# In Vitro Accuracy of the Single-Use Hunter TPS Periodontal Probe Considering Material Fatigue and Erroneous Assembly

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**Background:** The TPS Hunter periodontal probe design has disposable, pressure-sensitive probe heads and claims to meet established standards for a precise probing tool.
**Aims:** The aim of the present study was to evaluate the actual probing pressures. Furthermore, the influence of material fatigue as well as of erroneous mounting of the probe head on the probing force and pressure is investigated.
**Method:** Fifty TPS probe heads were analysed *in vitro* by loading the probe against a precision balance until two force indicator lines on the probe coincided. The resulting probing force was recorded at the time of the first loading and after 30 seconds of cyclic loadings. Dividing the probing force by the measured normal contact area of the probe tip yielded the true probing pressure. Probe heads were mounted on the handle either as recommended by the manufacturer or forcefully to the deepest possible position.
**Results:** The mean probing force for initial loading was 0.273 N. When accounting for the contact area the mean probing pressure was 148.6 N/cm$^2$. Forceful mounting of the probe head significantly reduced the mean probing force to 0.193 N ($p<0.0003$) and the mean probing pressure to 105.3 N/cm$^2$ ($p<0.0003$). Oscillating loading did not largely alter the observed probing force or probing pressure.
**Conclusions:** The Hunter TPS periodontal probe meets established clinical standards. However, only a forceful mounting of the probe head into the handle resulted in a mean probing force close to approximately 0.2 N, as suggested by the manufacturer.

Key words: probing pressure, periodontal, probing, probe, probing force

## INTRODUCTION

Repeated measurements of pocket depth (PD), probing attachment level (PAL) and bleeding on probing (BoP) are among the most important diagnostic means for evaluating the status of periodontal health (Listgarten, 1980; Lang et al, 1991; Hefti, 1997). Ideally a blunted probe is gently inserted into the gingival sulcus until the probe tip reaches the most apical extension of the dentogingival epithelium. Numerous experimental studies however have shown that in a clinical situation several parameters may substantially impair the precision and reproducibilty of the measurements. Among them are the probing force (Mombelli and Graf, 1986), the thickness of the probe tip (Attasi et al, 1992), the inflammatory status of the subgingival connective tissue (Spray et al, 1978; Fowler et al, 1982), and the difficulty to introduce the probe tip reproducibly at the identical position and angulation (Pihlström, 1992).
The control of the applied probing force is of particular concern, as the terminal position of the probe tip within the periodontal tissues is signifi-

Fig 1 Hunter TPS periodontal probe.

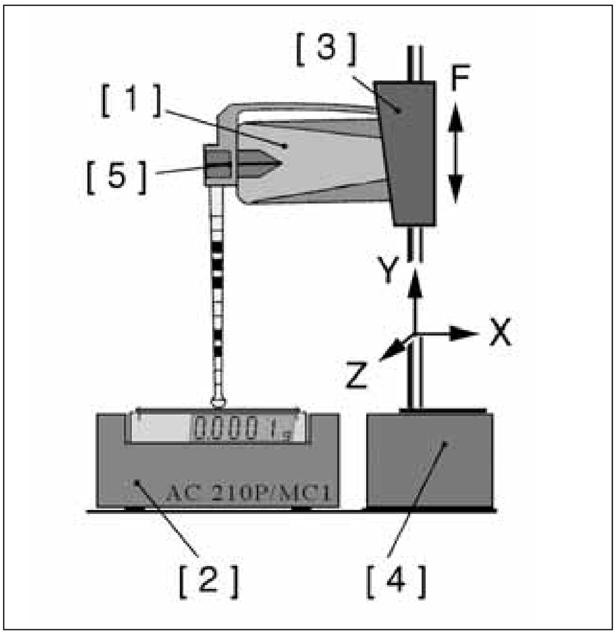


Fig 2 Experimental set-up.

