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Evaluation of characteristics of periodontal probes

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Aim: This study aimed to evaluate the millimeter distances and active tip diameters of different periodontal probes. **Methods:** Two types of periodontal probes were analyzed (North Carolina (15-UNC) and PCP-12). Two manufacturers were selected for each probe type. Digital images of the probes were obtained and the distances were measured using a software program. The diameter of the active tip was measured using a digital caliper. Both variables were measured by two trained and calibrated examiners. The data were analyzed using the Bland-Altman method and two-way ANOVA with Tukey's post-hoc test. Statistical significance was set at $p<0.05$. **Results:** A comparison of measurements between the 15-UNC and PCP-12 probes showed a significant difference in all millimeter markings. The 15-UNC probe showed differences between the 3 and 12 mm markings. The PCP-12 probe only showed differences between the marks at the 12 mm mark. The 15-UNC probe had a similar active tip diameter between the two manufacturers. The PCP-12 probe showed a significant difference between the two manufacturers. Both types of probes had similar active tip diameters when compared by the two manufacturers. **Conclusion:** There was no standardization in relation to millimeter marks and tip diameters of the two types of periodontal probes produced by the two different manufacturers. The probe types exhibited little variability.

Keywords: Periodontal index. Periodontal diseases. Periodontics.

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Introduction

Oral diseases are a global public health problem and periodontal disorders are among the most prevalent oral diseases worldwide[1,2]. Gingival and periodontal examinations are performed using periodontal probes[3]. A recent classification system proposed a new framework for periodontitis based on a multidimensional staging and grading system[4,5]. The various stages depend on the severity of the disease at presentation, as well as the complexity of disease management. Stages 1-4 were determined after considering several variables, including probing depth, clinical attachment loss, bone loss (amount and percentage), furcation, tooth mobility, and tooth loss due to periodontitis[4,5]. Grading (grade A: low risk; grade B: moderate risk; and grade C: high risk) provides information about the biological features of the disease, including the rate of progression, assessment of the risk of further progression, poor outcomes of treatment, and assessment of the risk of the disease or its treatment, which may negatively affect the patient's general health[4,5]. All these parameters are determined using the millimeter periodontal probe.

The current gold standard method for evaluating periodontal disease involves performing a full-mouth clinical examination, where six specific sites around each tooth (mesiobuccal, buccal, distobuccal, mesiolingual, lingual, and distolingual positions) are probed and measured to determine the depth and clinical attachment loss[3-7]. This comprehensive approach is commonly used in clinical research and in periodontal practice[6,7]. However, these examinations are susceptible to flaws or variability in obtaining periodontal parameter data due to several factors. These factors may be related to the person performing the examination, such as calibration, probing force, site, and insertion position of the probe. They may also be related to anatomical characteristics, such as crown and root shape, as well as tissue characteristics, due to increased softness or hardness[8]. Furthermore, periodontal probes have variability in millimeter distances and active tip diameters ranging from 0.28 to 0.70 mm[4,8]. Therefore, minimizing these variables can increase the accuracy and safety of examinations, which are not only performed by specialists, but also by students, hygiene technicians, and general practitioners.

There are several types of millimeter periodontal probes: conventional or manual (first-generation), controlled pressure (second-generation), and computerized periodontal probes (third-generation)[9,10]. The fourth and fifth generations of probes are 3D in character. Fourth-generation probes sequentially memorize the different probe positions along the gingival sulcus and record variations in depth along the sulcus using ultrasonographic techniques[11,12]. Fifth-generation probes provide three-dimensional assessment by periodontal pocket X-ray-based imaging using radio-opaque contrast agents, with no manual examination[11,12].

