CHARACTERIZATION OF THE PERIODONTAL PROBE BEFORE AND AFTER STERILIZATION CYCLES AND WEAR TEST

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Palavras-chave: instrumentos odontológicos. doenças periodontais. bolsa periodontal. perda de inserção periodontal. índices periodontais.

RESUMO:
Objetivo: avaliar as características estruturais, desgaste e tensão de penetração de sondas periodontais antes e após ciclos de esterilização e simulação de desgaste. **Materiais e Métodos:** foram testadas nove sondas periodontais da Carolina do Norte de três marcas comerciais disponíveis no Brasil (Hu-Friedy, HF; Millenium, MI; e Quinelato, Qui). Após avaliação inicial, os instrumentos foram submetidos à esterilização em autoclave por 60 ciclos. A precisão e a nitidez das marcas milimétricas e o formato das pontas foram registradas antes do primeiro ciclo e após cada 20 ciclos, utilizando estereomicroscopia. A microscopia eletrônica de varredura foi empregada para avaliar a topografia. Os testes *in vitro* avaliaram a tensão de penetração da sonda. A microscopia eletrônica de varredura e o teste de tensão de penetração foram realizados antes do processo de esterilização. A análise estatística utilizou análise de variância e teste de Student-Newman-Keuls, com nível de significância de 5%. **Resultados:** os resultados indicaram diferentes formatos de ponta de sonda entre as marcas, categorizados como chama (MI), arredondada (HF) e vértice obtuso (QUI). A morfologia e o ângulo da ponta foram semelhantes entre HF e QUI, mas maiores que MI. A nitidez da marcação a laser variou entre os instrumentos, com as sondas QUI induzindo a maior tensão e força de penetração *in vitro*. A morfologia da superfície permaneceu inalterada após 60 ciclos de esterilização e testes mecânicos, embora todas as sondas apresentassem falhas de acabamento superficial. A HF exibiu as gravações milimétricas mais precisas entre as marcas testadas. **Conclusão:** as sondas testadas apresentaram alguns defeitos de acabamento, com seus formatos e tamanhos impactando a tensão de sondagem, e as sondas Hu-Friedy demonstraram precisão superior em marcações milimétricas em comparação com outras marcas testadas.

Keywords: dental instruments. periodontal diseases. periodontal pocket. periodontal attachment loss. periodontal indexes.

ABSTRACT:
Objective: the aim of this study was to evaluate the structural characterization, wear and penetration tension of periodontal probes before and after sterilization cycles and wear simulation. **Materials and Methods:** nine North Carolina periodontal probes from three commercial brands available in Brazil (Hu-Friedy, HF; Millenium, MI; and Quinelato, Qui) were tested. Following initial evaluation, the instruments underwent sterilization in an autoclave for 60 cycles. Precision and sharpness of the millimeter marks and the shape of the tips were recorded before and after every 20 cycles using stereomicroscopy. Scanning electron microscopy was employed to assess topography. *In vitro* testing evaluated probe penetration tension. Scanning electron microscopy and penetration tension were performed before sterilization process. Statistical analysis utilized analysis of variance and the Student-Newman-Keuls test at a 5% significance level. **Results**: the results indicated differing probe tip shapes among brands, categorized as flame (MI), rounded (HF), and obtuse vertex (QUI). Morphology and tip angle were similar between HF and QUI but greater than MI. Laser mark sharpness varied among instruments, with QUI probes inducing the highest stress and penetration force *in vitro*. Surface morphology remained unchanged after 60 sterilization cycles and mechanical testing, though all probes exhibited superficial finishing flaws. HF exhibited the most precise millimeter engravings among the brands tested. **Conclusion**: tested probes displayed some finishing defects, with their shapes and sizes impacting probing tension, and Hu-Friedy probes demonstrating superior accuracy in millimeter markings compared to other brands tested.