cantly influenced by the applied probing pressure (Mombelli and Graf, 1986).
Excessive probing forces might also provoke traumatic bleeding, thus impairing the accuracy of a bleeding on probing status often used as a risk parameter for future disease progression (Lang et al, 1991). A variety of pressure-sensitive probe designs therefore has been introduced, allowing to apply standardised and reproducible probing forces in a range of 0.2 N – 0.25 N (Mayfield et al, 1996). A microscopic study of Armitage et al (1977), which preceded the publication of the WHO-621 standards, applied a pressure of 220 N/cm$^2$ by using a spherical tip with a diameter of 0.38 mm. For a given tip diameter of 0.42 mm to 0.5 mm (Hunter, 1994) these will result in probing pressures ranging from 102 N/cm$^2$ to 181 N/cm$^2$. This range is generally regarded the optimum for recording the true depth of a periodontal pocket while inflicting only minimal trauma to a sound periodontium (Gabathuler and Hassel, 1971; Hefti, 1997).
The aim of the present *in vitro* study was to evaluate whether the Hunter TPS periodontal probe (Fig 1), an inexpensive probe design utilising pressure-sensitive, single-use probe heads (Hunter et al, 1990; Hunter 1994), meets established standards regarding accuracy and reproducibility of probing force and probing pressure. Furthermore, the interfering influence of material fatigue as well as the impact of erroneous mounting of the disposable probe head on the true pressure values was analysed.

## STUDY DESIGN AND RESULTS

*Samples*

A random sample of 2 x 50 probe heads (disposable rigid metal tactile sensor's ball tip No. 539001, Charge No. B94_8032) (TPS; VIVACARE®, Vivadent, Liechtenstein) were investigated. One sample group of 50 probe heads was used according to the manufacturer's instructions and the other group as described in the following section. All parts were visually inspected for any obvious manufacturing defects.

*Mounting of the Probe Heads*

Any incorrect mounting of the probe head may influence the clinical performance and particularly the resulting probing pressure. Therefore the interfering influence of an overly forceful insertion of the probe head to the handle contrary to the recommendations of the manufacturer was evaluated. For this purpose the probe heads were mounted to the handle following two different insertion modes.

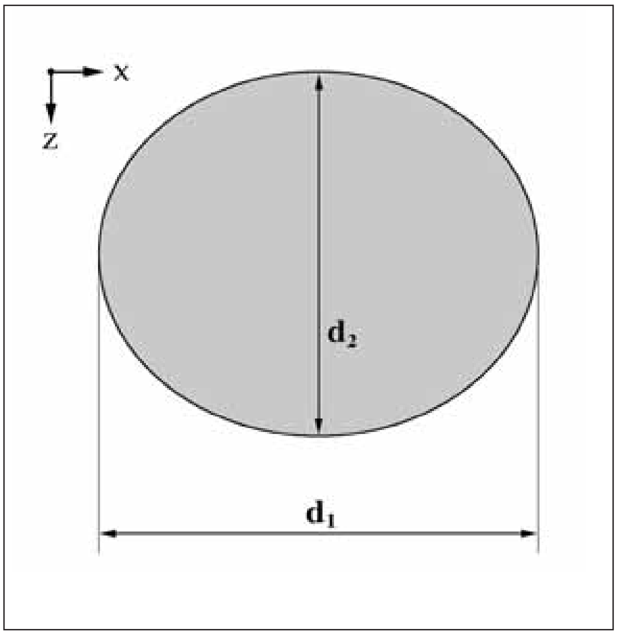


Fig 3 Schematic drawing of the probe tip contact area.

I. Proper insertion:
gentle insertion of the disposable probe head until an audible click occurred, as recommended by the manufacturer
II. Forceful insertion:
forceful insertion of the probing head down to the deepest possible stop in the clamping ramp of the handle

The forceful insertion was accomplished by force of fingers.

## *Experimental Set-up*

The experimental set-up is shown in Fig 2. It comprised a mechanical pick up [3] for the TPS handles and was mounted on an x/y/z-table [4] (Isel®, Isert-Electronic, Eiterfeld, Germany). A computer-controlled stepping motor device was interfaced to the x/y/z-table allowing to position every fixed TPS-probe ([1]) in the active centre of a digital damped balance (AC 210P/MC1, Sartorius, Germany) [2] and to precisely move and oscillate the TPS probing tip in y-direction under vertical loads F ([3]).