Despite these technological advances, manual periodontal probes remain the most widely used clinical method for academics, clinical practitioners, and researchers in clinical and epidemiological studies because they are low-cost instruments that are easy to handle[13-16]. Furthermore, periodontal procedures are often performed by public health services[17]. This procedure requires trained professionals and low-cost equipment, with the highest possible level of standardization, to allow for early diagnosis and performance of periodontal procedures[13,16]. Considering the wide use of manual periodontal probes, their cost-effectiveness, and the need for training and standardization to enable the proper diagnosis of periodontal diseases, we emphasize the importance of conducting further studies on the standardization of instrumental measurements. The dental industry is constantly reformulating its production processes, and better quality control of periodontal instruments can contribute to a more accurate periodontal diagnosis, which will lead to appropriate treatment plans and the possibility of comparing results after non-surgical periodontal therapy and follow-up in periodontal maintenance therapy[13,16]. Therefore, our study evaluated the millimeter distances and active tip diameters of periodontal probes.

Materials and Methods

We previously conducted a pilot study with a sample size of 10 using both the North Carolina (15-UNC) and PCP-12 types of probes. The effect size was 0.40, with an alpha level of 0.05, and a 95% confidence interval; the minimum sample size per group was 22 units. Considering the marking at 3 mm, the millimeter distances (mean ± standard deviation) were 3.21±0.05 (15-UNC) and 3.26±0.26 (PCP-12).

The types of periodontal and millimeter-marked probes analyzed are shown in Figure 1. The probes were as follows: 15-UNC (millimeter markings at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 mm with colored bands between 4 and 5 mm, 9 and 10 mm, and 14 and 15 mm) and PCP-12 (marked in black bands; each band was 3 mm in length; the millimeter markings were at 3, 6, 9, and 12 mm). The probes were purchased from two commercial brands (Millennium®, São Caetano do Sul, São Paulo, Brazil; Hu-Friedy®, Chicago, Illinois, USA). The final sample size comprised 25 periodontal probes (new, unused, and not sterilized) for each type and brand (15-UNC: Millennium®, n=25; Hu-Friedy®, n=25. PCP-12: Millennium® n=25; Hu-Friedy® n=25), which were purchased from different retailers and not from the same batch.

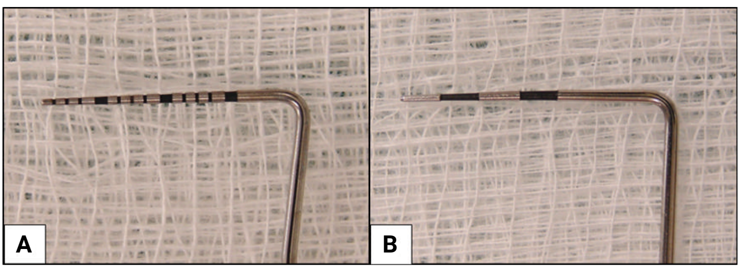

Figure 1. Types of periodontal probes evaluated. (A). 15-UNC North Carolina (millimeter markings at 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 mm with colored bands between 4 and 5 mm, 9 and 10 mm, and 14 and 15 mm). (B). PCP-12 (marked in black bands; each band is 3 mm in length; millimeter markings are at 3, 6, 9, and 12 mm).

The periodontal probes were photographed using a T5i digital camera (Canon®, Tokyo, Japan), which was adapted to a copy stand to standardize of the camera lens distance of the instrument as well as the manual mode configurations (ISO 100, f 8.0 aperture, and 1/100 speed, with a flash). We kept the handle and the active probe tips parallel and standardized the position of the images using a silicone guide.

An endodontic ruler (Kerr®, Orange, CA, USA) was used to calibrate the distance in millimeters using the Pro Plus 4.5® image measurement program (Media Cybernetics®, Silver Spring, MD, USA). Calibration was performed consistently using the first millimeter of the ruler. The same ruler and calibration process were applied to all the photos.

Examiners

The examiners were trained and calibrated using 21 measurements of millimetric distance marks and 15 measurements of instrument diameter. Images were randomly selected between the two types of probes and the two commercial brands of probes. The measurements were carried out in duplicate with a 48-hour interval. After the Bland-Altman method presented results above 90% agreement, the operators started the study measurements.