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INTRODUCTION

The clinical gold standard parameters for diagnosing periodontal disease are the measurement of periodontal probing depth and clinical attachment level.[1-4] These parameters, along with bleeding on probing, are employed to estimate the disease's severity at baseline, assess clinical response post-therapy, and longitudinally evaluate periodontal stability.[1-3,5-8] Thus, through periodontal probing, clinicians can record the endpoints of periodontal therapy.[9,10]

It is essential to determine the diameter of periodontal probing tips due to its influence on gingival tissue damage and resistance from healthy or inflamed tissue during diagnosis and evaluation of periodontal disease. The force applied to introduce the probe into tissues increases with the square of the probe diameter. A periodontal probe consists of three parts: the tine, the shank, and the handle. The tip, usually calibrated with markings in millimeters, is the working end of the tine, situated at an angle greater than 90° from the handle[2]. Several factors can affect the accuracy of periodontal probing, including probe design, the probe's position relative to the tooth during diagnosis, pocket depth, and tissue inflammation[8]. To ensure measurement accuracy and reproducibility, periodontal probes should exhibit minimal variation.[11-13]

The force applied by the operator is directly associated with the pressure on the probe tip. However, in probes with larger diameters, pressure increases, resulting in decreased probe penetration into tissues.[2,5] Furthermore, imprecisions in mark distances and probe tip thickness can affect probe insertion control during examination.[12]

The periodontal probe is crucial for periodontal diagnosis. Therefore, maintaining consistent quality in instrument production is of great interest to clinicians. This study thus investigated precision in mark distances and tip characteristics of periodontal probes from three different commercial brands before and after simulated wear, as well as their surface finishing and *in vitro* probing pressure.

MATERIAL AND METHODS

This is an in vitro study developed on the laboratory of material experiments at University of Grande Rio, Duque de Caxias, Brazil, and at the Instituto Militar de Engenharia, Rio de Janeiro, Brazil, from March to June of 2021.

The present study analyzed North Carolina periodontal probes from three commercial brands available in the Brazilian market: Hu-Friedy (HF; Hu-Friedy, Chicago, USA), Millenium (MI; Golgran, São Caetano do Sul, São Paulo, Brazil), and Quinelato (QUI; Quinelato, Rio Claro, São Paulo, Brazil). Nine probes from each manufacturer were analyzed according to the following identification: HF probes (lot #0119, 0219, and 0319), MI probes (lot #202-P, 204-P, and 221-P), and QUI probes (lot #19003, 19004, and 19005).

To simulate the use and wear of the periodontal probes during clinical use, 60 sterilization cycles were performed in an autoclave. Sterilization was conducted in a Vitale 12L autoclave with a capacity of 12 L (Cristófoli, Campo Mourão, Paraná, Brazil), for 55 minutes at 128 to 130°C and a pressure of 1.7 to 1.9 kGf/cm.[2] Measurements of the distance between marks were performed before the first sterilization and after every 20 cycles (Figure 1A). Images of all periodontal probes were obtained using a stereomicroscope (Opticam, São José dos Campos, SP, Brazil) attached to a digital camera, and the images were analyzed using software (TSView 7.2.1.7; Xintu Photonics, Fuzhou, China). The analysis evaluated the precision of the millimeter marks engraved on the instruments. The design of the North Carolina probe consists of marks in millimeters from 1 up to 15 mm, with marks at each 1 mm interval, except between 4 and 5 mm, 9 and 10 mm, and 14 and 15 mm. Tip conicity was calculated between marks at 1 and 4 mm, adopting diameters D4 and D1 for the calculation (Figure 1B). Then, the difference between the two diameters was divided by the distance between them. Additionally, a description of the shapes of the probe tips was obtained.

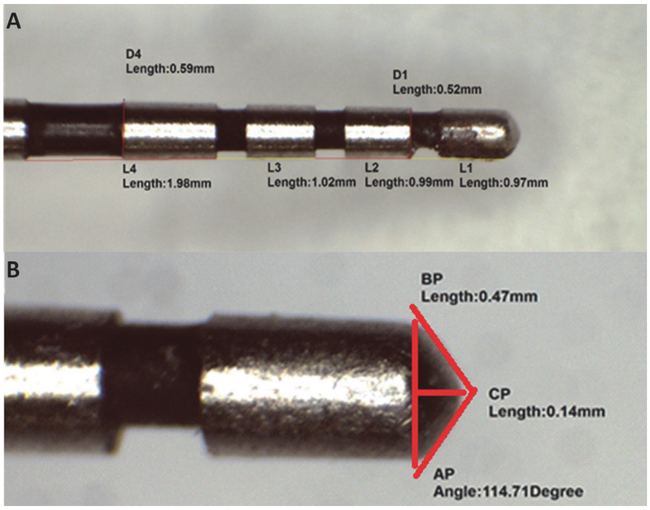

Figure 1: *Morphometric measurements. A) Measurements of the accuracy of the mm engravings; B) Calculation of the angles of the tip. L1, L2, and L3 represent the first three millimeters, each approximately 1 mm. L4 with approximately 2 mm, representing the 5 mm mark.*