## *Physical Measures*

*Normal Contact Area of the Probe Tip*
Based on a perfect circular shape the effective cross-sectional probe tip contact area was approximated to be 0.2 mm$^2$. However, in the actual batch of evaluated probe tips individual elliptical deviations were observed. Therefore the effective probe tip contact area that is perpendicular to the direction of force was calculated for each individual tip by measuring the main diameter of the tip head in x, y directions according to Eq. 1 and as illustrated in Fig 3.

$$A = d_1 \cdot d_2 \cdot \pi/4 \qquad \text{Eq. (1)}$$

The diameter of the tip ball of the probing head was determined using a digital calliper (DIGIMATIC®, Mitutoyo, Japan).

*Probing Forces*
Following the guidelines of the manufacturer the correct probing force was applied by loading the probe until two black indicator lines (Fig 2, [5]) on the probe head were shifted to a coincident position. Probing force measurements were performed twice by mass readings of a digital damped balance (Fig 2, [2]). The corresponding force measurements are:

A: The force (FA) recorded immediately after the first shift of the indicator lines to a coincident position (Initial loading).
B: The force (FB) recorded after a subsequent oscillating cyclic loading of the probe tip for 30 seconds and a re-alignment of the indicator lines. The deformation achieved during each of 100 loadings was within the order of magnitude relative to the most extreme elongations estimated during clinical applications. The indicator line was deflected by as much as the full height of the probe head. The cycle frequency was about 100/(30 s) = ca. 3.33Hz.

*Probing Pressures*
The resulting probing pressure (p) was calculated according to Eq. 2 i.e. dividing the recorded probing force (F) by the determined normal contact area (A) of each evaluated probe tip.

$$p = F / A \qquad \text{Eq. (2)}$$

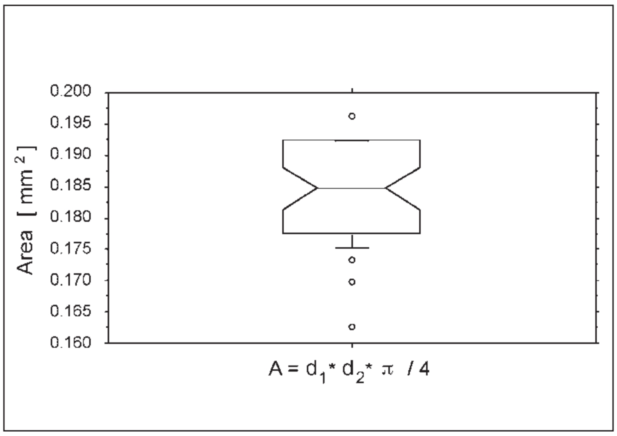


Fig 4 Whisker box plot showing the distribution of the measured normal probe tip contact area.

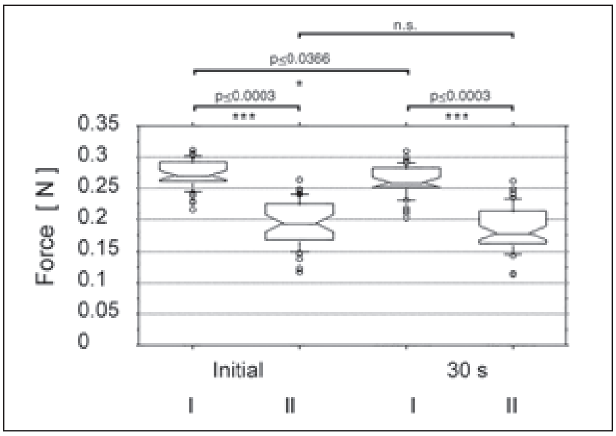


Fig 5 Whisker box plots of recorded probing forces subdivided by insertion modes I and II for initial loading and oscillating (30s) loading.

*Statistical Methods*

Statistical analysis of the data was performed using the Student t-test for independent and the paired t-test for dependent samples. The level of significance was set to $p \leq 0.05$ and was temporarily adjusted for multiple testing according to the method of Bonferroni. In order to maximize statistical power according to the method of Holm (Hochberg, 1988; Aickin and Gensler, 1996) the 'Holmed' p values were computed for the corresponding null hypotheses of no differences.
All experiments were performed by one examiner.