Measurements of the millimetric mark distances and the active tip diameter

The evaluators measured millimetric mark for each probe type. Measurements were performed in duplicate, and the mean was recorded. To compare both instruments, we considered measurements up to 12 mm.

All distances were measure using specific software (Image ProPlus 4.5®, Media Cybernetics, Silver Spring, MD, USA) after appropriate calibration, considering the length of a 1 mm distance of the millimetric-marked endodontic ruler image.

The ends of the active tips were measured in duplicate by a single examiner using a digital caliper (Mitutoyo Sul Americana Ltda, São Paulo, SP, Brazil). Immediately before each measurement, the reading was 0 mm. The active tip was positioned so that its end coincided with the caliper end and was kept perpendicular to the caliper during the reading.

To minimize bias related to tiredness and fatigue, each examiner took a 15-minute break after 45 min of continuous reading.

Statistical analysis

We verified the reproducibility of intra- and inter-examiner data using the Bland-Altman method combined with a one-sample t-test (assessing the difference of the hypothetical value zero, indicating perfect repeatability). Data normality was checked using the Shapiro-Wilk test and quantile-quantile (Q-Q) plot. The differences between the means of the mark distances at 3, 6, 9, and 12 mm, as well as the active tip diameter, were evaluated using two-way ANOVA (factors: periodontal probe and brand) and Tukey's post-hoc test for multiple comparisons. The level of significance was set at 5% (α=0.05). All calculations were performed using GraphPad Prism® 6.01 (GraphPad Software, San Diego, CA, USA) statistical software.

Results

The Bland-Altman method showed the agreement between examiners. All measurements of the periodontal probes were within the upper and lower limits of agreement. The difference between the mean of the millimeter marking and periodontal probe diameter measurements was very close to zero ($p=0.837$ and $p=0.763$, respectively; one-sample t-test). Thus, the suitability of the measurements for both the millimeter-distance measurements and the active tip diameter was confirmed.

The Millennium® 15-UNC instrument has both flat and rounded tips. The active tip shapes and millimetric distance printing method on the metallic surface and the active tip end shape were varied. The Millennium® instrument prints its marks using colors; some were well-defined, while others were not so noticeable. However, the metallic surface remained intact. This feature differs from that of the Hu-Friedy® instrument, which engraves the marks on the metal, creating a different color and a slight depression on the surface, thereby making it visually rougher in those regions.

The types of periodontal probes showed significant differences ($p<0.0001$) in all millimeter markings. Differences were observed in the 3 mm and 12 mm markings ($p<0.0001$) between the two brands. The interaction of the factors (periodontal probe and brand) was significant for the 3 mm ($p<0.0001$), 6 mm ($p=0.0146$), and 12 mm ($p=0.0227$) markings. The 15-UNC probe showed differences between the two brands at 3 mm and 12 mm markings. The PCP-12 probe only showed differences between the marks at the 12 mm mark (Figure 2). The 15-UNC probe showed a coefficient of variation of 1.96% (Millennium®), 1.23% (Hu-Friedy®), while for the PCP-12 probe it was 2.58% (Millennium®), and 1.25% (Hu-Friedy®).