To evaluate the topography and shape of the probes, the instruments were analyzed using a scanning electron microscope (Field Emission Gun FEI Quanta FEG 250, Hillsboro, Oregon, USA). Surface finishing was evaluated at a magnification of 800x, while the engraved marks were analyzed at a magnification of 5,500x. The qualitative analysis of the superficial finishing of the pobres was perfomed by a trained, masked examiner, who evaluated the presence of topographic defects.

In order to simulate the soft periodontal tissue *in vitro,* a new model proposed by the authors was used, silicon membrane was prepared using a condensation silicon (hydrophilic and catalyst; Zhermack, Polesine, Italy). A portion of light condensation silicon was placed in a glass plate coated with solid Vaseline, following the manufacturer's instructions. Approximately 5 cm of material was used for both the base and the catalyst. After mixing, another glass plate was placed on top of the first one, with a 5 kg weight on it to prevent displacement. Two glass slides, 1 mm thick for microscopy, were positioned laterally to the glass plates, creating an inner space for product flow, resulting in a homogeneous and regular pellicle. The membrane was tested using a universal testing machine (EMIC DL-200 MF, São José dos Pinhais, Paraná, Brazil) equipped with a customized setup. In summary, a load cell of 20 N was attached to the head of the EMIC, along with an apparatus specially designed to hold the periodontal probe. Figure 2a illustrates the probe positioned for mechanical testing, while Figure 2b shows the developed membrane positioned for testing. The test speed was set at 15 mm/ min. Deformation at rupture and maximum rupture force were recorded by the EMIC. Rupture force was calculated using an equation ó = F/A, where F represents the rupture force during the test, A (A = ð.r)^2 is the area of the probe tip, and r is the tip radius. A new membrane was utilized for each test.

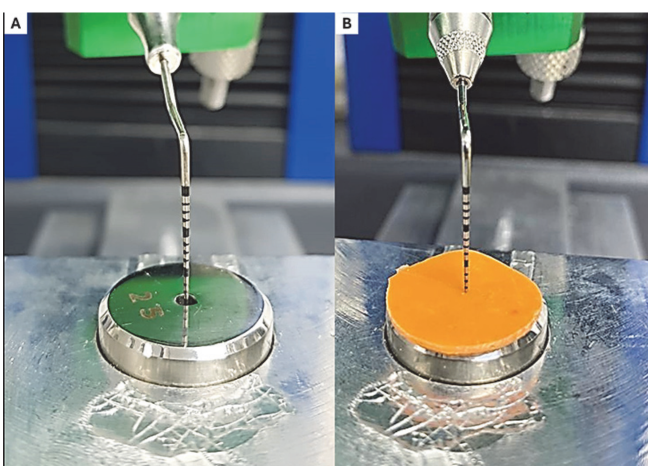

Figure 2*. Probing pressure assessment. The image illustrates the positioning of the probe: A) without the silicone membrane and; B) with the silicone membrane to simulate perforation.*

All groups underwent the Shapiro-Wilk normality test using the biostatistics software Primer (*MINITAB® Release 14.11.1*), employing a significance level of 5%. Normal distribution was observed in all groups. Sample size calculation was conducted using the software G*Power (*Version 3.1.9.4, Germany*). Out of the total of nine probes, three were selected for the test to estimate preliminary means, yielding values of 130, 150, and 200 MPa. The calculated effect size was 29.44, with a critical F-value of 9.55, resulting in a sample size of n = 6.

For the comparison of characteristics before and after sterilization, the first five measurements from the base of the HF probes tip were utilized to calculate the sample size. The means and deviations used for calculation were 0.47 ± 0.05 and 0.53 ± 0.03, respectively. The calculated effect size was 1.38, and the critical t-value was 1.89. The obtained sample size was n = 8. The statistical analysis of before and after was conducted using the paired t-test with a significance level of 5%.

Data were analyzed using a statistical package (*IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.).* Mean and standard deviation were calculated for the measures of the angles, base, and conicity of the probe tips. Differences among groups for morphometric measurements and probe tip pressure were tested using analysis of variance (*ANOVA*), followed by post-hoc analysis using the Student-Newman-Keuls (*SNK*) test. The significance level was set at 5%.