## RESULTS

*Probe Tip Contact Area*

Fig 4 depicts the distribution of the determined probe tip contact area. The mean value was 0.184 $mm^2$ ± 0.008 $mm^2$

*Probing Forces*

Fig 5 illustrates the recorded probing forces for the initial and the re-alignment measurement after 30 seconds of oscillating loading subdivided for the two different insertion modes of the probe tips.

*A: Probing force at initial loading*

Maximum probing forces during initial loading (FA) were 0.312 N for insertion mode I and 0.27 N for mode II. Mean probing forces (± S.D.) were 0.273 N ± 0.022 N for mode I, and 0.193 N ± 0.036 N for mode II. The median values were 0.270 N for mode I and 0.193 N for mode II.

*B: Probing force after oscillating loadings (30s)*

Maximum probing forces after oscillating loadings (FB) were 0.31 N for insertion mode I and 0.26 N for mode II. Mean probing forces (± S.D.) were 0.261 N ± 0.024 N for mode I, and 0.186 N ± 0.035 N for mode II. The median values were 0.26 N for mode I and 0.18 N for mode II.

The observed difference in the recorded probing force at initial loading and after oscillating loadings did not reach the level of significance for both insertion modes when adjusting according to Bonferroni. By contrast a significant difference was found for original insertion mode I when the corresponding last non-adjusted p-value of 0.0122 was compared for rejection with $\alpha/(n+1-i) = 0.0166$ according to the procedure described by Aickin and Gensler (1996). Furthermore, a significant difference of the recorded probing forces was observed between probe tips inserted as suggested by the manufacturer (mode I) and tips inserted to the deepest position possible (mode II) for initial loading ($p<0.0003$) as well as for oscillating loading ($p \leq 0.0003$).
The difference in mean values between immediate forces and forces after 30s of oscillation (± S.D.) was 0.012 N ± 0.013 N for insertion mode I and 0.007 N ± 0.008 N for mode II.

*Probing Pressures*

Fig 6 depicts the calculated probing pressures at initial and after oscillating loadings for both insertion modes.

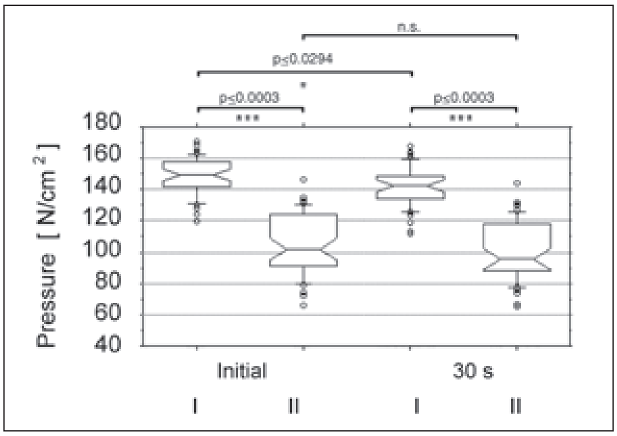


Fig 6 Whisker box plots of recorded probing pressures subdivided by insertion modes I and II for initial loading and oscillating (30s) loading.

*A: Probing pressure at initial loading*
Maximum probing pressures during initial loading (pA) were 170.8 N/cm$^2$ for insertion mode I and 146.3 N/cm$^2$ for mode II. Mean probing pressures (± S.D.) were 148.6 N/cm$^2$ ± 11.8 N/cm$^2$ for mode I and 105.3 N/cm$^2$ ± 19.8 N/cm$^2$ for mode II. The median values were 149.3 N/cm$^2$ for mode I and 102.3 N/cm$^2$ for mode II.

*B: Probing pressure after oscillating loadings (30s)*
Maximum probing pressures after oscillating loading (pB) were 168.1 N/cm$^2$ for insertion mode I and 144.4 N/cm2 for mode II. Mean probing pressures (± S.D.) were 142.2 N/cm$^2$ ± 12.6 N/cm$^2$ for mode I, and 101.3 N/cm$^2$ ± 18.9 N/cm$^2$ for mode II. The median values were 142.5 N/cm$^2$ for mode I and 95.8 N/cm$^2$ for mode II.