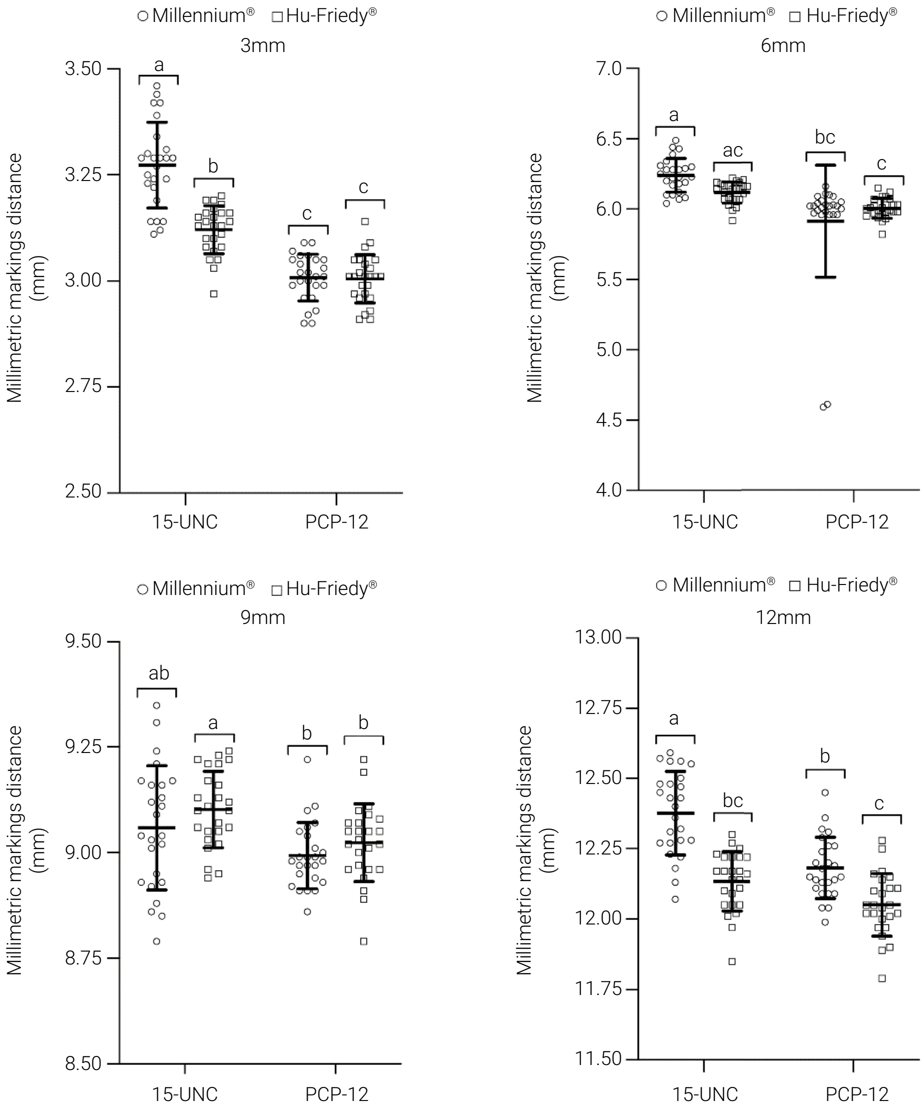

Figure 2. Scatter dot plots of periodontal probe millimetric marking comparisons at 3, 6, 9, and 12 mm. The periodontal probe type showed significant differences ($p<0.0001$) at all millimeter markings. Regarding brands, differences were observed for the 3 mm and 12 mm markings ($p<0.0001$). The interaction of the factors (periodontal probe and brand) was significant for the 3 mm ($p<0.0001$), 6 mm ($p=0.0146$), and 12 mm ($p=0.0227$) markings. Lines represent the mean and standard deviation, and dots correspond to each periodontal probe. Different letters represent significant differences ($p<0.05$, two-way ANOVA and Tukey's post-hoc test). The y-axis does not start at zero.

Active tip diameter analysis showed a significant difference between the brands ($p<0.0001$). The different types of periodontal probes showed similar active tip diameters ($p=0.3319$) when compared between the two brands. The interaction between these factors was significant ($p=0.0383$). The 15-UNC probe had a similar active tip diameter when compared between the two brands. The PCP-12 probe exhibited a significant difference between the two brands ($p<0.01$). The probe types had similar active tip diameters when the two brands were compared (Figure 3).