RESULTS

The measurement of the distance between marks showed that HF probes were more accurate. The 1 mm mark in MI was above 1 mm, which was significantly different from HF and QUI (p<0.05); for the 3 mm mark, QUI had higher measurement than 3 mm, which was significantly different from HF and MI (p<0.05); and for the 5 mm mark, all tested probes showed similar measurements (Table 1). Measurements conducted after repeated sterilization cycles in an autoclave showed that after 60 cycles, no significant alterations were detected in the visualization of the millimeter marks on all probes as presented in Table 2.

Baseline morphometric analysis (Table 1) indicated that the conicity of the probe tips was similar between HF and MI, both significantly higher than QUI (p<0.05; SNK test). HF and QUI exhibited similar tip angles, significantly higher than MI probes (p<0.05). HF probes had a significantly smaller base of the probe tip compared to the other two probes (p<0.05). The analysis revealed significant differences in the shape of the probes whithin each brand. The MI probes analyzed had a flame-like shape (Figure 3A). HF probes exhibited a rounded shape (Figure 3B), while QUI probes presented an obtuse vertices shape (Figure 3C). Laser marks for millimeters were made in the same plan as the body of the probe for MI (Figure 3D) and QUI (Figure 3F) probes. HF probes displayed a low relief for the millimeter marks (Figure 3E). The shape of the probe tip was not modified by sterilization cycles (Table 2).

Qualitative analysis of the superficial finishing outside the millimeter marks revealed that all brands exhibited defects, although a lower number of defects was found for HF probes (Figure 4B), followed by MI (Figure 4A). A similar pattern of surface topography was observed within the millimeter marks for the MI (Figure 5A), HF (Figure 5B), and QUI (Figure 5C) probes.

Figure 6 shows the tension (in MPa) during the introduction of the studied probe inserted into the membrane used to simulated soft tissue. The stress induced by QUI probes (196.1 ± 13.7 MPa) was the highest (p<0.05). The force required to introduce the MI (151.1 ± 13.52 MPa) and HF (159.3 ± 6.4

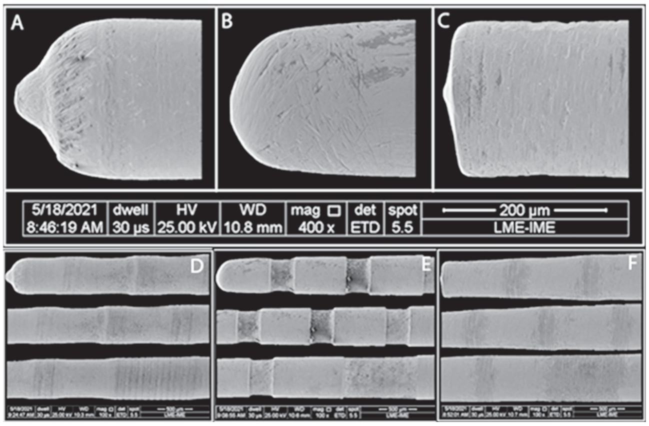

Figure 3: *Scanning electron microscopy showing details of the probe tips. A) Millenium (MI) probe, featuring a flame-shaped active tip; B) Hu-Friedy (HF) probe, exihibiting an active tip in a round shape; C) Quinelato (QUI) probe, presenting an active tip in the form of an obtuse apex. Examples of millimeter recordings on the MI; D) HF; E) and QUI F) probes.*

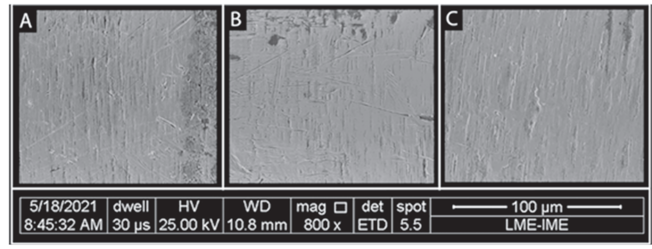

Figure 4: *Scanning electron microscopy of the surface finishing outside millimeter marks of the Millenium. A)Hu-Friedy B) and Quinelato C) probes.*

