected tooth root surfaces.

Fig. 2: Subgingival calculus evaluation performed on a typodont model within a phantom head attached to a dental operatory chair.

Fig. 3: The WHO periodontal probe (left), with an enlarged view, its hemispheric-shaped ball tip and colored band (right).

Fig. 4: Curved tip of ODU 11/12 dental explorer.

and 15 mandibular molars, with 4 mandibular premolars and 5 mandibular molars per typodont). Artificial subgingival DC in ledges and rings was randomly distributed beyond visual detection on 57 (52.8%) subgingival root surfaces. Mandibular posterior teeth were employed to standardize physical and visual access and present more difficulty to examiners than anterior teeth. The typodonts were mounted to a rubber manikin head to mimic a human head and neck, and attached onto a dental chair to simulate clinical patient conditions (Fig. 2). An artificial saliva solution (Aquoral spray, Bi-Coastal Pharmaceutical Corp., Red Bank, New Jersey, USA) was sprayed onto the typodont teeth immediately prior to the in vitro evaluations to further mimic normal human oral cavity conditions.

Subgingival DC on the typodont teeth was scored with a thermoplastic WHO periodontal probe (type C, DenMat, Lompoc, California, USA) (Fig. 3) and a stainless steel #11/12 explorer (Hu-Friedy Manufacturing Company, Chicago, Illinois, USA) (Fig. 4) initially in
duplicate by a newly trained periodontist. The duplicate assessments were performed only after all three typodont models were initially scored, with approximately 60 minutes separating first and second assessments of each typodont. Then, the typodont tooth surfaces were scored once with both instruments by the second periodontist with 31 years of clinical practice experience. The two periodontists were masked from the true distribution of subgingival DC until after completion of all evaluations. Subgingival DC was detected by holding each of the instruments parallel to the long axis of the typodont teeth. The WHO probe ball tip was then advanced apically in contact with the teeth, and moved repeatedly along the root surface areas with a light touch. With the #11/12 explorer, its curved tip was adapted to the contour of root surfaces, and moved in vertical/oblique strokes in an apical–coronal direction. DC was tactically identified by the periodontists as a bump or irregularity on the subgingival root surfaces, as previously described.²

Data analysis used 2 × 2 contingency table analysis to compare the two instruments for their sensitivity (true-positive rate), specificity (true-negative rate), positive predictive value, negative predictive value, and accuracy (diagnostic effectiveness; the percentage of subgingival surfaces accurately identified as DC positive or DC negative) in detection of subgingival DC.¹¹ Kappa values¹² were calculated to assess the reproducibility of duplicate assessments made by the first periodontist with the WHO probe and the #11/12 explorer, and to evaluate the level of agreement in subgingival DC detection by the first and second periodontists. Kappa values <0.40 were considered to reflect poor agreement in subgingival DC detection, 0.40 to 0.75 as fair to good agreement, and >0.75 indicative of excellent agreement.¹³ Data analysis was performed using the Stata/SE 14.2 for Windows (StataCorp PL, College Station, Texas, USA) 64-bit statistical software package.

**Results**

The #11/12 explorer exhibited good intraexaminer reproducibility (kappa = 0.61), but fair interexaminer reproducibility (kappa = 0.43), for subgingival DC detection between the two periodontists, which was better than the fair to poor intraexaminer reproducibility (kappa = 0.40) and interexaminer reproducibility (kappa = 0.37) found with the WHO probe (Table 1).

For both periodontists, the #11/12 explorer yielded a higher level of sensitivity (96.7% versus 86.0% for the first periodontist; 84.2% versus 63.2% for the second periodontist), similar specificity (51.1% versus 49.0% for the first periodontist; 90.2% versus 88.2% for the second periodontist), higher positive predictive values (72.0% versus 65.3% for the first periodontist; 90.6% versus 85.7% for the second periodontist), higher negative predictive values (92.3% versus 75.8% for the first periodontist; 83.6% versus 68.2% for the second periodontist), and greater overall accuracy (diagnostic effectiveness) (76.9% versus 68.5% for the first periodontist; 87.0% versus 75.0% for the second periodontist) than the WHO probe for subgingival DC detection (Table 2).