The observed difference in the recorded probing pressures at initial and after oscillating loadings did not reach the level of significance for both insertion modes according to Bonferroni. However, a significant difference was found for only the original insertion mode I because the corresponding p-value of 0.0098 is less than the Holm-adjusted value of 0.0125 (Hochberg, 1988; Aickin and Gensler, 1996). In addition, a significant difference of the recorded probing pressures was observed between the probe tips inserted as suggested by the manufacturer (mode I) and the tips inserted to the deepest position possible (mode II) for initial loading ($p \leq 0.0003$) as well as after oscillating loading ($p \leq 0.0003$).

The difference in mean probing pressures (± S.D.) between intial loading (A) and oscillating loadings (B) was 6.45 ± 7.13 N/cm$^2$ for insertion mode I and 4.004 ± 4.556 N/cm$^2$ for mode II.

## DISCUSSION

In the present study the true pressure values showed only small variations between the individual TPS probe heads which is in good accordance with the results of a study by Bergenholtz et al (2000) on the reproducibility of the probing forces. Any distinction between the measured probing force and the true probing pressure involves the contact area of the tip of ball-ended probes, which in turn varies as a function of the tip diameters observed. In the present study two perpendicularly measured diameters were evaluated, ranging from 0.45 mm to 0.51 mm. The World Health Organization recommends a spherical tip diameter of 0.5 mm. Rapp et al (2002) observed a range from 0.40 mm to 0.68 mm for the WHO-621 Trinity probe. Van der Zee et al (1991) reported the ball Tipp diameters of periodontal probes like the WHO 88 SE Ash/Dentsply (UK), the WHO 550B LM_Dental (Finland), and the WHO HuFriedy (USA) to be in the range of 0.59 mm ± 0.01 mm, 0.54 mm ± 0.03 mm, and 0.50 mm ± 0.01 mm, respectively.
The observed diameters of the TPS probe tips of the present study were 0.485 mm ± 0.011 mm and 0.482 mm ± 0.013 mm, with a median of 0.48 mm. TPS probe tip diameters are therefore in good accordance with the WHO recommendations. Although the injection moulded plastic material of the spring mechanism of the TPS probe is more prone to material fatigue than all-metal spring mechanisms used in most other probe designs, the present investigation could not detected a significant decrease of the actual probing force after the oscillating loading cycle of 30 seconds duration under all circumstances and for both insertion modes. This means that the effectiveness of the probe did not vary significantly during an assessment. The Bonferroni inequality is often used when conducting multiple tests of significance to set an upper bound on the overall significance level. Other improved Bonferroni procedures that are even sharper than Holm's sequentially rejective procedure were not applied in the present study 1) to keep the impression of a temporarily minor influence assigned with

any material fatigue (Hochberg, 1988), 2) to reduce the present work´s statistical efforts, and 3) to limit the discussion with respect to truly independent p-values and null-hypotheses.

The mounting forces were not measured during all insertions. No concurrent mechanisms were found that might necessitate an additional investigation of torsional effects on the bending behaviour of the flexible arms. However, it might be interesting to know if even stronger mounting forces may cause any plastic deformation of the two arms on the probe head. Here, it is estimated that the present mounting forces involved during forceful insertion of the head into the probe may have varied between 29.5 N and 37.5 N. Mounting of the TPS probe head to the handle until the first audible click as indicated by the manufacturer resulted in a mean probing force value of 0.273 N, which is considerably higher than the 'approximately 20g' suggested by the manufacturer. This is again in good agreement with the results of Bergenholtz et al. (2000), who reported a range from 20.3g to 28.7g for the TPS probe and is somewhat higher than the original alignment specification at 24 grams made by Hunter (1990). Only erroneous forceful mounting in contrast to the official TPS manual significantly decreased the observed mean probing force to 0.193 N, close to the manufacturers statement. Despite the higher median probing force observed for the correct insertion of the probe head the maximum recorded probing pressure of 178.1 $N/cm^2$ in this group fell short of the upper threshold of 200 $N/cm^2$. Nevertheless forceful mounting of the TPS probe head to the deepest possible fit may be useful to improve atraumatic probing conditions.

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