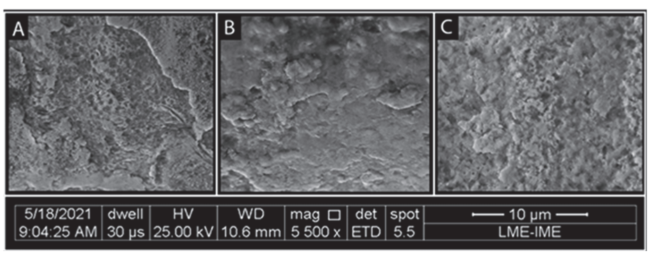

Figure 5: *Scanning electron microscopy showing the surface roughness within mm marks for Millenium. A) Hu-Friedy B) and Quinelato C) probes.*

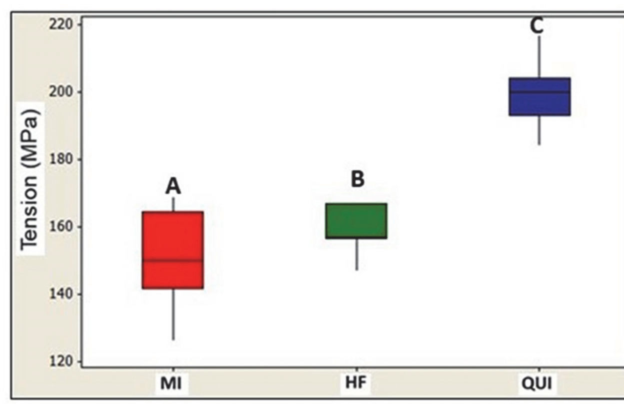

Figure 6: *Measurement of the tension of the probe tip (in MPa) for the tested probes. Different letters indicate significant differences between groups at p < 0.05, SNK test. MI: Millenium; HF: Hu-Friedy and QUI: Quinelato.*

Table 1: *Morphometric measurements of the tested periodontal probes at baseline.*

Measurements	Periodontal probes		
	MI	HF	QUI
Conicity of the probe tip	0.28 ± 0.01a*	0.29 ± 0.00a	0.01 ± 0.01b
Angle of the probe tip (degrees)	102.4 ± 5.84a	116.2 ± 7.92b	113.1 ± 12.16b
Base of the probe tip (mm)	0.50 ± 0.04a	0.45 ± 0.04b	0.55 ± 0.04c
1 mm marking (mm)	1.18 ± 0.12a	1.08 ± 0.08b	1.08 ± 0.08b
3 mm marking (mm)	3.14 ± 0.27a	3.08 ± 0.13a	3.25 ± 0.22b
5 mm marking (mm)	5.05 ± 0.12a	5.04 ± 0.09a	5.15 ± 0.06a

*Note: *Different letters in the same row indicate significant differences between groups at p<0.05, SNK test.*

Table 2: *Comparison between measurements done before and after wear simulation test.*

Measurement	Probe	Before	After	*p* value*
Tip angle	ML	102.4 ± 5.8	98.6 ± 8.1	0.172
	HF	116.2 ± 7.9	114.4 ± 6.3	0.526
	QUI	113.1 ± 12.1	115.1 ± 14.3	0.159
Tip base	ML	0.498 ± 0.044	0.512 ± 0.038	0.260
	HF	0.450 ± 0.042	0.460 ± 0.013	0.412
	QUI	0.550 ± 0.045	0.554 ± 0.050	0.753
1 mm	ML	1.182 ± 0.123	1.189 ± 0.102	0.739
	HF	1.079 ± 0.088	1.102 ± 0.091	0.062
	QUI	1.076 ± 0.045	1.101 ± 0.041	0.084
3 mm	ML	3.138 ± 0.273	3.169 ± 0.099	0.133
	HF	3.077 ± 0.132	3.096 ± 0.097	0.398
	QUI	3.246 ± 0.224	3.283 ± 0.073	0.083
5 mm	ML	5.049 ± 0.129	5.050 ± 0.103	0.525
	HF	5.042 ± 0.097	5.506 ± 0.102	0.564
	QUI	5.149 ± 0.064	5.186 ± 0.071	0.153

Note*: *Paired t-test.*

DISCUSSION

The findings of the current analysis revealed that HF probes exhibited superior features in terms of shape, design, finishing, and millimeter markings, affirming HF probes as the gold standard in periodontal probes. Interestingly, probes from a Brazilian brand, MI probes, shared many similar characteristics with HF probes. It is worth mentioning that dental professionals, particularly periodontists, rely on periodontal probes not only for initial periodontal diagnosis but also to detect any further attachment loss or increases in probing depth in patients undergoing periodontal maintenance. Therefore, it is imperative to ensure that manufacturers prioritize the quality control necessary to produce reliable instruments.