**Discussion**

These in vitro study findings provide additional support for the use of a #11/12 explorer for identification of subgingival DC, and question the reliability and clinical usefulness of the WHO periodontal probe for this purpose. Intraexaminer and interexaminer reproducibility of the WHO probe for subgingival DC detection, which has not been previously studied, was found to be lower than the reproducibility of a #11/12 explorer. For both periodontists who served as study examiners, a #11/12 explorer also yielded a higher level of sensitivity, similar specificity, higher positive predictive values, higher negative predictive values, and greater overall accuracy (diagnostic effectiveness) than the WHO probe for the detection of subgingival DC.

The WHO probe performed in vitro on typodont teeth remarkably similar to in vivo evaluations previously reported on human teeth.¹⁰ A lower level of sensitivity (63.2% versus 75.0%), similar specificity (88.2% versus 85.7%), identical positive predictive value (85.7% versus 85.7%), lower negative predictive value (68.2% versus 75.0%), and lower overall accuracy (75.0% versus 80.0%), were found for subgingival DC detection by the WHO probe on typodont teeth by the second periodontist examiner, as compared to the instrument’s performance in vivo on human teeth as calculated from data reported by Clerhugh et al.¹⁰ In a prior study. Thus, in vitro scoring of subgingival DC with the WHO probe on typodont teeth may approximate clinical findings with the instrument on

**Table 1: In vitro reproducibility of WHO probe and #11/12 explorer for detection of subgingival DC**

| Reproducibility | Outcome of duplicate examination | Kappa |
|-----------------|----------------------------------|-------|
| WHO probe       |                                  |       |
| Intraexaminer   | +/−                               | 63*   |
| Interexaminer   | −/−                               | 40    |
| #11/12 explorer |                                   |       |
| Intraexaminer   | −/+                               | 73    |
| Interexaminer   | −/−                               | 54    |

*Number of mandibular posterior subgingival tooth surfaces; +/− subgingival DC detected at both examinations, −/+ subgingival DC detected at first examination only, −− subgingival DC detected at second examination only, −− subgingival DC not detected at both examinations

**Table 2: In vitro diagnostic performance of WHO probe and #11/12 explorer for detection of subgingival DC**

| WHO probe                  | Sensitivity | Specificity | Positive predictive value | Negative predictive value | Accuracy |
|----------------------------|-------------|-------------|---------------------------|---------------------------|----------|
| Examiner #1                | 86.0        | 49.0        | 65.3                      | 75.8                      | 68.5     |
| Examiner #2                | 63.2        | 88.2        | 85.7                      | 68.2                      | 75.0     |
| #11/12 explorer            |             |             |                           |                           |          |
| Examiner #1                | 96.7        | 51.1        | 72.0                      | 92.3                      | 76.9     |
| Examiner #2                | 84.2        | 90.2        | 90.6                      | 83.6                      | 87.0     |

*Number of mandibular posterior subgingival tooth surfaces; TP, true-positive diagnostic detection of subgingival DC; FP, false-positive diagnostic detection of subgingival DC, FN, false-negative diagnostic detection of subgingival DC, TN true-negative diagnostic detection of subgingival DC
human teeth, strengthening the validity of comparisons made in the present study.

Overall, the in vitro diagnostic performance of the WHO probe in the present study was inferior in all evaluated aspects to a #11/12 explorer for the detection of subgingival DC. The WHO probe also appears potentially inferior to a differential reflectometry device for subgingival DC detection, in comparison of findings from a previous study using the same in vitro methodology on typodont teeth. The WHO probe exhibited a lower overall accuracy, ranging from 68.5 to 75.0% between the two periodontists in the present study, as compared to an 80.6% overall accuracy previously reported for a differential reflectometry device.