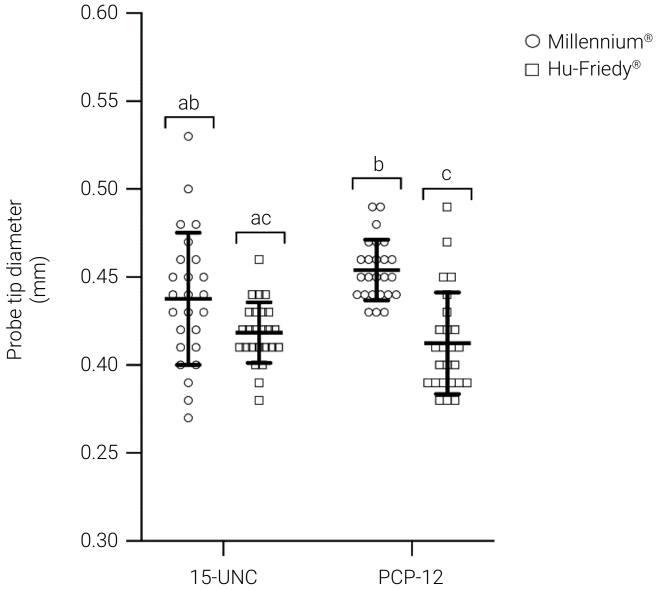

Figure 3. Scatter dot plots of measurements of periodontal active tip diameter. The analysis showed a significant difference between brands ($p<0.0001$). Different brands of probe types showed similar active tip diameters ($p=0.3319$). The interaction between these factors was significant ($p=0.0383$). Lines represent mean and standard deviation; dots correspond to each periodontal probe. Different letters represent a significant difference ($p<0.05$, two-way ANOVA and Tukey's post-hoc test). The y-axis does not start at zero.

Discussion

Our results showed that the markings of periodontal probes of different brands and types varied by tenths of a millimeter. Regarding this inaccuracy, it seems relevant to emphasize that the research was carried out using images enlarged by specific software and that the human eye observing standard dimensions might not detect such differences. It should also be noted that a statistical difference often does not denote clinical significance[13]. When this variation was over 0.5 mm, it could generate an inaccurate periodontal diagnosis considering the parameters of probing depth, gingival recession, and clinical attachment loss[18,19]. During clinical periodontal examinations, a false-positive diagnosis may occur because of the tendency to round up the probing depth measurement (3.5 mm, rounded to 4 mm)[4,20].

The tip diameters of the periodontal probes were similar for the different types of probes from the same manufacturer. The 15-UNC probe had an equal tip diameter when the two brands were compared; however, the PCP-12 type differed between the two evaluated brands. Therefore, in pre- post- treatment examinations or when comparing examiners, we would recommend using the same brand of probe to avoid bias. The diameter of the periodontal probe active tips influences the probing depth[19]. In contrast, the pressure during periodontal probing is directly proportional to the application of the probing force, and indirectly proportional to the probe tip area[18,19,21]. The minimum value is 0.37 mm, and the maximum is 0.53 mm. For tissue measurement, a of force 0.20 N (20 g) with a probe tip diameter of 0.6 mm is recommended when placing the probe tip at the coronal end of the junctional epithelium. Using thin probes (0.45 mm) might result in excessive probing[18,19,22]. In clinical practice, standardization of the probing force is difficult to achieve. The periodontal probe manufacturing process should control the diameter of the probe used to evaluate diagnostic and treatment results. It should be noted that the active tip ends have different shapes (round or flat). No studies have evaluated the effect of the tip shape on the clinical probing depth and the patient's perception of pain during periodontal examinations.