As periodontal diagnoses are based on millimeter thresholds, the precision of millimeter marks on the periodontal probe is a relevant factor to consider. The use of different brands of periodontal probes or even periodontal probes of the same brand can pose challenges to clinicians, especially in surveys involving more than one examiner[8]. The current study showed that all probes tested presented some distortion in the millimeter markings, which were less evident as they reached the 5 mm marking. Another study, which analyzed different periodontal probes, including Michigan “0” Ceramicolor, Williams, and WHO models, showed that all tested instruments presented errors in the markings, although the mean accuracy of all markings did not differ.[14] In the current investigation, the brand that had the highest accuracy in the markings of the millimeters was

HF, although a similar finding was found for the 1 mm marking with QUI, and for the 3 mm with MI probes. Additionally, scanning electron microscopy showed that all analyzed probes are manufactured through the machining process, and the millimeters are produced using lasers. The MI and QUI have their markings on the same plane as the probe body, while the HF has them in low relief. After 60 sterilization cycles, which was estimated to be approximately three months of clinical use, assuming the probe would be sterilized every weekday, no alterations in surface morphology, color intensity or the sharpness of the millimeters were observed. Clinically, the HF indentations may be relevant to make the measurement reading easier.

The design and the diameter of the probe tip impact probing penetration because thick probe tips can lead to lower probing depth recordings, while thin tips can penetrate more easily, especially in inflamed tissues.[8] It was previously demonstrated that the use of tapered probes without force control can result in a higher measurement of the clinical attachment level beyond its true position.[5] Another study analyzed probes with different types of tine, including tapered, parallel, and WHO (ball-ended tine) styles, and demonstrated that they had tip diameters of 0.5 mm.[12] In addition, that study showed that the shape of the tine impacts significantly on probing depth recording.[12] Consistent with our findings, Attassi *et al*.[11] also found a diameter slightly below 0.5 mm in their tested probes. In the current analysis, we included only tapered probes, which presented different tip ends, which were named, for similarity, as flame, rounded, and obtuse apex. The apex of the tip is an important factor in surface stress distribution. The tension exerted by the probe tip is directly proportional to the probing force and inversely proportional to the area of the base.[4] Garnick and Silverstein[4] also explained that a change in the base of the tip has a greater effect on the probing result than employing a higher force while probing. However, our findings showed that the force of probing was greater for the larger tip diameter (QUI probe), which might imply that not only the diameter must be taken into consideration but also the geometric shape of the tip. We found that MI and HF probes had similar conicity in their tips, while the QUI probe had tips with a cylindrical shape. Moreover, clinicians should be aware that probing force should be adjusted to the different shapes of probes existing in the market to accurately measure a given periodontal pocket.[15]

The surface finishing of the tested probes presented a series of defects, which can facilitate biofilm adhesion. Regarding all the surface defects found, we can consider a porous aspect inside the millimeter markings as the worst, and it was more evident in QUI probes. This kind of defect can be attributed to the melting of the material during laser engraving. In alignment with the current SCANNIG ELECTRON MICROSCOPY. images, a previous report has also demonstrated that metal probes present a rough surface when analyzed in SCANNIG ELECTRON MICROSCOPY.[16] Clinically, surface finish is important to avoid bacteria adhesion as it can work as a factor of transmission among periodontal sites.[13] The translocation of bacteria through the periodontal probe is even higher when considering probing depths of four or more mm.[16]

We tested a force of penetration in a fabricated membrane to simulate an *in vitro* periodontal tissue. The use of this synthetic material may be a methodology limitation. However, it allowed for standardization, such as the thickness of the material, which cannot be obtained in clinical samples. Clinically, other features can influence this kind of evaluation, including the degree of inflammation.[8] Moreover, tissue alteration after the use of the first probe could affect the use of the following probe, if three probes were to be tested in the same site.

CONCLUSION

Tested probes displayed some finishing defects, with their shapes and sizes impacting probing tension, and Hu-Friedy probes demonstrating superior accuracy in millimeter markings compared to other brands tested. After wear simulation, no brand demonstrated significant alterations in millimeter markings and tip shape.

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