Two reasons may account for the failure of the WHO probe to provide better subgingival DC detection. First, the thermoplastic WHO probe was noted by both periodontists to be relatively pliable and flexible during exploration of root surfaces, which seemed to diminish tactile discrimination and allowed the instrument tip to skip over raised subgingival DC deposits without inducing a discernable "bump." Second, due to the relatively small dimension (0.5 mm in diameter) of the WHO probe’s hemispheric ball tip, extensive overlapping of instrument strokes was needed to adequately examine the subgingival tooth surfaces. In contrast, the #11/12 explorer, with its curved tip adapted across a larger root surface area than is possible with the smaller-sized WHO probe tip, enabled the periodontist examiners to more rapidly evaluate the subgingival tooth surfaces. Epidemiologic periodontal surveys and periodontal screening employing the WHO probe may thus underestimate the true occurrence of subgingival DC, as a result of its relatively poor level of sensitivity as compared to a #11/12 explorer.

Several limitations in the present study need to be appreciated. Artificial DC on plastic teeth was used for the in vitro study instead of a naturally developing DC on human teeth. The ability of the two instruments to detect subgingival DC deposits of varying size and volume was not determined. Only periodontists, and not a wider range of general dentists and dental hygienists, served as examiners. The WHO probe and the #11/12 explorer require considerable training and experience in order to attain reliable detection of subgingival DC in clinical practice settings. Other types of periodontal probes (i.e., CP-8 probe) and dental explorers (i.e., G-2, 3CH cowhorn) have been found to provide a relatively poor identification of subgingival DC. Similarly, radiographs exhibit low sensitivity values for the detection of subgingival DC, resulting in exceedingly high false-negative findings. Thin diameter ultrasonic scaler tips (Thinsert®, Dentsply Sirona, York, PA, USA) have been utilized to detect DC, yielding sensitivity and specificity levels of 75% and 97%, respectively, but require development of new tactile sensitivity skills by clinicians to be effective.

To overcome tactile sensitivity issues, more automated forms of subgingival DC detection may be helpful. One approach employs a low-power diode laser fitted with a probe-like sapphire tip that emits visible red light at a 655 nm wavelength (DIAGNoDent Pen, KaVo Dental Corp., Charlotte, North Carolina, USA). Recent in vitro studies have reported excellent intra- and inter-examiner reproducibility with the instrument for the detection of subgingival DC with DC-positive root surfaces, exhibiting significantly greater autofluorescence from the laser light than DC-free tooth roots. A recent clinical study with the laser reported an 82% probability of correctly detecting subgingival DC. Another study outfitted a piezoelectric ultrasonic scaler with an automated "smart" tip to detect subgingival DC through feedback from the frequency of tip oscillations (Perioscan, Sirona Dental Systems GmbH, Bensheim, Germany), with a reported sensitivity for DC of 91%, specificity of 82%, positive predictive value of 59%, and negative predictive value of 97%.

Importantly, direct visual examination of subgingival root surfaces, particularly with high-power magnification, remains the optimal method for identifying DC on root surfaces. This is most often accomplished with periodontal access flap surgery, which improves DC removal beyond that attained via tactile explorer–assisted nonsurgical periodontal therapy. Visual inspection of root surfaces may also be attained with fiber optic endoscopy devices introduced into the periodontal pockets, which reveal significantly more subgingival DC than dental explorer assessments. Dental endoscopes improve removal of DC and enhance periodontal healing when they are used to guide delivery of nonsurgical periodontal therapy on deep periodontal pockets. However, dental endoscopic instruments are expensive and require considerable training and experience for proficiency in DC detection.

Further research is needed to develop and validate DC detection methods that are accurate, minimally invasive, inexpensive, and clinically easy to use.

Conclusion

The in vitro diagnostic performance of a #11/12 explorer was superior in all evaluated aspects to the WHO periodontal probe for subgingival DC detection.

Clinical Significance

Based on the superior in vitro findings with typodont models, a #11/12 explorer, rather than the WHO probe, is recommended for clinical practice detection of subgingival DC.

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