Millennium® instruments are widely used in periodontics and dentistry. Responsible manufacturers continuously develop their products by contacting professors and professionals in the area of dentistry, who are concerned about factors such as the design, innovation, and quality of dental products. Therefore, Millennium® periodontal probes are recognized as an excellent cost-benefit option by customers and opinion makers, and they are present in 95% of all dental schools in Brazil (https://golgran.com.br). In addition to being a Brazilian brand, they are on average 3.7 times cheaper for 15-UNC probes (US$ 12.57) and 2.5 times for PCP-12 (US$ 14.02) than the Hu-Friedy® equivalents (US$ 47.12 and US$ 34.78, respectively) (Price search: Available from: [https://www.dentalcremer.com.br], accessed on July 21, 2023; Conversion of the Brazilian real to the US dollars: Available from: [https://www.bcb.gov.br/conversao], accessed on July 21, 2023). Hu-Friedy® probes were analyzed in this study because they are a well-known brand that is used worldwide and is recognized as being accurate[20,22-24]. Therefore, the Hu-Friedy® probes have been widely used in clinical and epidemiological studies.

In our study, an important tool for ensuring data accuracy was the calibration of the software used (Image ProPlus®). The operators ensured the reliability of the results, and the intra- and inter-examiner agreement obtained using the Bland-Altman method[25] was over 90%. The use of image analyzer software and stereomicroscope results in greater reproducibility and accuracy. The reliability of the data is due to the quality of the images, and the analysis tools resulted in a standardized and static approach, which minimized the possibility of measurement errors between the calibrated operators, as well as making the sample analysis more flexible in the case of operator fatigue. The digital caliper[16,26,27] adopted for diameter measurements is a fast method for obtaining measurements. However, the operator should be thoroughly trained in terms of body positioning, as well as the positioning of the periodontal probe at the time of measurements. This positioning could result in a high level of measurement variability. Breaks should be taken at systematized times to minimize result bias due to fatigue. Consequently, the methods used to verify the millimeter markings and diameters of the active tips of the periodontal probes were accurate and sensitive.

Several types of periodontal probes are commercially available; however, only conventional first-generation probes were used in this study so as to be more clinically and economically relevant for students, professionals, and researchers[4,10,24]. The fact that we did not evaluate other types and brands of periodontal probes can be considered a limitation of our study because we might have obtained different results.

The Hu-Friedy® probes presented higher accuracy in all of the evaluated parameters, mainly in relation to the active tip diameter. However, Millennium® probes can produce results of similar quality. Nevertheless, carrying out periodontal exam diagnosis, periodontal re-evaluation, and monitoring of periodontal therapy of the same patient using periodontal probes of different types and brands is not advisable. Variations higher than 0.5 mm during periodontal probing can lead to a false-positive diagnosis. Previous studies that have investigated periodontal probes produced by Brazilian manufacturers, including other commercial brands, have concluded that they should be better standardized[4,18,26,28]. We suggest a need to improve the standardization of the manufacturing process with regard to the accuracy of millimetric distance marks, diameter, and shape of the active tip of the periodontal probes.

However, it is essential to emphasize that further studies are still required to determine whether this variability of tenths of millimeters and range of diameter influences periodontal diagnosis and whether pain is affected by the use of different periodontal probes.

Conclusion

There is no standardization regarding the millimeter marks and tip diameters of periodontal probes of different types and commercial brands. The probe types exhibited little variability. Clinical studies are required to evaluate the differences in tenths of millimeters and the diameter of the active tips in relation to the measurement of probing depth, sensitivity, and pain.

Conflict of interests

The authors have no conflicts of interest to declare.

Data availability

Datasets related to this article will be available upon request to the corresponding author.

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Authors contribution

Ana Cristina Kovalik: Concept/Design, Data collection, Data analysis/interpretation, Drafting article. **Alessandra Carla Sousa Girardi:** Data collection, Data analysis/interpretation. **Naiara Vendrami:** Data collection, Data analysis/interpretation. **Fábio André dos Santos:** Concept/Design, Critical revision of the article, Approval of article.

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